Kennedy/Jenks Consultants

2355 Main Street, Suite 140
Irvine, California 92614
949-261-1577
FAX: 949-261-2134

Pilot Implementation of Smart Timers: Water Conservation, Urban Runoff Reduction, and Water Quality

27 September 2010

Prepared for

Municipal Water District of Orange County
18700 Ward Street
Fountain Valley, CA 92708

K/J Project No. 0753001*01

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Study Participants

Joe Berg, Municipal Water District of Orange County
Steve Hedges, Municipal Water District of Orange County
Doug Shibberu, Santa Ana Regional Water Quality Control Board
Terresa Moritz, City of Newport Beach
Elizabeth Clatfelter, City of San Clemente
Nathan Adams, City of San Clemente
Chris Crompton, County of Orange
Fiona Sanchez, Irvine Ranch Water District
Nick Mrvos, Irvine Ranch Water District
Mike Hollis, Metropolitan Water District of Southern California

List of Acronyms

α	Alpha, Statistical term which (1 – α) = percent Confidence Interval. (α = 0.05 is equivalent to 95 percent Confidence Interval).
ANOVA	Analyses of Variance
DHS	Department of Health Services
EC	Electrical Conductivity
ET	Ev
gpd	Gallons per day
GPS	Global Positioning System
HCF	Hundred Cubic Feet
HOAs	Homeowners Associations
IRWD	Irvine Ranch Water District
mg/L	Milligrams per liter
MWDOC	Municipal Water District of Orange County
N	Nitrogen
NO_2/NO_3	Nitrate/Nitrite
Ortho-P	Ortho Phosphate
R3	Residential Runoff Reduction
SFR	Single Family Residency
SOPs	Standard Operating Protocols
sf	Square Foot
SWRCB	State Water Resources Control Board
TKN	Total Kjeldahl Nitrogen
Total-P	Total phosphorus
TSS	Total suspended solids
μmho/cm	micro-mho/centimeter

Executive Summary

Study Background and Methodology

In the summer of 2003, Municipal Water District of Orange County (MWDOC) was awarded a Proposition 13 Non-Point-Source Pollution Control Grant from the State Water Resources Control Board (SWRCB)) to provide funding assistance for the installations of a new irrigation timer (Smart Timer) technology. As part of this grant, it is required of the lead agency (MWDOC) to capture both pre- and post-Smart Timer installation data for water-quality and runoff flow for two distinct neighborhoods in Orange County, California. In addition to this requirement, MWDOC is required to have a water savings evaluation performed on those Smart Timers installed through this program.

This grant titled "Orange County's Weather Based Irrigation (Smart Timer) Timer Rebate Reimbursement Program" is founded on two earlier studies partnered by MWDOC and Irvine Ranch Water District (IRWD). Figure 1 is a summary of the evolution of the efforts in this area. The first study was conceptual in nature and is known as the Westpark Study, evaluated water demand reduction in Westpark neighborhood of Irvine, California after installation of 40 Smart Timers. The Westpark study identified water savings of 37 gpd, representing 7% of total household water use or approximately 16% of estimated outdoor use. This was followed by the Residential Runoff Reduction (R3) Study (R3 Study in Figure 1) (MWDOC, 2004). This study included five neighborhoods with isolated drainages. Three of these neighborhoods were control sites. A fourth neighborhood received education, and the fifth neighborhood received education and installation of Smart Timers. Water savings, runoff reduction and improved runoff water quality were evaluated from these local sites. The R3 Study concluded that installation of Smart Timers resulted in 41 gallons-per-day savings (~10% of total household water use) for residential accounts. The "Education-only" group conserved 26 gpd (6% of household use). The study also concluded that for the dedicated landscape irrigation accounts there was a 575 gallons-per-day savings. The reduction in water consumption also resulted in less runoff into the storm drain system. It was observed that a 49% reduction in runoff occurred because of the application of proper water management.

The current study (Pilot Implementation Study in Figure 1), examines a county-wide pilot implementation program involving a large number of Smart Timer installations and builds on the above two field studies. This study is divided into two parts. The first part of the study addressed water savings due to installation of approximately 1,700 Smart Timers in Orange County installed from September 2004 through November 2006. As part of this program-wide evaluation, water savings were determined from a statistical representative number of Smart Timers by three evapotranspiration (ET) zones, brand (eight brands), type of site (residential or commercial), and installer (professional or homeowner).

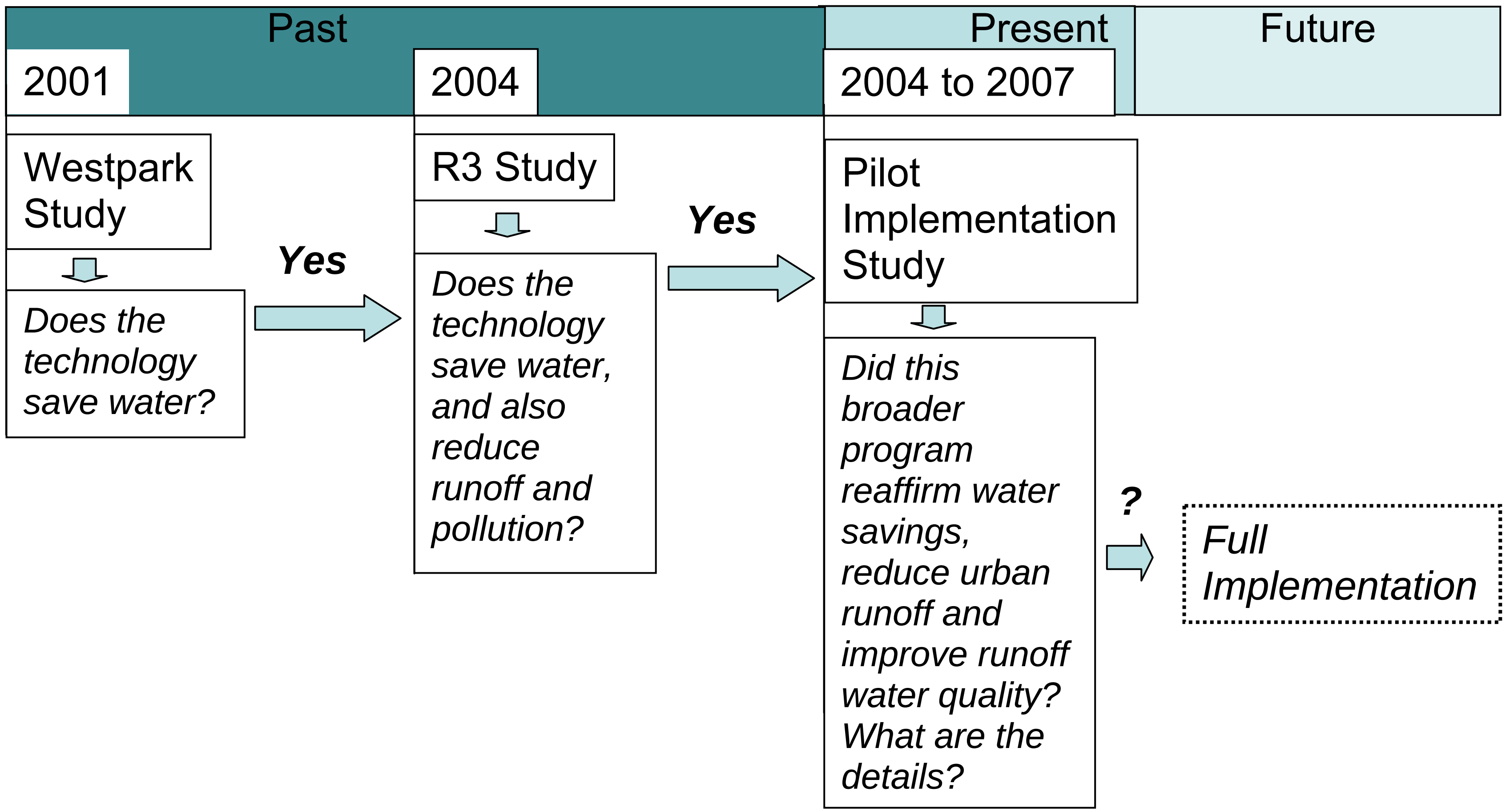


Figure 1: Evolution of Smart Timer Program

The second part of the study was to examine the role of Smart Timers in reducing the quantity of urban runoff and lowering the water quality impact of the runoff on the receiving water. Sampling and measurements of water flows occurred in two areas of the County of Orange. The first, Portola Hills, is located in the City of Lake Forest, with the second in the City of Newport Beach.

The Portola Hills neighborhood is a residential area, consisting of approximately 500 newer single-family homes. About 50 homes were retrofitted with Smart Timers in this neighborhood. Runoff flow and water quality measurements were taken during dry weather periods before and after installation of Smart Timers.

In Newport Beach the Buck Gully watershed was selected for this study. The irrigation of the common landscaped areas is separately metered and under the control of approximately 15 homeowner associations (HOAs). In Buck Gully, runoff flow and water quality measurements were done in two completely isolated watersheds. In one of the sites (Retrofit site), 32 of the 51 irrigation accounts had Smart Timers installed in the common area irrigation systems. In the other site (Control site) none of the 37 HOAs had their irrigation systems retrofitted with Smart Timers. Pre- and post-installation runoff monitoring occurred during summer months of 2003 and 2006, respectively.

Study Partners

Participants in this project include the MWDOC, the County of Orange, SWRCB, 21 retail water agencies in Orange County, IRWD, and the City of Lake Forest.

Study Goals and Objectives

The following were the study goals and objectives for the program:

1. A determination of water savings for the entire Program area by single-family residential installations;

2. A determination of water savings for the entire Program area by commercial installations;

3. A determination of water savings by season, brand of Smart Timer, and type of installer;

4. Determination of runoff flow pattern during pre- and post-intervention period (in the Portola Hills and Buck Gully areas);

5. Determination of water quality changes resulting from Smart Timer installation (in the Portola Hills and Buck Gully areas).

Study Results

The data collected during this study are compiled and evaluated for water savings, changes in dry weather runoff patterns and impact on runoff water quality, due to installation of Smart Timers. The results are summarized below:

a) Program-wide Water Savings in SFR

The program-wide installation of Smart Timers for SFR accounts resulted in an average water saving of **1.48 HCF/month** (about **37.2 gpd**; 0.0045 gpd/sq ft irrigated area). This estimate is arrived by dividing the total change in water use and ET between the pre- and post-installation periods by all qualifying installations (899). This represents an average savings of 7.1 percent for all water use and an estimated 9.7 percent of outdoor use.

The coastal zone had 662 installations and conserved nearly an average of 41 gpd per installation. The central and foothill zones had 146 and 91 installations and conserved on average approximately 28 and 26 gpd, respectively, per installation. The program-wide average conservation of 37.2 gpd is comparable to the average conservation of 42 gpd estimated in the R3 study.

b) Program-wide Water Savings by Commercial Installations

The program-wide installation of Smart Timers in commercial accounts resulted in an average water saving of **22.3 HCF/month** (about **556 gpd**; 0.0045 gpd/sq ft irrigated area). This estimate is arrived by calculating the total change in water use and ET between the pre- and post-installation periods by the all qualifying installations (209). This represents an average savings of 2.5 percent savings for the commercial account.

The coastal zone had 85 installations and conserved an average of nearly 763 gpd per installation. The central and foothill zones had 58 and 66 installations and conserved and average of approximately 468 and 366 gpd, respectively, per installation.

c) Water Savings by Season

Evaluation of pre- and post-intervention water use in SFR accounts indicated that significant water savings due to Smart Timers occurred in about six months of the year. These evaluations were performed typically using two years of pre-intervention data and at least one year of post-installation water use data. The water use increased significantly in two to three winter months (January to March) in SFR accounts installed with Smart Timers. No significant changes occurred in three or four months (June, July, November, and December) of a year. The savings typically occurred in spring, late summer and early fall months. Figure 2 shows the SFR observed water use during pre- and post-installation periods for the coastal zone. The ET-adjusted water use pattern for the three ET zones varied in accordance to the following: Coastal >> Central >Foothill. In general, the pre-installation use patterns were similar to previous studies in that without the smart timers, there was less irrigation during spring months and more irrigation in the fall season when compared to the post-installation usage.

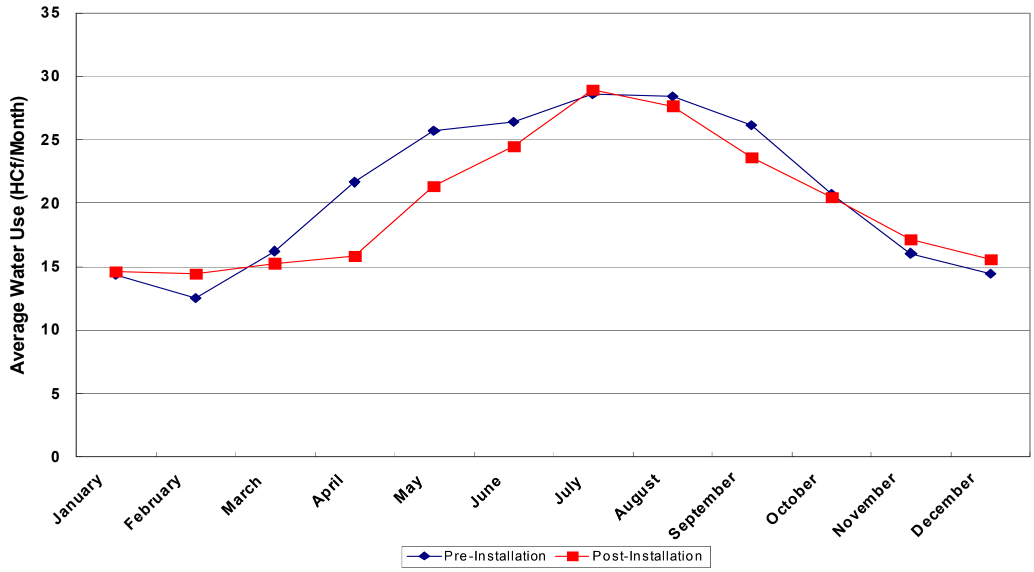


Figure 2: SFR Pre- and Post Smart Timer Installation Water Consumption for Coastal Zone

Water consumption in commercial accounts appear to follow the general trends observed with SFR, although, the savings occurred over eight months of the year. Figure 3 shows the observed program-wide commercial water use during pre- and post-installation periods. The ET adjusted water use pattern by ET zone varied in the same manner as seen in the SFR accounts, i.e., Coastal >> Central >Foothill.

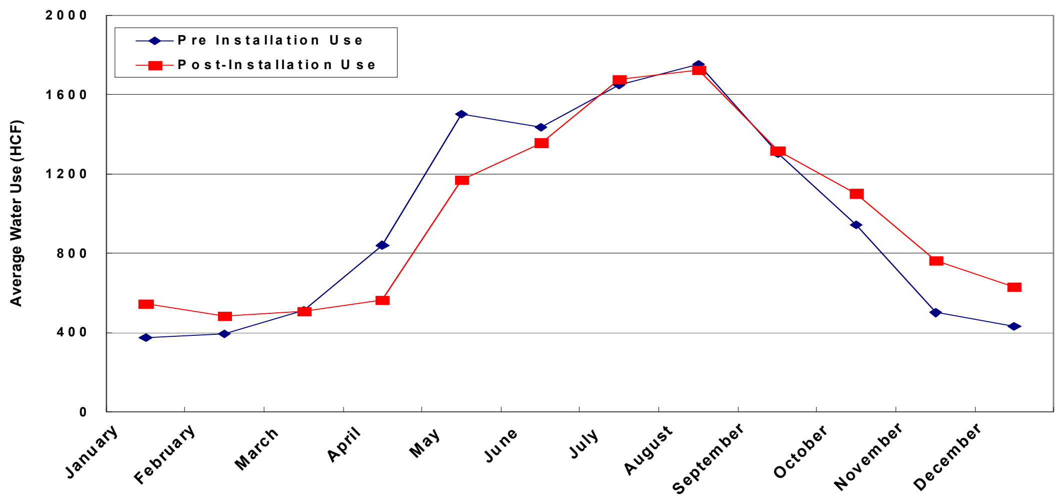


Figure 3: Commercial Pre- and Post Smart Timer Installation Water Consumption for Coastal Zone

d) Program-wide Water Savings by Smart Timer Brand

Seven different brands of Smart Timers were used in SFR accounts under this study. However, only Brands A, B and E had a sufficient number of installations (> 15) in each ET zones to obtain representative comparable data. Brands A and B, in general significantly reduced water consumption in SFR accounts. Brand A reduced nearly 60, 25 and 60 gpd per installation in coastal, central and foothill zones, respectively. Brand B reduced 50, 35 and 1 gpd per installation in coastal, central and foothill zones, respectively. However, Brand E increased water use by 16 gpd in coastal zone, but conserved water by 8 gpd in central zone. Brand E did not have sufficient number of installations in foothill zone to perform statistical analyses for this study.

Nine different brands of Smart Timers were used in Commercial accounts under this study. However, only two brands (Brand G, and Brand I) had more than 15 installations in each ET zone. Brand G, and Brand I conserved substantial amount of water (1,450 and 900 gpd, respectively in coastal; and 950 and 490 gpd, respectively in foothill zones). Brand G conserved almost twice as much water than Brand I in these zones.

e) Program-wide Effect of Smart Timer Installation by Home Owners or Professional

The performance of SFRs Smart Timers was evaluated by the type of installer (home owner or professional). There were 336 timers that were installed by home owners and the remaining 566 were installed a professional contractor. There were 124 Smart Times installed by homeowners and 170 Smart Timers installed by professionals that had significantly saved water. A statistically significant higher percentage of homeowners installed Smart Timers (~37%) saved water as compared to professionally installed Smart Timers (~30%). However, this study did not evaluate many factors that contributed to the differences in performance of the two groups. For example, it is possible that more professionally installed Smart Timers may be present in the Coastal area (lower ET where there is more savings variability) or cities where other conservation measures or rate structures also exist that may contribute to water savings irrespective of whether Smart Timers have been installed. There also may be a difference in the brands installed (some brands performed a lot better than others). Further investigations are suggested to identify the role of these factors.

f) Runoff Evaluation Due to Installation of Smart Timers

Runoff flow in the Retrofit area of Buck Gully in the post-intervention period (200 gpd/irrigated acre) was significantly lower than that of the Control area (420 gpd/irrigated area) during dry weather months of the post-intervention period. Comparison of pre- (Year 2003) and post-intervention (Year 2006) runoff indicated a reduction in runoff flow in the Control as well as the Retrofit areas. In the Control Area alone, the average runoff flow decreased from 669 gpd/acre in 2003 to 476 gpd/acre (net decrease of about 190 gpd/acre). Since there are no known Smart Timers in this area, the decrease in reduction may be attributed to other, non-Smart Timer factors—including, but not limited to operator education, financial incentives, better maintenance, etc. In the Retrofit Area, the runoff flow decreased from 545 to 175 gpd/acre (net decrease of 367 gpd/acre). Assuming the same factors were equally effective in both areas that caused water savings, the approximately 175 gpd/acre higher net decrease in runoff reduction can be assigned to the installation of Smart Timers in the Retrofit area.

In Portola Hills area, the dry weather runoff flow during post-intervention period (Year 2006, 25,100 gpd) is about 55 percent lower than the runoff recorded during the pre-intervention period (Year 2005, 54,400 gpd). Since the decrease was so large with only 10 percent of the homes having Smart Timers, it is likely that other factors—including, but not limited to public education, incentives, maintenance, etc. may also have played a part in the observed reduction.

g) Runoff Water Quality Evaluation

No definite conclusions could be drawn from water quality analyses of either the Buck Gully or Portola Hills areas. In Buck Gully, the concentrations of conductivity (EC) and nitrate-related parameters appear to be higher in the Retrofit Area than in the Control Area. However, evaluation of the total mass indicated that only nitrite/nitrate nitrogen (NO_2/NO_3) and Total Nitrogen (TN) mass were significantly higher in the Retrofit Area runoff. The conductivity (and hence, possibly the total dissolved solids) flux (μmho/day/acre) was lower in the Retrofit Area. No significant change was observed between pre- and post-intervention periods in the Portola Hills runoff water quality. EC flux was the only parameter in Portola Hills that significantly decreased after Smart Timer installation.

Additional Studies

The recommended additional studies are divided into two categories. The first category is a short term and can proceed with the current data set and some additional analyses. The second category is long term and generally requires the collection of additional data before performing the analyses. Only the titles of the proposed studies are summarized below (for more details, the reader should review Section 6.4):

a) Near Term Studies

- Smart Timers analysis normalized to irrigated area and type of vegetation
- Role of non-Smart Timer factors in water savings

b) Mid to Long Term Studies

- Inclusion of database information of for other structural changes such as changing from vertical to horizontal axis clothes washers, low flush toilets exchanges, etc. with and without Smart Timers
- Forensic Smart Timer study to investigate brand differences
- Matched control with homes with Smart Timers (similar size home next to or near Smart Timer account, number of occupants, square feet irrigated area, type of irrigation nozzles, etc.)
- Study comparing with and without Smart Timers with exterior usage water budgets
- Improved data set for runoff volume and runoff water quality
- Improved data set to estimate percolation

Section 1: Introduction

1.1 Background

In the summer of 2003, the Municipal Water District of Orange County (MWDOC) was awarded a Proposition 13 Non-Point-Source Pollution Control Grant from the State Water Resources Control Board (SWRCB) to provide funding assistance for the installations of a new irrigation timer technology (“smart” timers). As part of this grant, it is required of the lead agency (MWDOC) to capture both pre- and post-Smart Timer installation data for runoff water quality and runoff flow for two distinct neighborhoods in Orange County, California. In addition to this requirement, MWDOC is required to have a water savings evaluation performed on those Smart Timers installed through this Program.

In the Orange County area, approximately 1,700 Smart Timers have been installed over a period from September 2004 through November 2006. These timers have been installed in both residential homes (SFRs) and commercial properties - the majority of commercial properties have been homeowners associations (HOAs). Installations have involved approximately 20 retail water agencies and eight brand name Smart Timers produced by five manufacturers.

This study is divided into two parts. The first part of the study addressed all the irrigation timers within the MWDOC service area (program-wide). As part of this program-wide evaluation, water savings were determined from a statistically valid sample by manufacturer, split between residential and commercial installations, seasonality variability, and sub-classes within the commercial designation (i.e., HOAs, schools, public buildings). MWDOC provided a database for these Smart Timer installations that contained all appropriate data such as the timer manufacturer, make and model; date of installation; date of verification that the installation met the program requirements; and irrigated area of the Smart Timer. Monthly water consumption data were provided by the retail agencies for the accounts within their service areas that had installed Smart Timers.

The second part of the study was to examine the role of Smart Timers in reducing the quantity and improvement of water quality in the urban runoff. Sampling and measurements of water flows occurred in two areas of Orange County. The first, Portola Hills, is located in the City of Lake Forest; the second is in the City of Newport Beach. The Lake Forest location is served by the Trabuco Canyon Water District as well as the Irvine Ranch Water District (IRWD). The Newport Beach site, called the Buck Gully Watershed, is served by the IRWD.

All runoff sampling and measurements occurred over the dry-weather period, approximately May through the end of September. The pre-installation monitoring for the Portola Hills area occurred in the summer months of 2005. The pre-installation monitoring for Buck Gully area occurred in the summer months of 2003 (runoff flow) and 2004 (runoff water quality). Installation of Smart Timers subsequently took place from October 2005 through April 2006 for both areas. Post-installation monitoring then occurred during the summer dry-weather period in 2006.

1.2 Study Goals and Objectives

The study goals and objectives for the program-wide part of the study were as follows:

1. A determination of water savings for the entire Program area by single-family residential (SFR) and commercial installations;
2. A determination of water savings for SFR and commercial installations by season;
3. A determination of water savings by manufacturer for SFR and commercial installations;
4. A determination of water savings by manufacturer-installed SFR installations; and
5. A determination of water savings by homeowner-installed SFR installations.

The study goals and objectives for the specific Portola Hills and Buck Gully study areas were as follows:

1. A determination of water savings within the study area;
2. A determination of the urban runoff quantity as a result of the installation of Smart Timers;
3. A determination of water quality changes in the urban runoff as a result of the installation of Smart Timers (in the Portola Hills and Buck Gully areas); and
4. A determination of changes in the percolation of urban runoff to ground water as a result of the installation of Smart Timers (in the Portola Hills and Buck Gully areas).

1.3 Study Partners

Participants in this project include MWDOC, the County of Orange, SWRCB, a total of 22 retail water agencies in Orange County, IRWD, the City of Lake Forest, US Bureau of Reclamation, and Mission Resources Conservation District.

1.4 Report Organization

The project background is presented in Section 1. Section 2 summarizes the study methods, and Sections 3 to 5 address the water savings, reduction in runoff, and the water quality aspects associated with the runoff, respectively. The findings, conclusions, and recommendations are summarized in Section 6.

Section 2: Study Methods

2.1 Sources and Types of Data

A number of types of data and sources for these data were used in this study. These include a Smart Timer installation database, water use by water meter database, evapotranspiration and rainfall database, runoff flow database, and a water quality database. Each is described in more detail below and provided electronically as part of this report's appendices.

2.1.1 Smart Timer Installations

The data used in this report was collected during the installation process of this study. Two implementation processes were used during the course of this study; one for residential participants (Portola Hills) and another for commercial participants (Buck Gully).

For the commercial program participants in Buck Gully, MWDOC and IRWD implemented the installation of the Smart Timers in a joint endeavor. Both MWDOC and IRWD staff contacted and directly met with six property management companies that oversee properties in the Buck Gully area approximately two to three times each. This established a working relationship in which MWDOC and IRWD were able to convince these property managers of the need for the program and their potential water and money savings. After all of the property managers formally filed their Rebate Program applications, both IRWD and MWDOC staff performed post-installation verification inspections. The data gathered from these audits was then transmitted to MWDOC.

In the Portola Hills residential neighborhood of Lake Forest, the implementation process of this program involved the various steps of marketing, the actual rebate program, and post-installation verification as described below:

Marketing

Several forms of direct marketing campaigns were used in the Portola Hills neighborhood, a subdivision of approximately 500 homes, in order to enroll as many participants as possible including: directly-mailed postcards, directly-mailed letters, two weekends of direct door-to-door marketing by a Boy Scout Troop under an Eagle Scouts' Project, and a final directly-mailed letter to the residents.

Rebate Program

Following the marketing campaigns, the fifty-three (53) interested residents contacted the Rebate Program, purchased and installed an approved weather-based irrigation controller (a.k.a. Smart Timer), and then filed a Rebate Program Application with MWDOC. The participation level was a little over 10% for this neighborhood.

Post-Installation Verification

After MWDOC received the completed applications from program participants, MWDOC then forwarded this information to the Resource Conservation District (RCD) in order for them to conduct an on-site post-installation verification inspection. The RCD would complete a comprehensive visual inspection of the participant's property to ensure that the Smart Timer indicated on the application was in fact properly installed and functioning. The RCD staff would then forward this verification sheet to MWDOC for final approval of the rebate process.

For both the residential and commercial program participant data collected, MWDOC hired an independent database consultant to create a comprehensive electronic Smart Timer database that was used for this report's analyses. The data contained in the database was collected by the Resource Conservation District (RCD), which conducted the on-site visual post-installation verification audits at the properties of residential program participants and the post-installation audit reports performed by IRWD and MWDOC staff from the commercial program participants. This electronic database contained retail agency, service account, type of account (commercial or SFR), manufacturer of the timer, date install, date verified, and irrigated acreage. Table 1 summarizes the number (1,222) and type of account by retail agency that had sufficient data out of the installed 1,700 Smart Timers that were located within Orange County. In the program evaluation, even some of these accounts did not meet the criteria needed for inclusion in certain portions of the study. For example, there were only 261 accounts with 12 months of usage data for each year from 2002 to 2005 prior to the installation of a Smart Timer.

Table 1: Program-Wide Smart Timer Installed Base by Retail Agency and Type of Account

Retail Agency	Residential	Commercial	Total
Anaheim	18	16	34
Brea	0	5	5
East Orange	2	0	2
El Toro	8	5	13
Fountain Valley	5	5	10
Fullerton	1	0	1
Garden Grove	10	0	10
Golden State Water Company	15	12	27
Huntington Beach	26	11	37
Irvine Ranch Water District	83	83	166
Laguna Beach	3	0	3
Mesa Consolidated Water District	14	8	22
Moulton Niguel Water District	23	32	55
Newport Beach	40	65	105
Orange	49	25	74
San Clemente	506	8	514
San Juan Capistrano	4	4	8
South Coast Water District	11	2	13
Santa Margarita Water District	15	28	43
Trabuco Canyon	33	2	35
Westminster	7	12	19
Yorba Linda	26	0	26
Total	**899**	**323**	**1,222**

2.1.2 Water Use by Water Meter

This information was provided to MWDOC by the retail agencies and in turn MWDOC provided this information to Kennedy/Jenks Consultants. The information provided was the number of accounts (each account is equivalent to 100 cubic feet of water or 748 gallons) for each account of interest. Water usage for each account of interest, typically from monthly or bi-monthly meter readings, was provided for years 2002 to 2007.

Monthly water usage was determined by calendar month. The water meter readings were not typically for a calendar month, but were usually separated by 25-65 days depending on the frequency of meter readings. Water usage had to be allocated to the appropriate calendar month to match the ET data set so analyses to determine differences in ET between pre- and post-installation periods were based on the same periods.

Each meter read was disaggregated by month using a daily average for each meter read interval if the reading did not correspond to a calendar month. Using the calculated daily average, each meter read was then re-aggregated to assign a usage corresponding to a calendar month. Both pre and post meter reads were transformed in this manner prior to estimating difference between these two periods.

2.1.3 Evapotranspiration and Rainfall

The daily ET data was provided by California Irrigation Management Irrigation System (CIMIS) for years 2004 through 2007. The project area was divided into three ET zones (coastal, central and foothill zone), and the ET pertaining to the three zones were modeled and provided by CIMIS. Some ET and daily rainfall data was provided by IRWD from their three weather stations (Coastal, Central and Foothill). This information is provided electronically in Appendix B.

2.1.4 Runoff Flow Data

Flow data from the flow monitoring stations were provided by the County of Orange and the IRWD. The flow measurement intervals were between 5 and 15 minutes. During the monitoring periods, County of Orange and IRWD staff visited the monitoring sites on a weekly basis, and collected the data. The data were downloaded within 24 hours of field collection. During the weekly field visits the battery in the monitoring equipment was replaced and the flow monitoring area checked for debris that could compromise the accuracy of the data. These monitoring sites "inspection and maintenance" records were also provided by the IRWD. Flow measurement at Portola Hills (J01P08) station was done using a temporary flow gauging station that consisted of a flume and ISCO 4230 Bubbler Flow meter. Runoff flow was recorded every five to fifteen minutes. The Buck Gully Monitoring Station was also visited on a weekly basis for maintenance and monitoring. These data were then transformed to average daily, weekly, and monthly flow. The appropriate flow data needed for analysis in this report is provided electronically in the Appendix.

2.1.5 Water Quality Data

Parameters for the dry-weather monitoring at the Portola Hills site in Lake Forest were collected for analyses both by the IRWD and the County of Orange. IRWD samples were analyzed by IRWD certified water quality lab. County of Orange analyses consisted of *in situ* analyses and physical measurements, and laboratory analyses of several constituents. Samples collected were analyzed for the following parameters:

- Turbidity
- Reactive Phosphorous (ortho-phosphate)
- Nitrate Nitrogen
- Ammonia Nitrogen

- Total Phenols
- Surfactants (MBAS)
- Total hardness
- Total Chlorine
- Oil and grease
- Organophosphate Pesticides (Diazinon, Chlorpyrifos, Malathion, Dimethoate)
- Cadmium (dissolved)
- Copper (dissolved)
- Lead (dissolved)
- Zinc (dissolved)
- Fecal coliform bacteria
- *Enterococcus* bacteria
- Total coliform bacteria
- Total suspended solids (TSS)
- Dissolved Oxygen
- pH
- Electrical conductivity (EC)
- Temperature

Monitoring in the Buck Gully Watershed consisted of laboratory analyses of nutrient constituents. Samples were collected and analyzed by the IRWD's certified water quality laboratory for the following parameters:

- Ammonia Nitrogen
- Nitrogen as TKN (Total Kjeldahl Nitrogen)
- Nitrate Nitrogen
- Nitrite Nitrogen
- Total Phosphorus (TP)
- Reactive Phosphorous (ortho-phosphate)
- Electrical Conductivity (EC)

The appropriate data that was used for analysis in this report is provided electronically in the Appendix of this report.

2.2 Urban Runoff and Water Quality Impacts

There were two study designs for the urban runoff and water quality impact evaluations. The first was a comparison of runoff volume of pre- and post-installation of the Smart Timers within a watershed. This study design was used for both Portola Hills and Buck Gully. The second design—using a watershed with Smart Timers and a similar watershed without Smart Timers—was used at Buck Gully.

2.2.1 Description of Watersheds

There were two watersheds in this study. The Portola Hills study site in Lake Forest had Smart Timers installed only on SFR water accounts. The Buck Gully study site in Newport Beach had only commercial Smart Timers installed on HOA water accounts.

2.2.1.1 Portola Hills

Specifically, the Portola Hills sampling location is at outfall pipe J01P08 located in the Aliso Creek watershed at N 33° 40.700' W 117° 37.400' in the city of Lake Forest. The pipe drains approximately 150 acres of a neighborhood consisting of approximately 500 newer SFRs. This area is relatively hilly and homes are of the two-story variety on small to medium lot sizes. Figure 3 maps the sampling site.

Runoff flow measurement at the Portola Hills station was done using a temporary flow gauging station installed at the outfall by County of Orange. The station comprised of a flume and ISCO 4230 Bubbler Flow meter. The flow meter was set to take readings of water level in the flume every five to fifteen minutes during the entire dry-weather sampling period. Measurements were downloaded regularly using an ISCO 581 Rapid Transfer Device, and then uploaded to a computer. Flowlink® software was be used to convert the water level readings to discharge measurements based upon the dimensions of the flume. In order to assure quality of flow measurement, the flow meter station was visited once a week for maintenance and a status check. The water level measurements were also manually calibrated during these weekly visits.

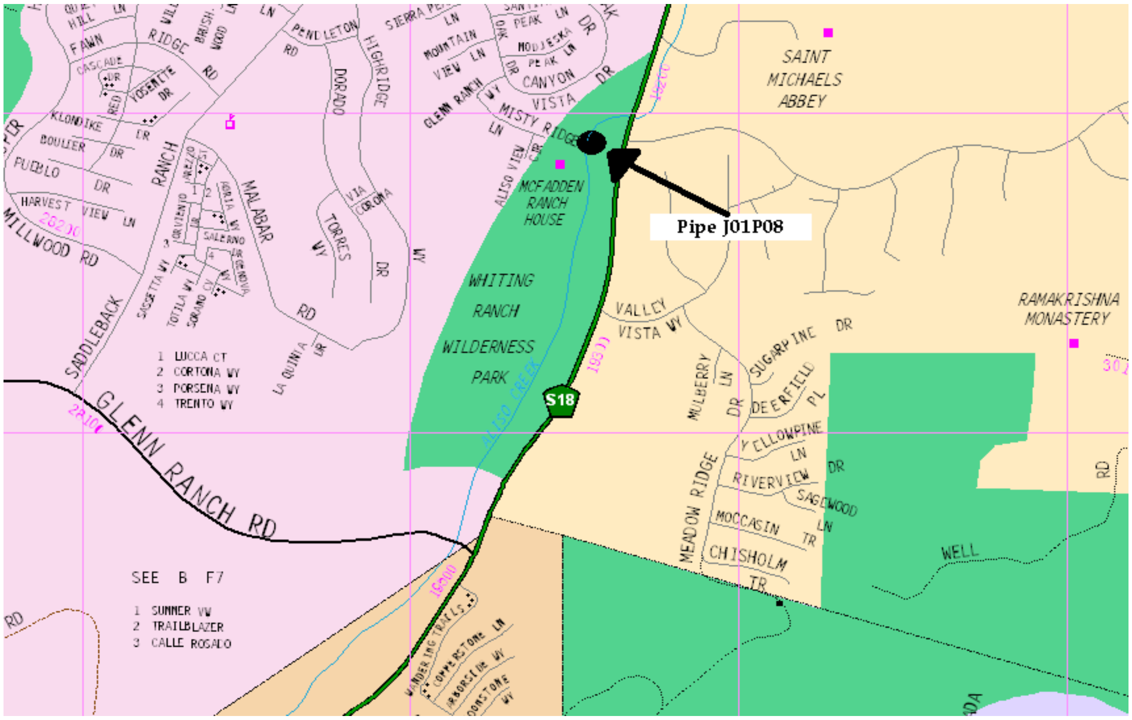


Figure 4: Detailed Map of Portola Hills Study Area

2.2.1.2 Buck Gully Watershed

The Buck Gully Watershed housing developments were constructed over a 10-year period and are comprised of single-family, condominium and multi-family housing, with large common landscaped areas. Most of the irrigation for the landscaped areas is fully and separately metered, under the control of approximately 15 HOAs. The landscaped front yards of most of the housing accounts are irrigated as part of the common landscaped areas. The backyards of housing accounts are not separately metered; their irrigation is included as part of the water consumption for the home. Table 2 lists the watershed's characteristics.

Table 2: Smart Timer Installed Base and Type of Account in Buck Gully

Period of Development	1994 to 2003	
Gross Area (approximate)	451 acres	
Irrigated Common Area Landscape	152 acres	
Backyard Irrigated Landscape	10 acres	
Water Meters:		
Condominium	578	55%
Single-Family	308	29%
Multi-Family	66	6%
Landscape Irrigation	72	7%
Homeowner Assoc	11	1%
Retail Development	1	1%
Elementary School	1	1%
Total Meters	1,037	100%

IRWD staff surveyed the Buck Gully watershed to determine each monitoring station's location and which areas are tributary to each. Figure 4 shows a schematic overview of the Buck Gully monitoring area, monitoring stations, surrounding basins, and access roads. This evaluation identified two completely isolated watersheds (B1 and B2 in Figure 4).

These watersheds combine with additional land area to form the watershed monitored at a point labeled Site 3002 and the stream continues further westward to the beach to the final monitoring point, labeled Site 3003. Coordinates for each site were determined using GPS equipment, and are summarized in Table 3.

Table 3: Coordinates for Monitoring Sites

Station	Latitude	Longitude	Elevation (feet)
3001	N 33° 36.333'	W 117° 49.948'	455
3011	N 33° 36.337'	W 117° 49.991'	460
3002	N 33° 35.844'	W 117° 51.709'	87
3003	N 33° 35.397'	W 117° 52.109'	8

Monitoring equipment for each station was placed in an underpass, an energy dissipater, a pipe, and the concrete structure at the outlet, respectively. Water quality and continuous flow rate monitoring was conducted by the IRWD at each station. Water quality grab samples were collected, secured, and transported by the IRWD staff to their certified water quality laboratory, following DHS approved Standard Operating Protocols (SOPs). Continuous flow equipment consisted of the American Sigma 950 Flow Meter which was maintained on a weekly basis during the monitoring period.

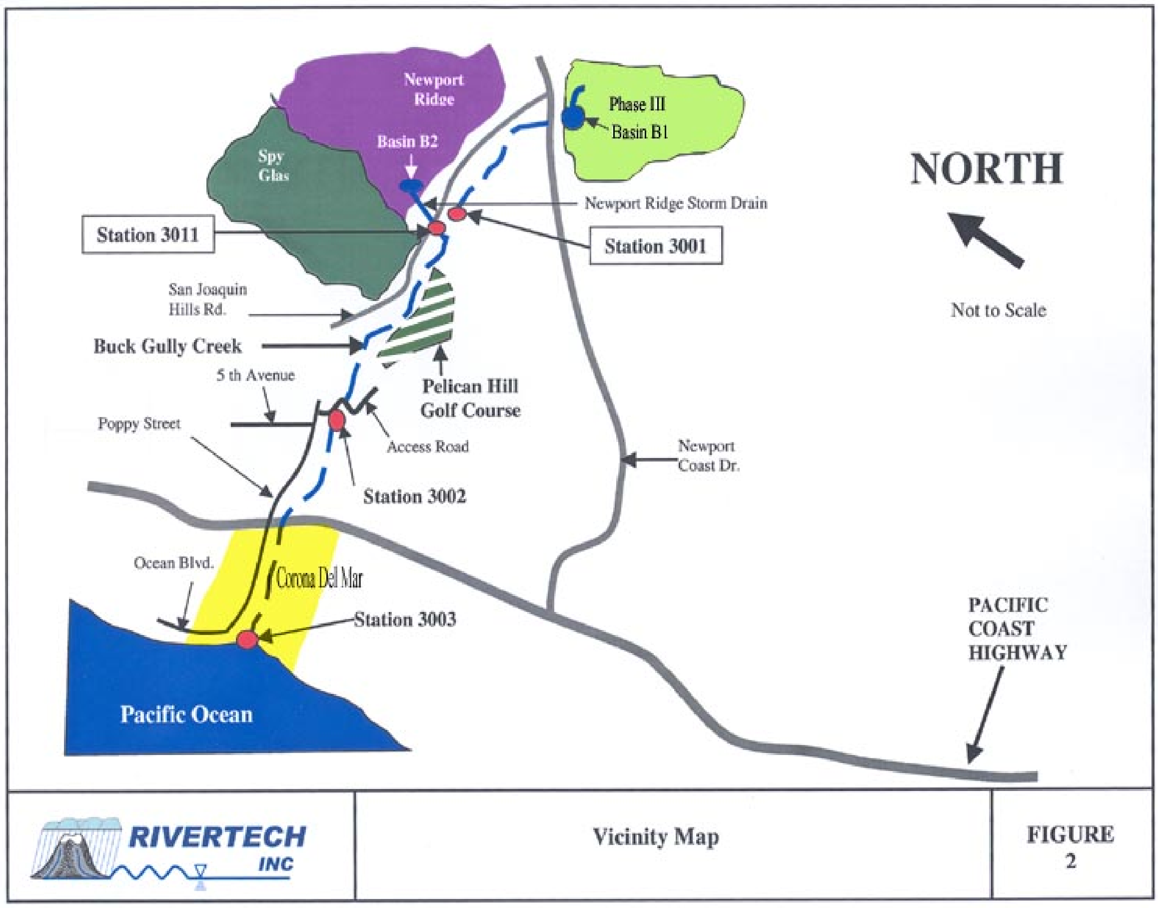


Figure 5: Schematic Map of Buck Gully Study Area

For the evaluation of this site, two similar areas were compared. The Control Area, with no Smart Timers or other known changes, had all runoff flow to Station 3001 for flow monitoring and collection of nutrient data. The Retrofit Area, with the addition of Smart Timers, had all runoff flow to Station 3011 for flow monitoring and collection of nutrient data. Each of these stations is separately monitored before flowing into tributaries that eventually flow into Buck Gully.

The common-area landscape in the Retrofit Area is estimated at approximately 85.7 acres. The common-area landscape in the Control Area is estimated at approximately 65.1 acres. These are based on irrigated area submitted by the IRWD for the accounts within the identified Retrofit Area. The common area is estimated to represent approximately 75 percent of the total irrigated area within the Retrofit Area. The Retrofit Area had 32 timers installed, consisting of five HOAs and one large shopping center. There were 18 other accounts in the Retrofit Area that were not retrofitted with Smart Timers during the study period. The Control Area had 37 commercial accounts which were not retrofitted with Smart Timers during the study period.

Section 3: Water Conservation

3.1 Overview

This section describes the statistical analysis of water use by residential and commercial customers who installed Smart Timers. Specific information includes the following: (more information on the study methods and results is provided in Appendix A):

- A summary of study methods and evaluation approach.
- Evaluation results for SFR and commercial facilities.
- Effect of Smart Timers on seasonal water consumption.
- Water savings by brands of Smart Timers. Some brands have the same manufacturer, but may have different settings resulting in different performances.

3.2 Evaluation Approach

This section summarizes the overall evaluation approach, data reduction steps, and data assessment techniques.

The account of analysis was an account. In some commercial accounts, they may have had more than one Smart Timer installed.

Water meter records for participants before and after Smart Timer installations was used as the basis for determining the change in water consumption. The hypothesis was that installation of Smart Timers would reduce the irrigation water consumption of customers participating in this program. Both SFRs and commercial installations were evaluated.

From the total of about 1,700 Smart Timers for which data were received, 1,222 Smart Timers representing 1108 accounts (899 SFRs and 209 commercial) qualified after data reduction for statistical evaluation in this study. .

Various types of information required for statistical evaluation on these installations and associated accounts were provided by MWDOC. These included type of account, historic water use by billing dates, type and manufacturer of Smart Timers installed, Smart Timer installation date, irrigated area associated with the Smart Timer, city, and type of SFR installer (homeowner or professional).

3.3 Data Reduction Process

Several techniques were employed to develop robust data set for performing valid statistical analyses on pre- and post- Smart Timer installation water use data. An overview of this approach is provided below:

- Of the records received, only those accounts where the Smart Timers were installed on or before April 2006 were considered for further analyses so that there would be at least 12 months of post-installation water usage data for comparison.

- Monthly consumption data for some accounts were reported as “0” and these data were flagged. The flagged data were sent to MWDOC who asked the appropriate retail agencies to verify these meter reads.

- Several commercial customers had multiple Smart Timers installed under one account. Analyses were performed comparing water use for each account rather than individual Smart Timers.

- Using the billing periods and respective water use information obtained from the retail agencies, water use for each calendar month was calculated for each customer.

- Subsequently, the data considered as outliers (> 10 times the mean) were deleted from further considerations.

- The following approach was then used to process the records: For each account, the average water use for a given month over the years 2003 to 2005 for which data were provided before the Smart Timer installation was calculated to represent the pre-installation water use for that month. For example, if the Smart Timer was installed in January 2005, then water use data for January 2003, and 2004 were averaged to represent the pre-intervention water use for January. A similar approach was used to estimate post- installation water use by a customer (e.g. if January 2005 and January 2006 post-installation data were available, an average water use was generated)

- After the above steps have been applied, statistical evaluations were performed first using the measured water use, and then after adjusting the water use for the ET differences between pre- and post-installation periods.

- To determine the impact of ET, for each day of a month, the ET for pre-installation period was estimated by averaging 2003 and 2004 ET data. For example, for pre-installation ET for January, the 31 days of ET were generated by averaging the ET for 2003 and 2004 for the same calendar day. Only those months with at least 27 days of ET were included. Similarly, post-installation period ET was determined by averaging 2005 and 2006 ET for each calendar day.

3.3.1 Data Assessment Techniques

Upon data reduction, the following statistical evaluation techniques were used in this study as follows:

- The accounts that were selected after the data reduction processes were separated into residential and commercial customers. Analyses of residential and commercial customers were performed separately throughout the study.

- Each account type was then separated into three ET zones (Coastal, Central and Foothill). These zones were selected on their geography, and their ETs tend to differ from each other. The zip codes assigned to each ET zones are in Appendix B.

- It is assumed that no significant reduction in interior water use occurred by the customers during the study period. If the analyses indicated significant difference in water use after installation, it was assumed that the installation of the Smart Timer was responsible for the change.

- For each ET zone a linear regression relationship was generated for the pre and post periods with their respective water use.

- The change in water consumption was then determined through the following three-step process:

  - Student's t-tests for water consumption: For each month a t-test compared pre and post-installation water use for each group of accounts. For example, the January average water use for the pre and post periods for 662 accounts (SRF accounts in the Coastal ET zone) were compared in a t-test. Using this same group, the February average water use was processed through a t-test. This procedure was done until all SRF and commercial accounts for each of the ET zones were processed through the t-test analysis.

  - Student's t-tests for ET: For each month, a t-test was performed to compare ET during pre- and post-installation periods for each zone.

  - Finally, the following rules (Table 4) were applied to evaluate water conservation resulting from installation of Smart Timers.

Table 4: Approach Used to Evaluate the Impact of ET on Water Use

Case	ET (Pre Vs Post)	Water Use (Pre Vs Post)	Inference & Approach
1	Remained Same (=)	a. Remained Same	No change in water use
		b. Significantly increased	Water use increased
		c. Significantly decreased	Water use decreased
2	Significantly Increased during Post Installation Period (↑)	a. Remained Same	Water use decreased. Use the pre ET regression to estimate savings.
		b. Significantly increased	Use regression analyses to estimate relative change in water use with respect to ET
		c. Significantly decreased	Water use decreased.

Case	ET (Pre Vs Post)	Water Use (Pre Vs Post)	Inference & Approach
3	Significantly Decreased during Post Installation Period (↓)	a. Remained Same	Water use increased. Use regression to estimate increased water use.
		b. Significantly increased	Water use increased
		c. Significantly decreased	Use regression analyses to estimate relative change in water use

Note that under the scenarios 2a, 2b, 3a, and 3c the water use was estimated by the appropriate ET-water usage regression line developed for each ET zone. A regression analyses was performed to relate the average monthly ET to average monthly water use for each ET zone during the pre and post installation period. This analysis indicated no difference in ET between the two periods. Subsequently, the differences in actual water use was compared against the water use predicted by pre-installation period regression analyses with ET. If the increase in actual water use is lower than the ET predicted increase, the difference between the two was assumed to be the minimum savings due to Smart Timers. Similarly, if the increase in actual water use is more than the ET predicted increase, the difference between the two was assumed as the increase in water use after Smart Timer installation.

- Finally, similar analysis was performed to determine water savings for individual brands of Smart Timers in each ET Zone. This analysis was performed only if there are at least 15 accounts with pre- and post-installation water use is available for a given brand. Brands with fewer than 15 accounts were considered too small a sample size to be representative of performance.

3.4 Results

Table 5 provides the summary of the nine brands of Smart Timers qualified for statistical analyses after the data reduction process. In summary, 899 residential and 209 commercial Smart Timer accounts were used for paired t-test to determine water savings.

Table 5: SFR and Commercial Smart Accounts by ET Zones

ET Zone	SRF Accounts	Commercial Accounts
Coastal	662	85
Central	146	58
Foothill	91	66
Total	**899**	**209**

3.4.1 Program- wide SFR Estimate of Water Conservation

This section presents evaluation results for single-family residence (SFR) customers for each ET zone. Independent t-tests for each month were performed by matching usage for pre- and post- intervention periods for various accounts. Table 5 summarizes the number of accounts considered for each month in each zone. In general, there were a large number of installations in the coastal zone (662), followed by central zone (156). Foothill zone (91) contained the least number of installations.

Figure 6 shows the ET trends in the three zones during the project period. In general, the Coastal zone had the lowest ET and the Central Zone had the highest ET. Compared to years 2003 and 2004, the ET decreased in year 2005 in all the three zones. The ET then increased in 2006

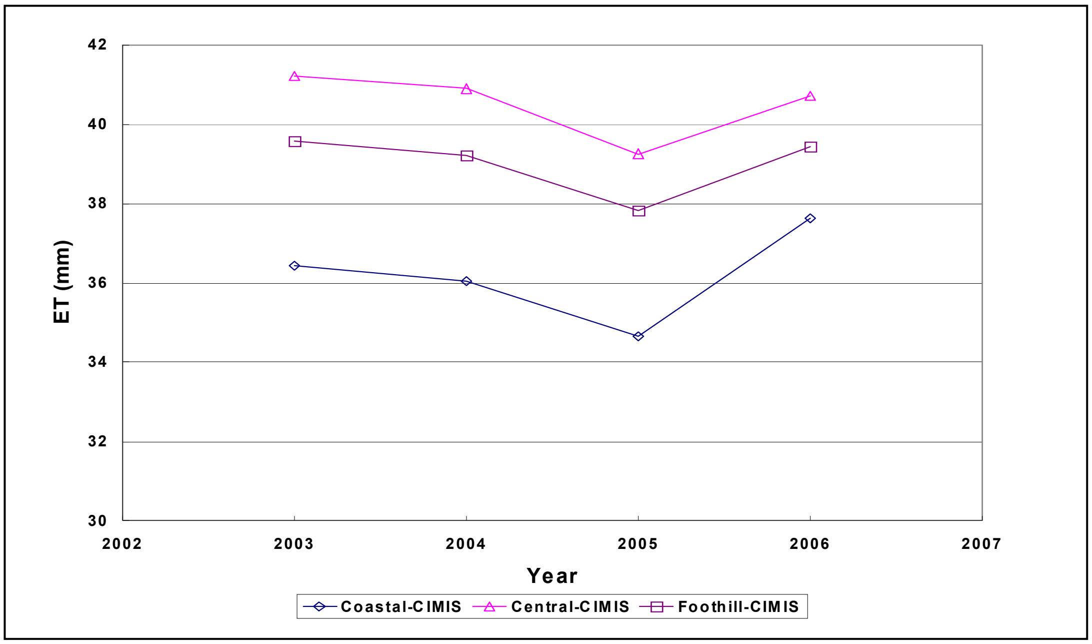


Figure 6: Annual ET Estimates for the Three ET Zones

Figures 7 to 9 shows the average water use in each of the three ET zones during the project period. The water use shown in these figures was not adjusted for ET effects. The water use data indicated that, predictably, water use during winter months were substantially lower than that during summer months for all the zones. The average water use per installation was more in the foothill zone than the coastal and central zones.

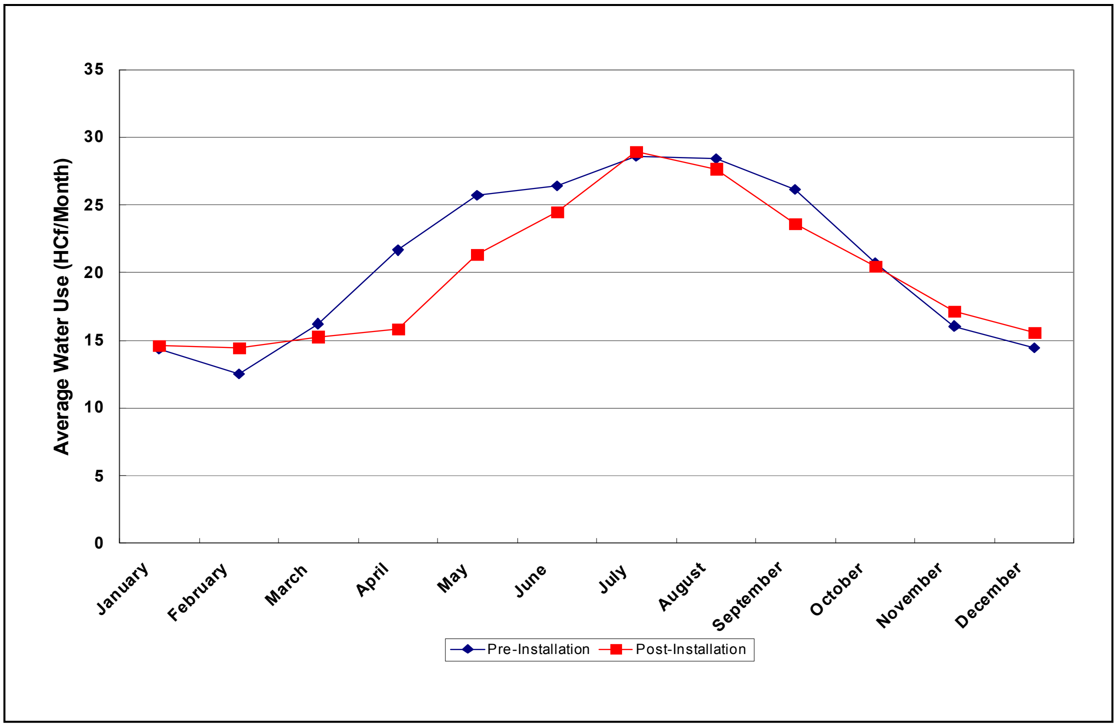


Figure 7: Coastal Zone Mean Monthly Water Use by SFRs for Pre- and Post-Smart Timer Installation Periods

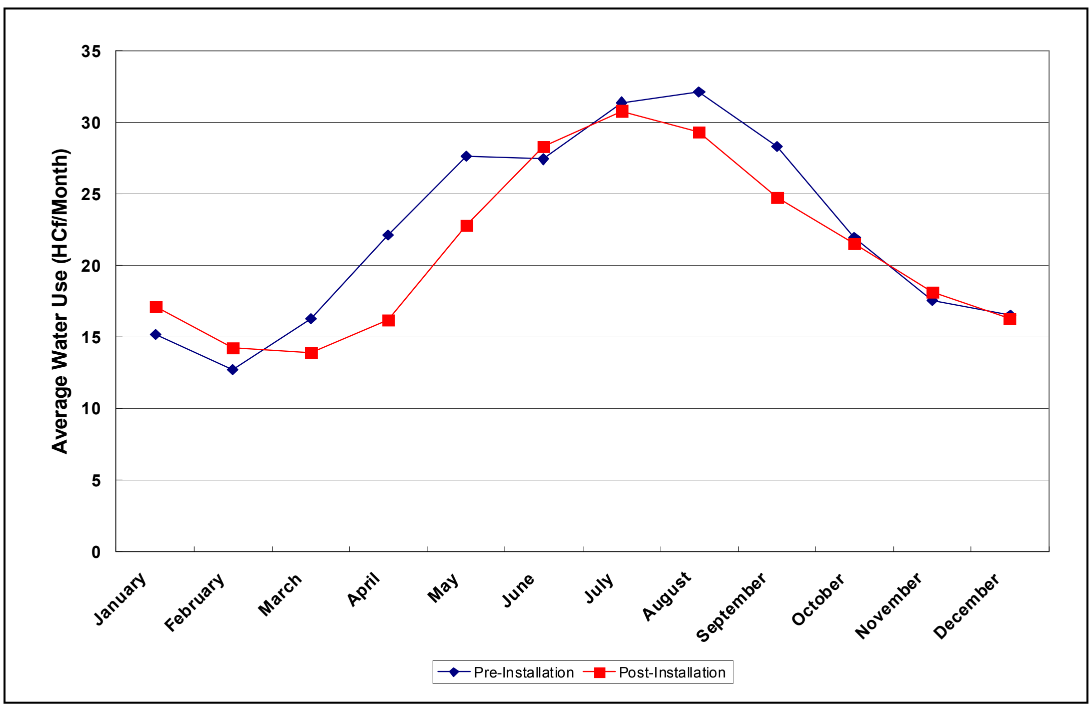


Figure 8: Central Zone Mean Monthly Water Use by SFRs for Pre- and Post-Smart Timer Installation Periods.

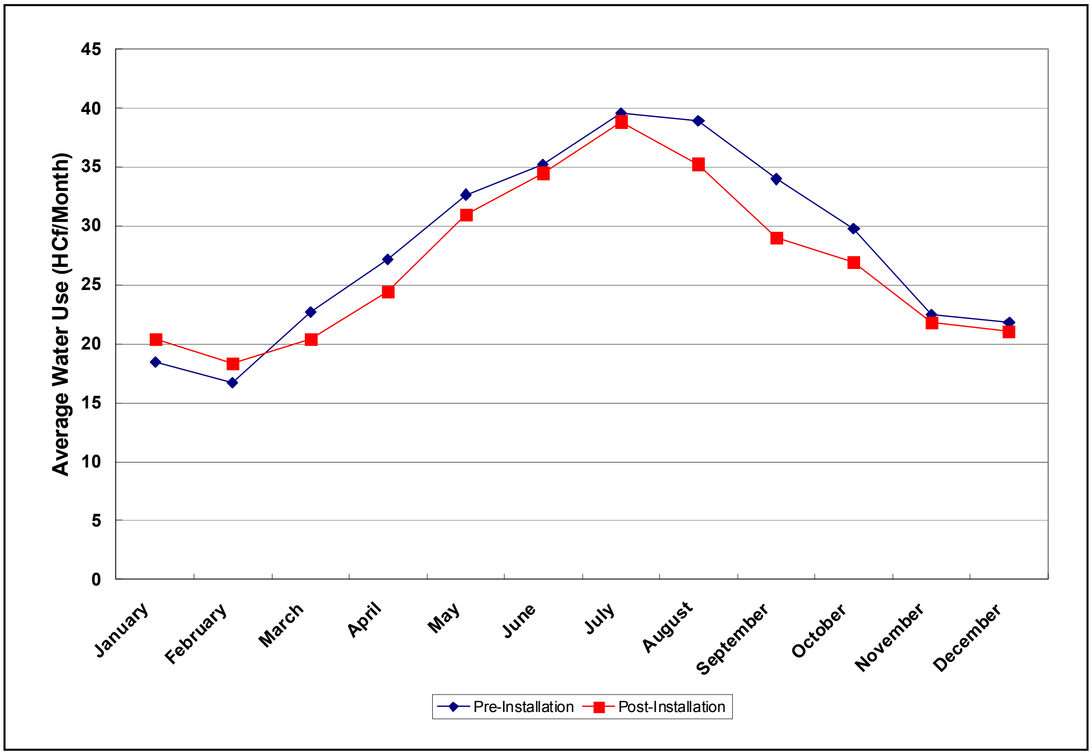


Figure 9: Foothill Zone Mean Monthly Water Consumption by SFRs for Pre- and Post- Smart Timer Installation Periods

3.4.1.1 Water Conservation in Coastal ET Zone for SFR Accounts

Table 6 summarizes the results from Student's t-tests that compared pre- and post- Smart Timer installation actual water (not adjusted for ET) use in the Coastal zone. The data indicated that the water use significantly decreased during April, May and September. The water use increased in four months after the installation Smart Timers. The increase occurred primarily during late Fall or winter months (January, February, November and December). The water use did not change significantly during five months.

Table 6: Average Monthly Pre- and Post-Installation Period Water Use in SFR Accounts in Coastal Zone

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)
January	14.35	14.59	Yes. Significant Increase (↑)
February	12.52	14.44	Yes. Significant Increase (↑)
March	16.22	15.24	No Change (=)

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)
April	21.65	15.83	Yes. Significant Decrease (↓)
May	25.68	21.31	Yes. Significant Decrease (↓)
June	26.41	24.50	No Change (=)
July	28.64	28.97	No Change (=)
August	28.42	27.64	No Change (=)
September	26.16	23.56	Yes. Significant Decrease (↓)
October	20.70	20.42	No Change (=)
November	16.03	17.12	Yes. Significant Increase (↑)
December	14.45	15.54	Yes. Significant Increase (↑)

Table 8 shows the Student's t-test results for ET during pre- and post-installation periods. The data indicated that the ET increased significantly during seven months during the post-installation period. ET decreased significantly during 2 post-installation months (April and May). ET did not change significantly during March, September and October.

Table 7: Average Monthly Pre- and Post-Installation Period ET in Coastal Zone

Month	Pre-Installation ET (mm/day)	Post-Installation ET (mm/day)	Is the difference significant (α = 0.05)
January	1.51	2.06	Yes. Significant Increase (↑)
February	1.98	2.24	Yes. Significant Increase (↑)
March	2.71	2.78	No Change (=)
April	3.55	3.06	Yes. Significant Decrease (↓)
May	4.12	3.56	Yes. Significant Decrease (↓)
June	3.88	4.48	Yes. Significant Increase (↑)
July	4.47	5.30	Yes. Significant Increase (↑)
August	3.97	4.36	Yes. Significant Increase (↑)
September	3.58	3.78	No Change (=)
October	2.3	2.62	No Change (=)
November	1.78	2.08	Yes. Significant Increase (↑)
December	1.49	1.87	Yes. Significant Increase (↑)

Figure 10 shows the relationship between water use and ET in the coastal zone during the pre-installation period. Regression co-efficient (R^2) of 0.8672 was observed. The equation for the pre-installation period was used to estimate the anticipated change in water use due to differences in ET for cases 2a, 2b, 3a, and 3c in Table 4 (Section 3.3.1).

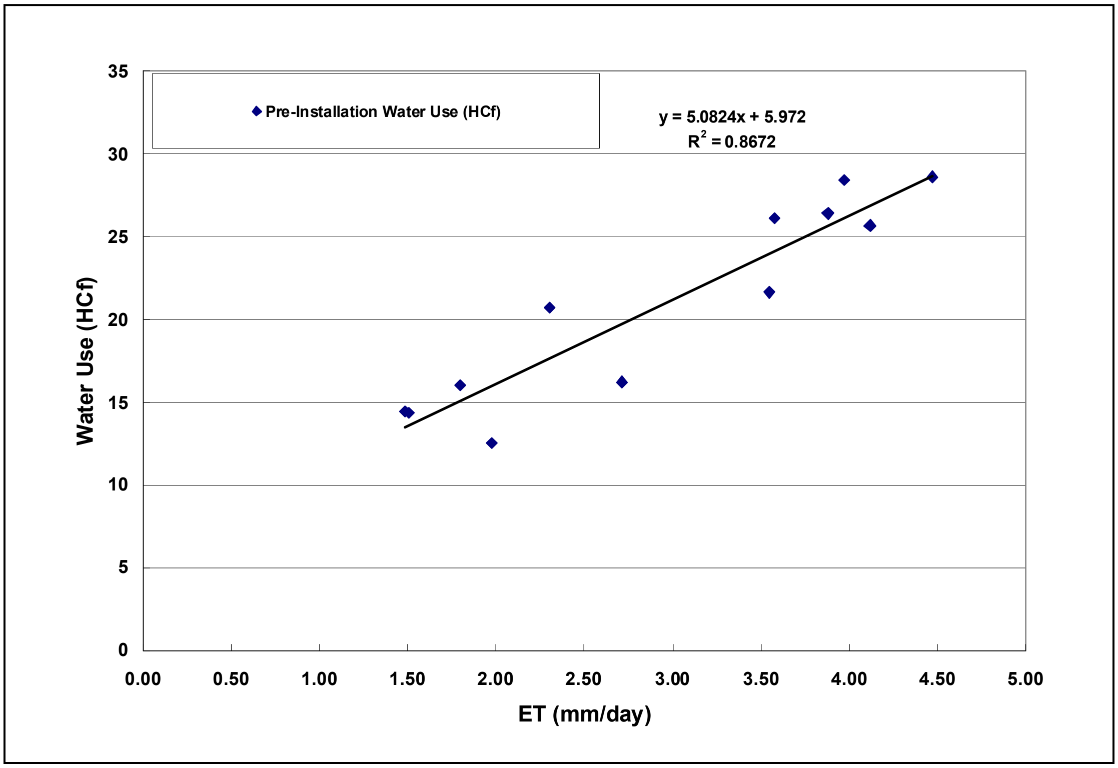


Figure 10: Regression Analyses for Water Use in Coastal Zone for SFRs with Respect to ET During Pre-installation Period.

Table 8 summarizes the net change in water use for the SFR accounts in coastal zone after making the ET adjustments described in Table 4. Analyses indicated that installation of Smart Timers conserved water during nine months of the year. No change in water use was observed during two months and the water increased during one month after Smart Timer installation. Overall, the ET adjusted water conservation is 19.93 HCF/year (40.85 gpd) due to installation of Smart Timers in the coastal zone.

Table 8: Average Monthly SFR Water Conservation Due to Installation of Smart Timers in Coastal Zone

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)	Pre-Installation ET (mm/day)	Post-Installation ET (mm/day)	Is the difference significant (α = 0.05)	Net Water Conservation (HCF)
January	14.35	14.59	Significant Increase (↑)	1.51	2.06	Significant Increase (↑)	2.55
February	12.52	14.44	Significant Increase (↑)	1.98	2.24	Significant Increase (↑)	-0.57
March	16.22	15.24	No Change (=)	2.71	2.78	No Change (=)	0.00
April	21.65	15.83	Significant Decrease (↓)	3.55	3.06	Significant Decrease (↓)	3.34
May	25.68	21.31	Significant Decrease (↓)	4.12	3.56	Significant Decrease (↓)	1.55
June	26.41	24.50	No Change (=)	3.88	4.48	Significant Increase (↑)	2.99
July	28.64	28.97	No Change (=)	4.47	5.30	Significant Increase (↑)	4.20
August	28.42	27.64	No Change (=)	3.97	4.36	Significant Increase (↑)	1.99
September	26.16	23.56	Significant Decrease (↓)	3.58	3.78	No Change (=)	2.60
October	20.70	20.42	No Change (=)	2.3	2.62	No Change (=)	0.00
November	16.03	17.12	Significant Increase (↑)	1.78	2.08	Significant Increase (↑)	0.42
December	14.45	15.54	Significant Increase (↑)	1.49	1.87	Significant Increase (↑)	0.89
						Annual Water Conservation (HCF/Year)	**19.93**
						Water Conservation (gpd)	***40.85***

3.4.1.2 Water Conservation by SFRs in Central ET Zone

The ET and water use patterns for the central zone were different than the coastal zone (Figure 11, Table 9). Table 9 summarizes the water use and ET data for the central zone. The ET increased significantly during four months during the post-installation period. Significant decrease in ET was observed during two months and no change was observed during six months. After adjusting for the change in ET, installation of Smart Timers conserved water during six months, increased water use during two months. Water use did not change during four months. Overall, the ET adjusted water conservation is 13.69 HCF/year (28.05 gpd) due to installation of Smart Timers in the central zone.

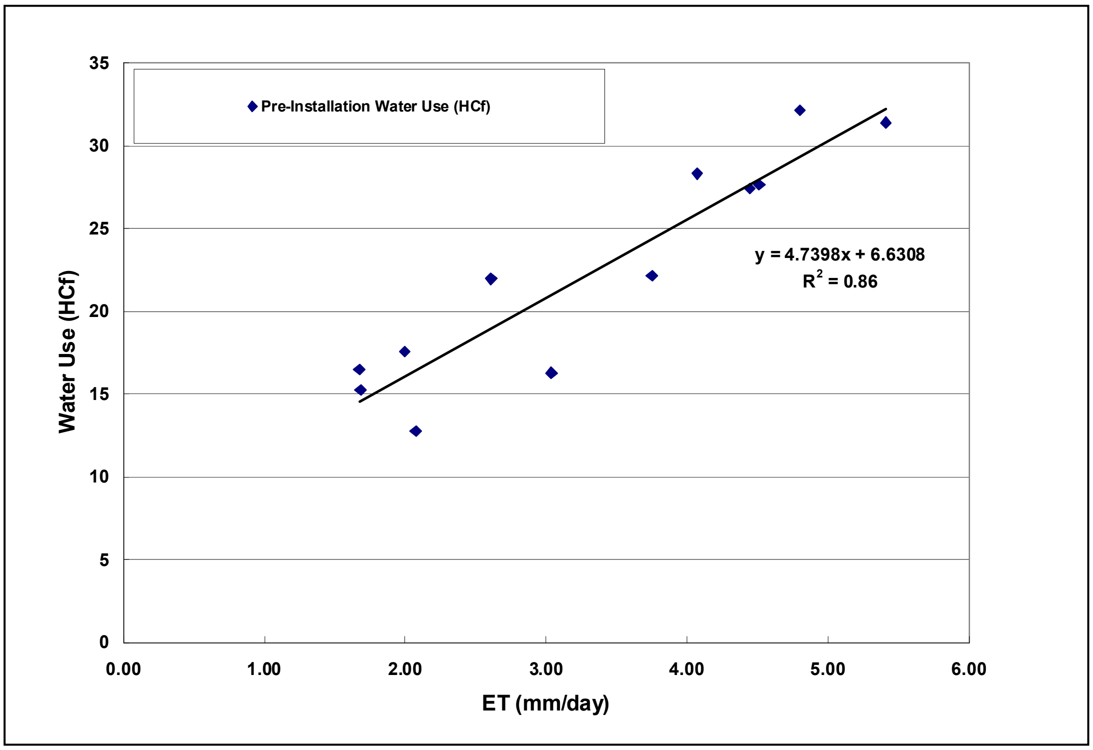


Figure 11: Pre-installation Regression Analyses for Central Zone of SFRs Water Use and ET.

Table 9: Average Monthly SFR Water Conservation Due to Installation of Smart Timers in Central Zone

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)	Pre-Installation ET (mm/day)	Post-Installation ET (mm/day)	Is the difference significant (α = 0.05)	Net Water Conser-vation (HCF)
January	15.23	17.16	No Change (=)	1.66	2.17	Significant Increase (↑)	2.42
February	12.76	14.27	Significant Increase (↑)*	2.1	2.37	Significant Increase (↑)	-0.21
March	16.30	13.90	No Change (=)	2.96	2.83	No Change (=)	0.00
April	22.16	16.20	Significant Decrease (↓)*	3.71	3.02	Significant Decrease (↓)	2.72
May	24.43	21.54	No Change (=)	4.41	3.81	Significant Decrease (↓)	-2.84
June	27.44	28.30	No Change (=)	4.19	4.76	Significant Increase (↑)	2.70
July	31.41	30.82	No Change (=)	5.05	5.58	Significant Increase (↑)	2.52
August	32.14	29.32	Significant Decrease (↓)	4.45	4.57	No Change (=)	2.82
September	28.33	24.77	Significant Decrease (↓)	3.87	4.03	No Change (=)	3.56
October	21.97	21.57	No Change (=)	2.51	2.70	No Change (=)	0.00
November	17.61	18.12	No Change (=)	1.96	2.12	No Change (=)	0.00
December	16.51	16.32	No Change (=)	1.66	1.88	No Change (=)	0.00
Annual Water Conservation (HCF/Year)							**13.69**
Water Conservation (gpd)							**28.05**

* - Savings / Water use increase estimated by regression approach for these months

3.4.1.3 Water Conservation by SFRs in Foothill ET Zone

The ET and water use patterns for the foothill zone were generally similar to that observed in the central zone (Figure 12, Table 10).Table 10 summarizes the water use and ET data for the foothill zone. The ET increased significantly during three months during the post-installation period. Significant decrease in ET was observed during two months and no change was observed during seven months. After adjusting for the change in ET, installation of Smart Timers conserved water during six months, increased water use during two months. Water use did not change during four months. Overall, the ET adjusted water conservation is 12.85 HCF/year (26.33 gpd) due to installation of Smart Timers in the foothill zone.

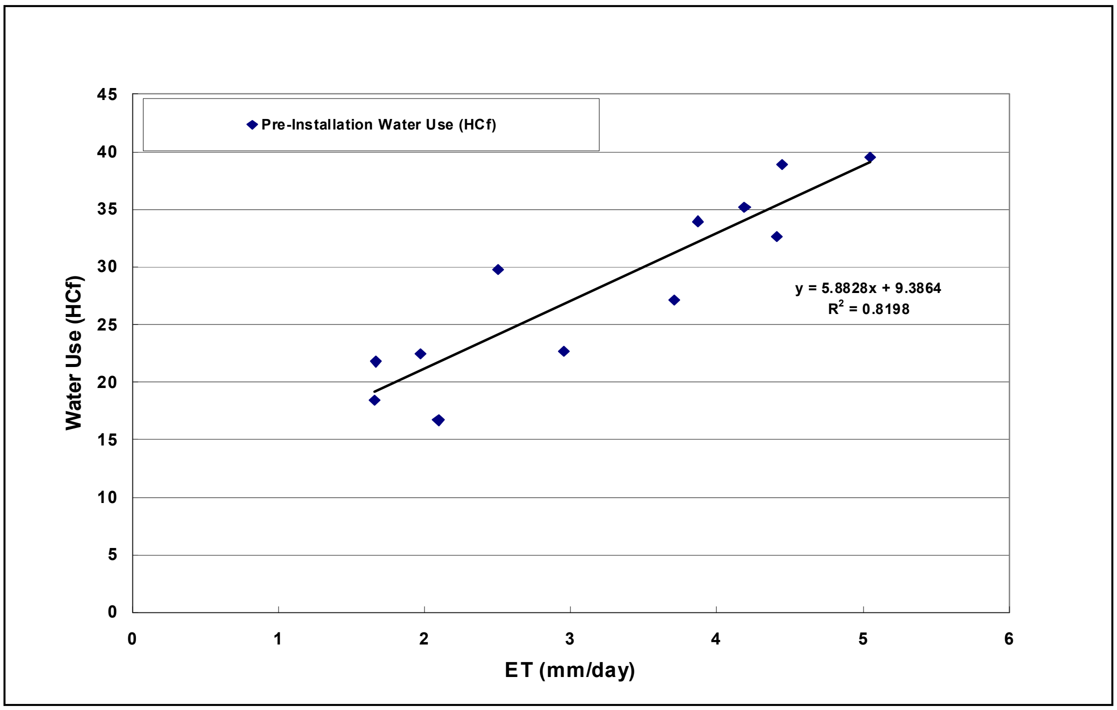


Figure 12: Pre-installation Regression Analyses for Foothill Zone of SFRs Water Use and ET.

Table 10: Average Monthly SFR Water Conservation Due to Installation of Smart Timers in Foothill Zone

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)	Pre-Installation ET (mm/day)	Post-Installation ET (mm/day)	Is the difference significant (α = 0.05)	Net Water Conser-vation (HCF)
January	18.04	20.40	No Change (=)	1.68	2.17	Significant Increase (↑)	2.86
February	16.39	18.18	No Change (=)	2.08	2.42	Significant Increase (↑)	2.02
March	22.34	20.49	Significant Decrease (↓)	3.04	2.86	No Change (=)	1.86
April	26.94	24.66	Significant Decrease (↓)	3.75	2.98	Significant Decrease (↓)	-2.37
May	32.63	31.34	No Change (=)	4.51	3.99	Significant Decrease (↓)	-3.07
June	35.00	34.88	No Change (=)	4.44	5.01	Significant Increase (↑)	3.33
July	39.59	39.29	No Change (=)	5.41	5.73	No Change (=)	0.00
August	39.00	35.60	Significant Decrease (↓)	4.80	4.85	No Change (=)	3.40
September	32.42	27.59	Significant Decrease (↓)	4.08	4.28	No Change (=)	4.83
October	28.25	25.45	No Change (=)	2.61	2.79	No Change (=)	0.00
November	21.77	21.88	No Change (=)	1.99	2.20	No Change (=)	0.00
December	21.01	20.99	No Change (=)	1.67	1.90	No Change (=)	0.00
						Annual Water Conservation (HCF/Year)	**12.85**
						Water Conservation (gpd)	**26.33**

3.4.1.4 Summary of SFR Water Savings

Table 11 shows the program-wide water conservation due to installation of Smart Timers. The analyses indicated that there was a net water conservation of approximately 41, 28 and 26 gpd in the coastal, central and foothill zone, respectively. The average account, irrespective of ET zone, used approximately 37 gpd less water. This reduction constitutes approximately 7 percent conservation in water use in SFR accounts during the project period.

Table 11: Weighted Program-wide SFR Water Conservation Due to Installation of Smart Timers

Zone	Accounts	Water Conservation (gpd)
Coastal	662	40.85
Central	146	28.05
Foothill	91	26.33
	Average Savings per Account (gpd)	37.12

The analyses indicated that installation of Smart Timers resulted in water conservation. The amount of water conserved varied with the ET zone. The conservation was higher in the coastal zone than in central and foothill zones. The number of installations in the coastal zone (662) was significantly higher than the installations in the other two zones. Water conservation was observed during nine months in the coastal zone, and six months in the central and foothill zones. The differences in the proportional distribution of various brands in each zone may have some role in the differences in the observed savings. The average account savings of 37.2 gpd is slightly lower than the estimated 41 gpd savings in the R3 study.

3.4.2 Program-wide Estimation of Water Conservation by Commercial Accounts

Table 12 summarizes the number of commercial meters (accounts) considered for analyses in each ET zone. Some of these accounts had multiple Smart Timer installations. Independent t-tests for each month were performed by matching usage for pre- and post- intervention periods for various accounts.

Table 12: Commercial Smart Timer Accounts in Each ET Zones

ET Zone	Accounts
Coastal	85
Central	58
Foothill	66
Total	**209**

Figures 13 to 15 show the actual average monthly water use (not adjusted for ET) data for commercial accounts for the three zones during pre- and post- Smart Timer installation periods. The average water use per account with Smart Timers in the coastal zone was larger than that in central. The foothill zone had the lowest average water use per account.

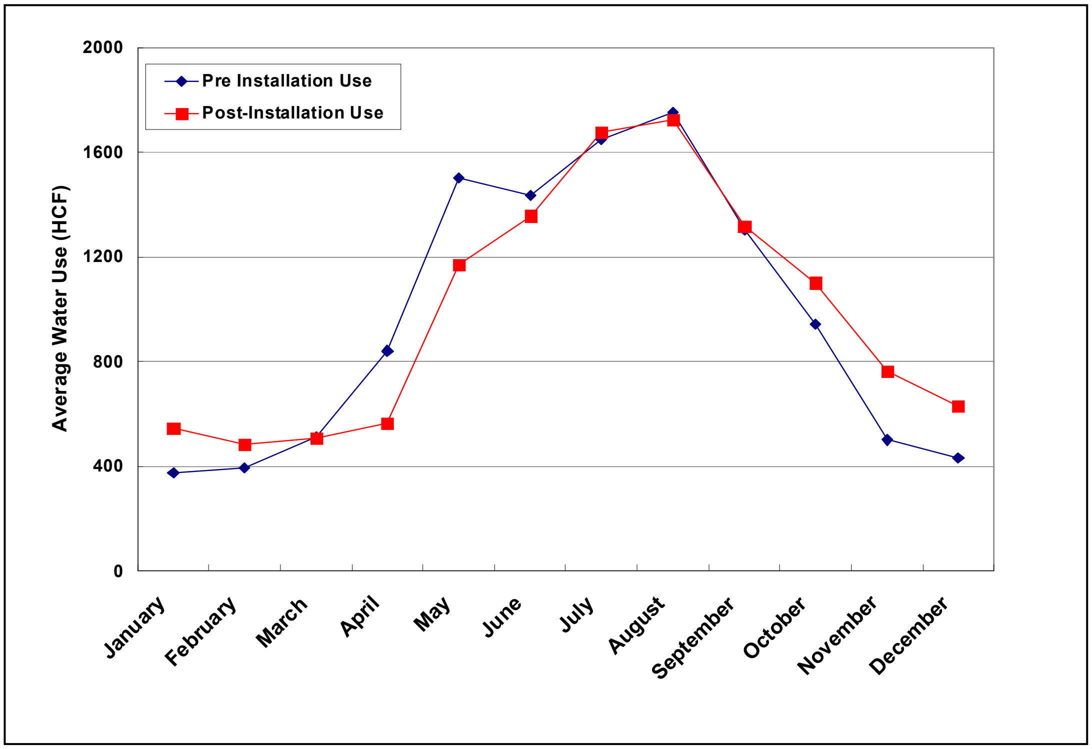


Figure 13: Coastal Zone Average Monthly Water Consumption for Commercial Accounts for Pre- and Post- Smart Timer Installation Periods.

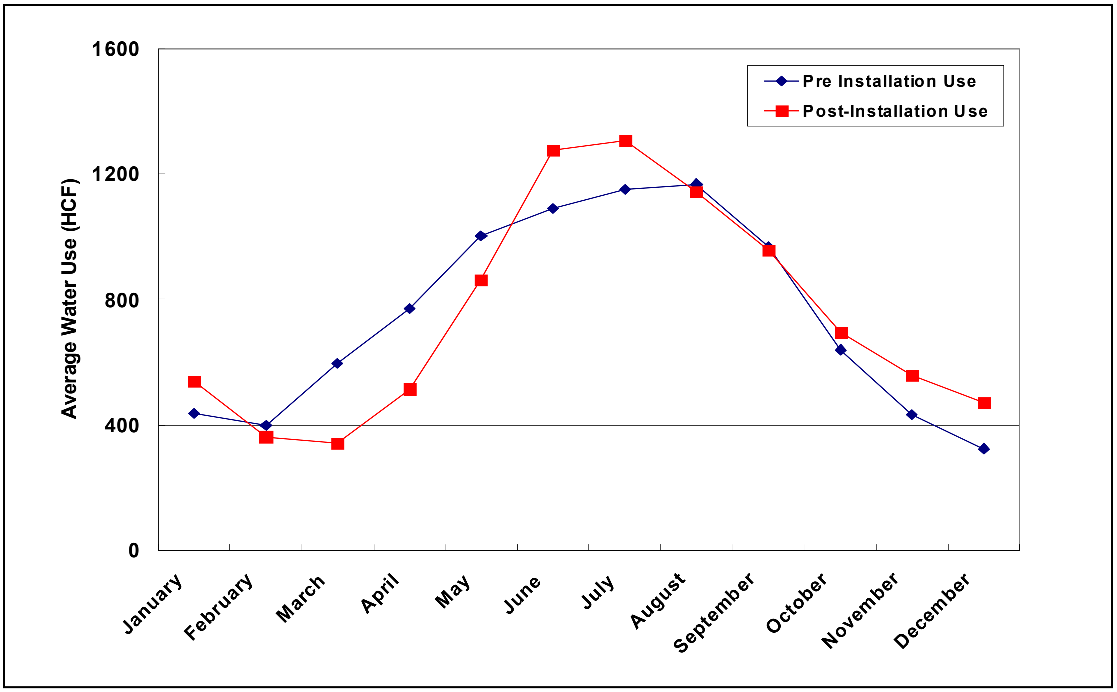


Figure 14: Central Zone Average Monthly Water Consumption for Commercial Accounts for Pre- and Post- Smart Timer Installation Periods.

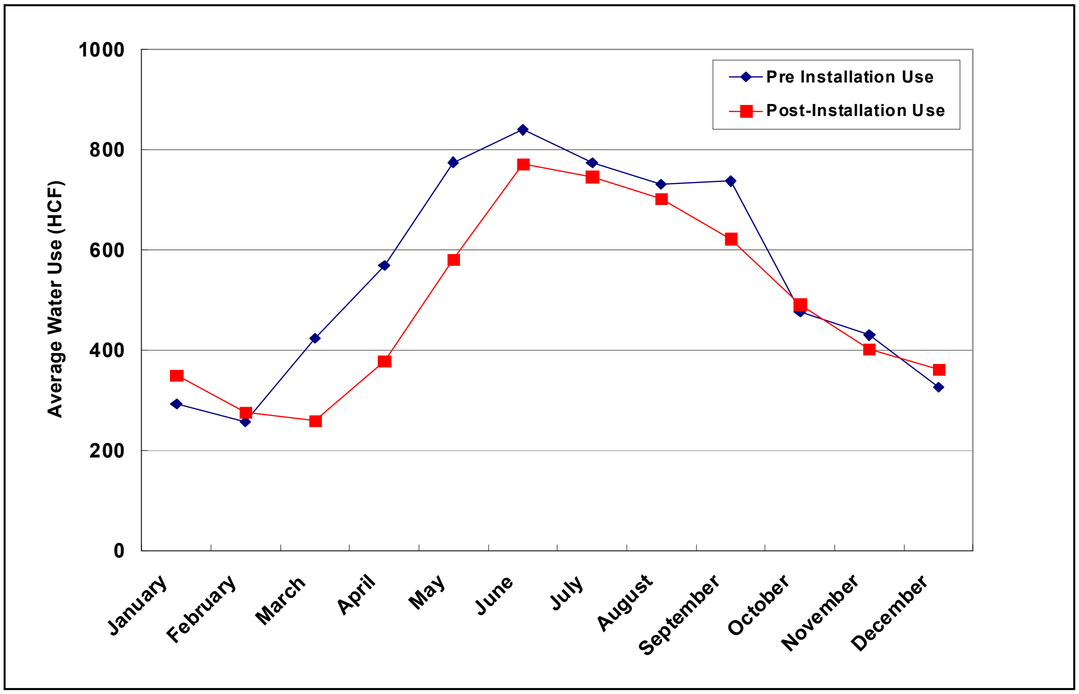


Figure 15: Foothill Zone Average Monthly Water Consumption for Commercial Accounts for Pre- and Post- Smart Timer Installation Periods.

3.4.2.1 Water Conservation by Coastal Zone Commercial Accounts

Table 13 summarizes the results from independent t-tests to compare pre- and post- Smart Timer installation water use in the Coastal zone. The data indicated that no change in water use were observed during nine months during the post-installation period. The water use increased in three months. The increase occurred primarily during late Fall or winter months (January, February and December).

Table 13: Average Monthly Pre- and Post-Installation Period Water Use in Commercial Accounts in Coastal Zone

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)
January	375	545	Significant Increase (↑)
February	392	484	No Change (=)
March	510	508	No Change (=)
April	840	563	No Change (=)
May	1500	1168	No Change (=)

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)
June	1436	1357	No Change (=)
July	1649	1678	No Change (=)
August	1753	1722	No Change (=)
September	1303	1318	No Change (=)
October	944	1101	No Change (=)
November	501	762	Significant Increase (↑)
December	432	628	Significant Increase (↑)

It must be noted that the water use comparison shown in Table 13 was performed prior to considering the differences in ET between the pre- and post-installation periods. Subsequently, statistical analyses were performed to compare the ET between these periods. Figure 16 shows the ET and water use relationship in the commercial installations in the coastal zone during pre-installation period. Table 14 summarizes the net change in water use for the commercial accounts in coastal zone after considering the effects of ET. Analyses indicated that installation of Smart Timers conserved water during five months of the year. No change in water use was observed during three months, and the water increased during four months after Smart Timer installation. Overall, the ET adjusted water conservation is 372 HCF/year (763 gpd) due to installation of Smart Timers in the coastal zone.

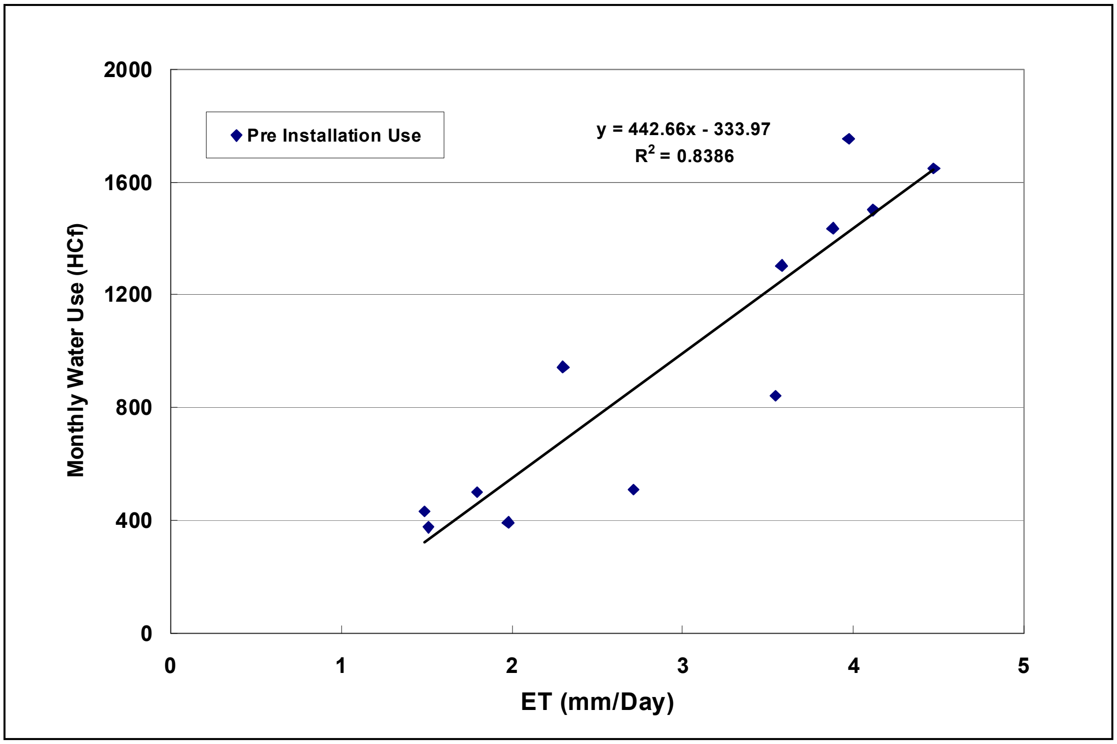


Figure 16: Pre-installation Regression Analyses of Commercial Water Use and Coastal Zone ET.

3.4.2.2 Water Conservation by Central Zone Commercial Accounts

Figure 17 shows the ET and water use relationship in the commercial installations in the central zone during pre- and post-installation periods. Table 15 summarizes the net change in water use for the commercial accounts in central zone after considering the effects of ET. Analyses indicated that installation of Smart Timers conserved water during four months of the year. No change in water use was observed during six months, and the water increased during two months after Smart Timer installation. Overall, the ET adjusted water conservation is 228 HCF/year (468 gpd) from Smart Timers in the coastal zone.

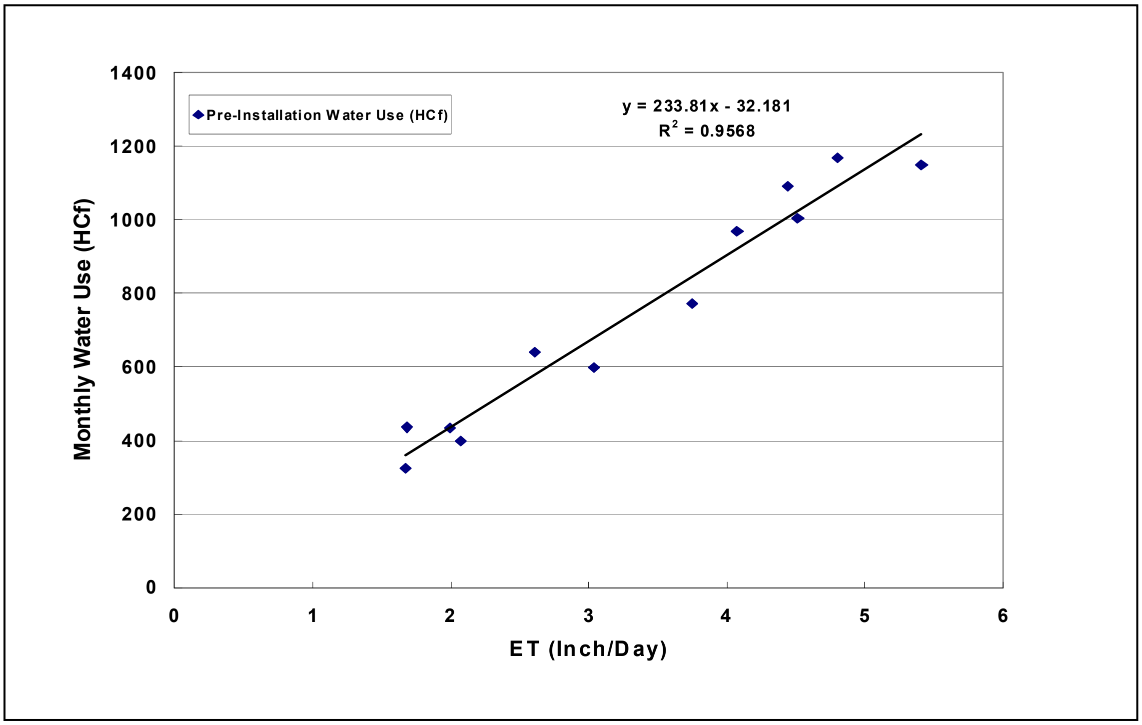


Figure 17: Pre-installation Regression Analyses of Commercial Water Use and Central Zone ET.

Table 14: Coastal Zone Average Monthly Water Conservation of Commercial Smart Timers

Month	Pre-Installation Water Use/Account	Post-Installation Water Use/Account	Is the difference significant (α = 0.05)	Pre-Installation ET	Post-Installation ET	Is the difference significant (α = 0.05)	Net Water Conser-vation (HCF)
January	375	545	Significant Increase (↑)	1.51	2.06	Significant Increase (↑)	73
February	392	484	No Change (=)	1.98	2.24	Significant Increase (↑)	118
March	510	508	No Change (=)	2.71	2.78	No Change (=)	0
April	840	563	No Change (=)	3.55	3.06	Significant Decrease (↓)	-216
May	1500	1168	No Change (=)	4.12	3.56	Significant Decrease (↓)	-246
June	1436	1357	No Change (=)	3.88	4.48	Significant Increase (↑)	260
July	1649	1678	No Change (=)	4.47	5.30	Significant Increase (↑)	365
August	1753	1722	No Change (=)	3.97	4.36	Significant Increase (↑)	173
September	1303	1318	No Change (=)	3.58	3.78	No Change (=)	0
October	944	1101	No Change (=)	2.3	2.62	No Change (=)	0
November	501	762	Significant Increase (↑)	1.78	2.08	Significant Increase (↑)	-130
December	432	628	Significant Increase (↑)	1.49	1.87	Significant Increase (↑)	-24
Annual Water Conservation (HCF/Year)							**372**
Water Conservation (gpd)							***763***

Table 15: Central Zone Average Monthly Water Conservation of Commercial Smart Timers

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)	Pre-Installation ET (mm/Day)	Post-Installation ET (mm/Day)	Is the difference significant (α = 0.05)	Net Water Conservation (HFC)
January	436	540	No Change (=)	1.66	2.17	Significant Increase (↑)	120
February	398	363	No Change (=)	2.1	2.37	Significant Increase (↑)	64
March	598	340	No Change (=)	2.96	2.83	No Change (=)	0
April	773	514	No Change (=)	3.71	3.02	Significant Decrease (↓)	-129
May	1003	861	No Change (=)	4.41	3.81	Significant Decrease (↓)	-85
June	1091	1277	No Change (=)	4.19	4.76	Significant Increase (↑)	133
July	1150	1305	No Change (=)	5.05	5.58	Significant Increase (↑)	124
August	1168	1144	No Change (=)	4.45	4.57	No Change (=)	0
September	968	958	No Change (=)	3.87	4.03	No Change (=)	0
October	640	693	No Change (=)	2.51	2.70	No Change (=)	0
November	433	559	No Change (=)	1.96	2.12	No Change (=)	0
December	325	471	No Change (=)	1.66	1.88	No Change (=)	0
						Annual Water Conservation (HCF/Year)	**228**
						Water Conservation (gpd)	***468***

3.4.2.3 Water Conservation by Foothill Zone Commercial Accounts

Figure 18 shows the ET and water use relationship in the commercial installations in the foothill zone during pre- and post-installation periods. Table 17 summarizes the net change in water use for the commercial accounts in foothill zone after considering the effects of ET. Analyses indicated that installation of Smart Timers conserved water during four months of the year. No change in water use was observed during six months, and the water use increased during two months after Smart Timer installation. Overall, the ET adjusted water conservation is 178 HCF/year (366 gpd) due to installation of Smart Timers in the coastal zone.

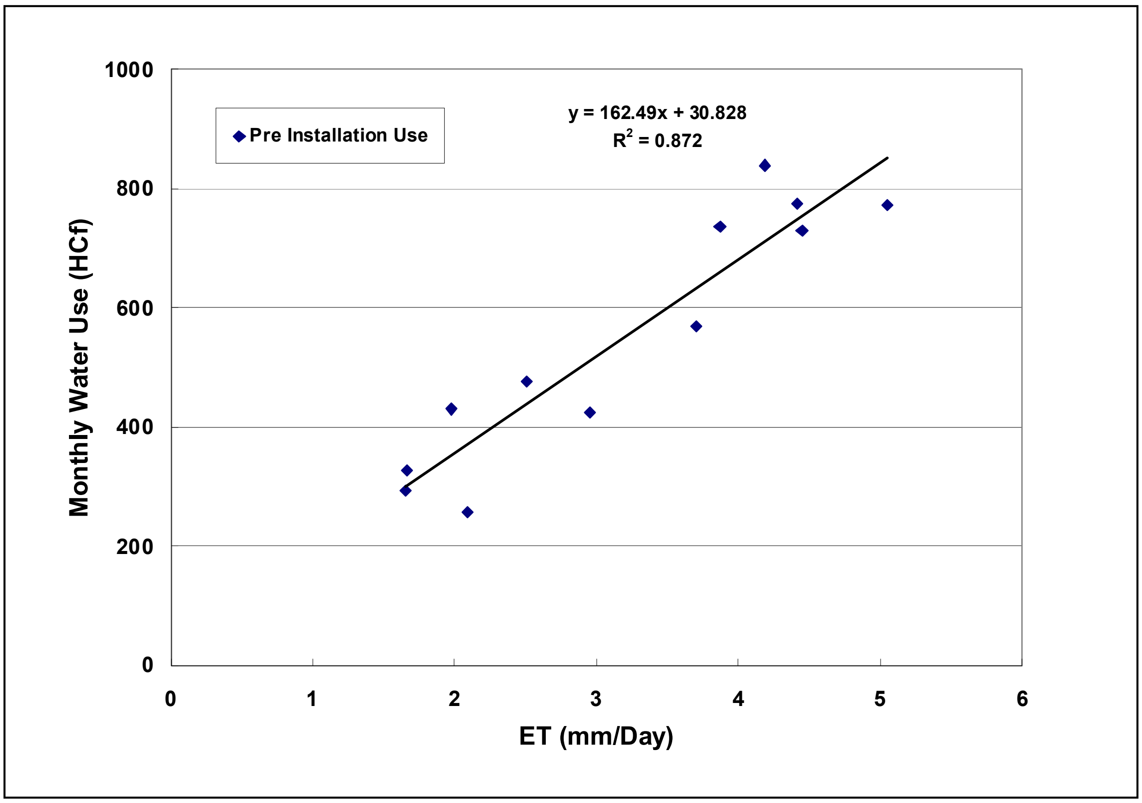


Figure 18: Pre-installation Regression Analyses of Commercial Water Use and Foothill Zone ET.

Table 16: Average Monthly Water Conservation for Commercial Smart Timer Accounts in the Foothill ET Zone

Month	Pre-Installation Water Use (HCF)	Post-Installation Water Use (HCF)	Is the difference significant (α = 0.05)	Pre-Installation ET (mm/Day)	Post-Installation ET (mm/Day)	Is the difference significant (α = 0.05)	Net Water Conservation (HCF)
January	293	350	No Change (=)	1.68	2.17	Significant Increase (↑)	79
February	257	278	No Change (=)	2.08	2.42	Significant Increase (↑)	56
March	424	259	Significant Decrease (↓)	3.04	2.86	No Change (=)	165
April	568	379	No Change (=)	3.75	2.98	Significant Decrease (↓)	-129
May	774	581	No Change (=)	4.51	3.99	Significant Decrease (↓)	-85
June	839	772	No Change (=)	4.44	5.01	Significant Increase (↑)	92
July	773	746	No Change (=)	5.41	5.73	No Change (=)	0
August	730	703	No Change (=)	4.80	4.85	No Change (=)	0
September	737	622	No Change (=)	4.08	4.28	No Change (=)	0
October	476	491	No Change (=)	2.61	2.79	No Change (=)	0
November	430	402	No Change (=)	1.99	2.20	No Change (=)	0
December	327	362	No Change (=)	1.67	1.90	No Change (=)	0
						Annual Water Conservation (HCF/Year)	**178**
						Water Conservation (gpd)	***366***

3.4.2.4 Summary of Water Savings by Commercial Accounts

Table 17 shows the program-wide water conservation due to installation of Smart Timers. The analyses indicated that there was a net water conservation of approximately 763, 468 and 366 gpd per account in the coastal, central and foothill zone, respectively. The average commercial account saved approximately 556 gpd. This reduction represents a 3 percent conservation in water use in commercial accounts during the project period. The conservation was higher in the coastal zone than in central and foothill zones. This savings pattern by ET zone was also seen in the SRF accounts.

Table 17: Average Commercial Account Water Conservation from Smart Timers

ET Zone	Accounts	Water Conservation (gpd)
Coastal	85	763
Central	58	468
Foothill	66	366
Average Water Savings per Account (gpd)		**556**

3.4.3 SFR Water Conservation by Smart Timer Brand (Manufacturer)

In order to determine the performance of different Smart Timer brands, an analyses similar to the one used for program-wide conservation was performed. The same approach was used to evaluate the performance of individual brands of Smart Timers. Only those brands that had more than 15 installations in each ET zone was analyzed.

3.4.3.1 Coastal Zone Water Conservation by SFR Smart Timer Brands

Figure 19 shows the number of installations and water use for different brands in SFR accounts in Coastal Zone. Brands A (120), B (239) and E (150) had significantly more installations than brands C, F and G (< 15). Hence, only these three brands were analyzed. The pre-installation water use in residences installed with brands A, B and E varied from ~ 450 to 480 gpd.

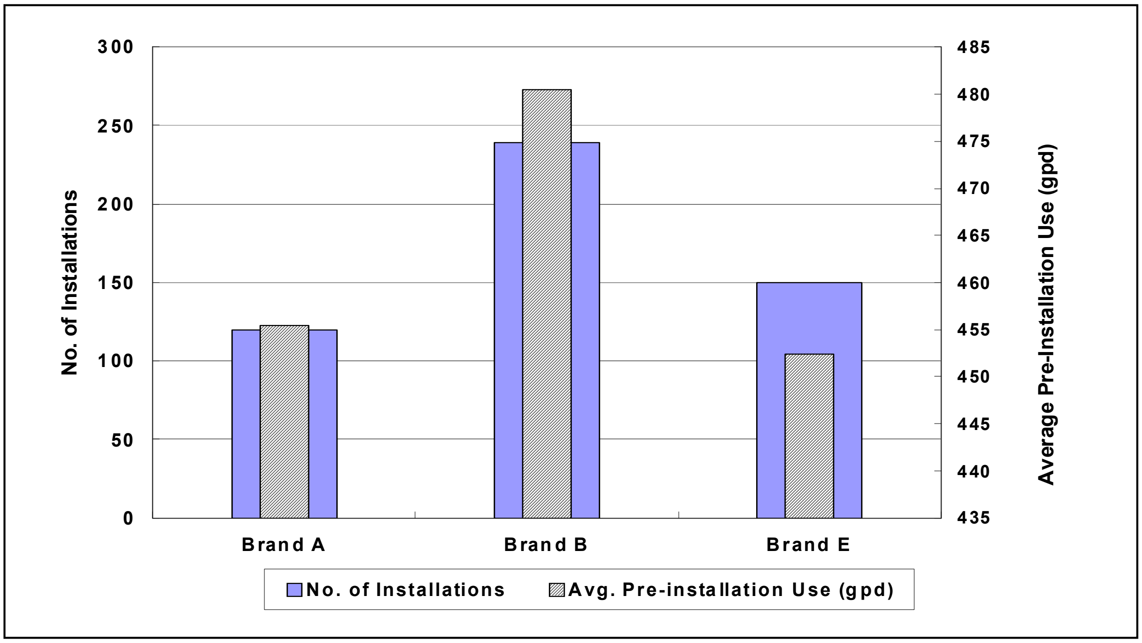


Figure 19: Coastal Zone SFR Installations and Average Water Use during Pre-Installation Period for Smart Timer Brands.

Since, the average per-installation water use per account varied among different brands, regression analyses relating pre-installation water use and ET were performed separately for each brand. Figure 20 shows the relationship between ET to pre-installation water use for the three brands. The equation thus developed, rather than the one developed for all the brands together, was used to estimate water savings for each brand. Table 18 summarizes the net water conservation for different brands after adjusting for ET. The analyses indicated that brands A and B conserved approximately 48 and 55 gpd of water use in the coastal zone. However, for Brand E, the water use increased by about 16 gpd.

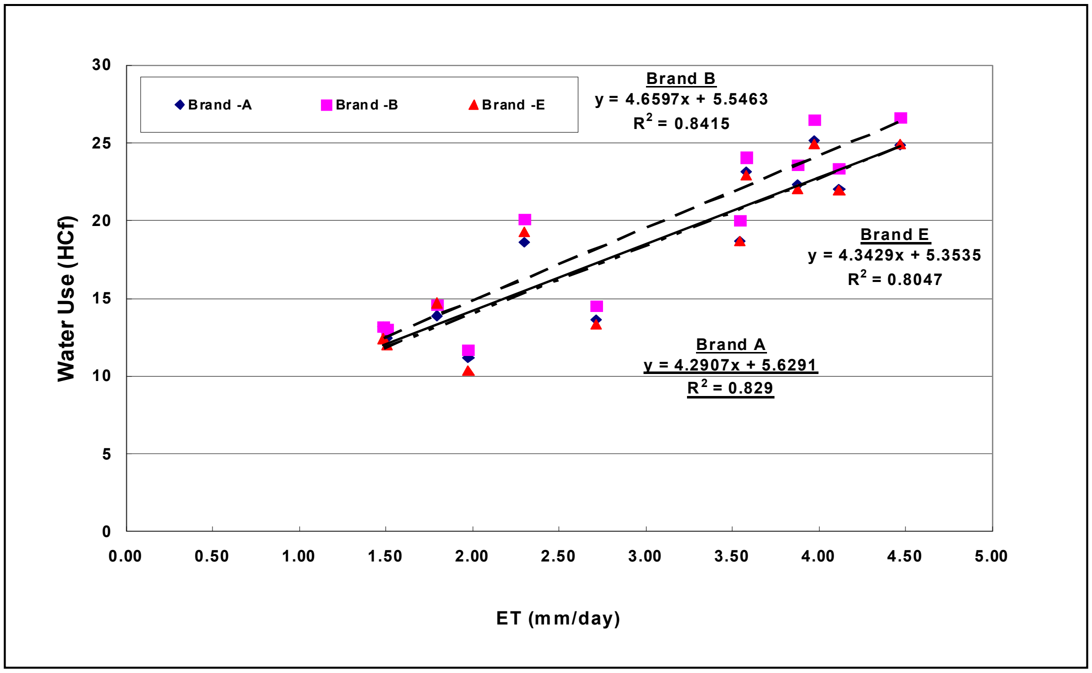


Figure 20: Pre-installation Regression Analyses for Smart Timer Brands of SFR Water Use and Coastal Zone ET.

Table 18: Coastal Zone Average Monthly SFR Water Conservation by Smart Timers Brands

	Net reduction in water use (HCF)		
Month	**Brand A**	**Brand B**	**Brand E**
January	2.35	2.55	-0.68
February	-0.54	0.06	-3.01
March	0.00	0.00	0.00
April	3.29	4.73	1.50
May	2.85	2.99	-2.41
June	5.19	5.07	0.11
July	3.54	3.85	-1.12
August	1.68	1.82	1.70
September	2.13	2.13	0.00
October	0.00	0.50	0.00
November	1.27	1.38	-2.18
December	1.67	1.81	-1.72
Annual Savings in Water Use (HCF)	23.41	26.88	-7.81*
Savings in Water Use (gpd)	47.98	58.1	-16.03*

* Negative value indicates more water used

3.4.3.2 Central Zone Water Conservation by SFRs Smart Timer Brands

Brands A (65), B (28) and E (24) more than 15 installations and brands D and G (6 &14, respectively) had less than 15 installations. Hence, data for only Brands A, B and E were analyzed. Figure 21 shows the average number of installations and water use for different brands in SFR accounts in Central Zone. The pre-installation water use in residences installed with brands A, B and E are 590, 465 and 490, respectively.

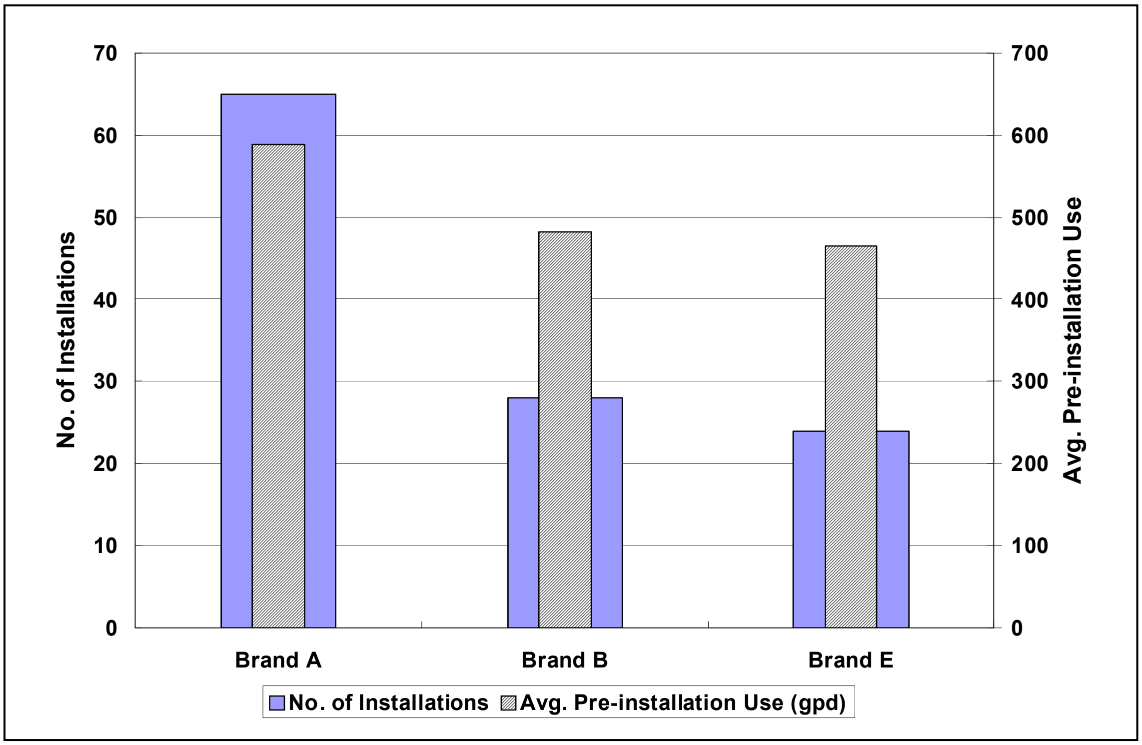


Figure 21: Central Zone SFR Installations and Average Water Use during Pre-Installation Period for Different Smart Timer Brands.

Figure 22 shows the relationship between ET and pre-installation water use for the three brands. Table 19 summarizes the net water conservation for each brand after adjusting for ET effects. The analyses indicated that, all of the three brands, including Brand E, conserved water use in the central zone. However, brands A and B conserved substantially more water (~26 to 35 gpd) than brand E (~ 8 gpd).

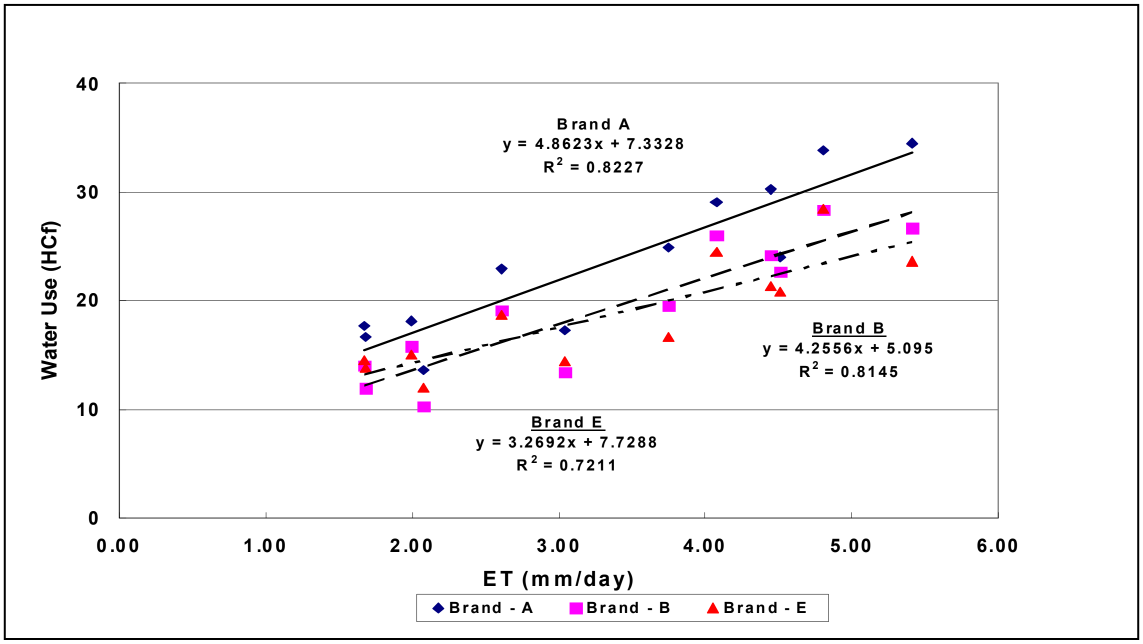


Figure 22: Pre-installation Regression Analyses for Smart Timer Brands of SRF Water Use and Central Zone ET.

Table 19: Central Zone Average Monthly SFR Water Conservation by Smart Timers Brands

	Net Reduction in Water Use (HCF)		
Month	**Brand A**	**Brand B**	**Brand E**
January	2.49	2.18	1.67
February	1.34	-0.91	0.90
March	0.00	0.00	0.00
April	5.59	2.26	-2.24
May	-2.17	-2.55	-0.20
June	2.77	2.43	1.87
July	2.59	2.26	1.74
August	0.00	5.53	0.00
September	0.00	6.09	0.00
October	0.00	0.00	0.00
November	0.00	0.00	0.00
December	0.00	0.00	0.00
Annual Savings in Water Use (HCF)	12.61	17.29	3.74
Savings in Water Use (gpd)	***25.85***	***35.43***	***7.67***

3.4.3.3 Foothill Zone SFR Water Conservation by Smart Timer Brands

Figure 23 shows the average number of installations and water use for different brands in SFR accounts in Foothill Zone. Only brands A (643) and B (27) had more than 15 installations. The average pre-installation water use in residences installed with brands A and B were approximately 590 to 770 gpd, respectively.

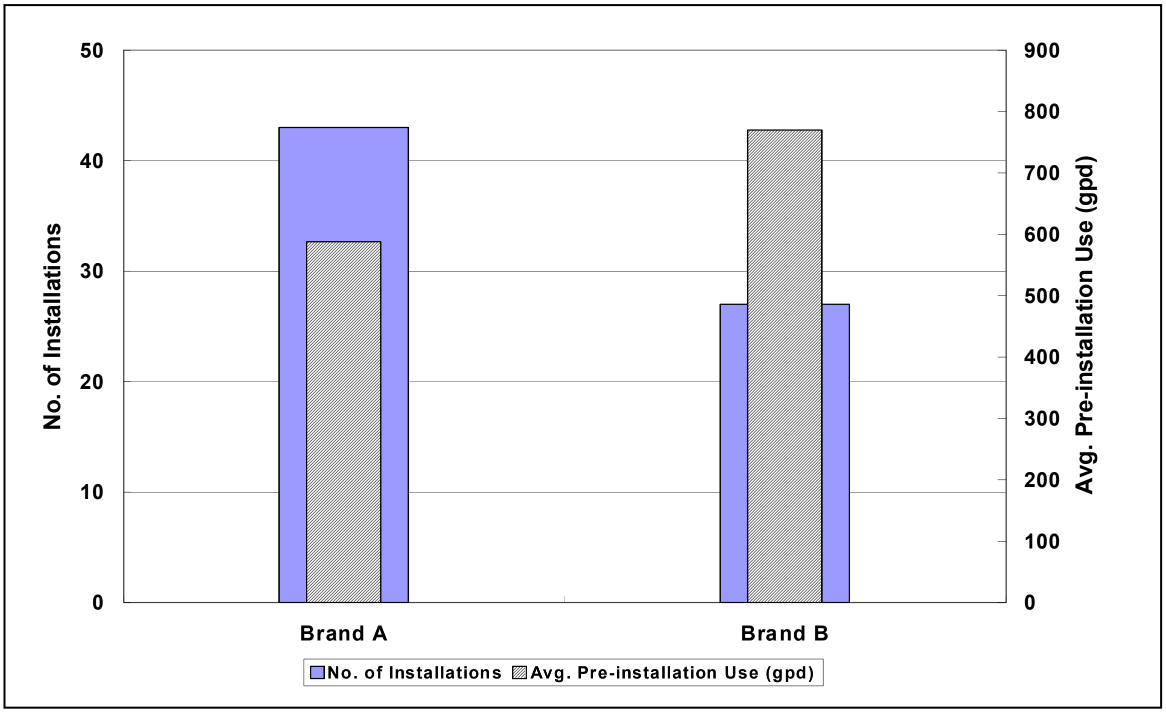


Figure 23: Average Number of SFRs Installations and Water Use during Pre-Installation Period for Smart Timer Brands in Foothill Zone.

Figure 24 shows the ET to pre-installation water use for brands A and B. Table 20 summarizes the net water conservation for different brands after adjusting for ET effects. The analyses indicated that brands A and B conserved approximately 60 and 1 gpd, respectively. The reasons for the lower water conservation by Brand B is not currently known.

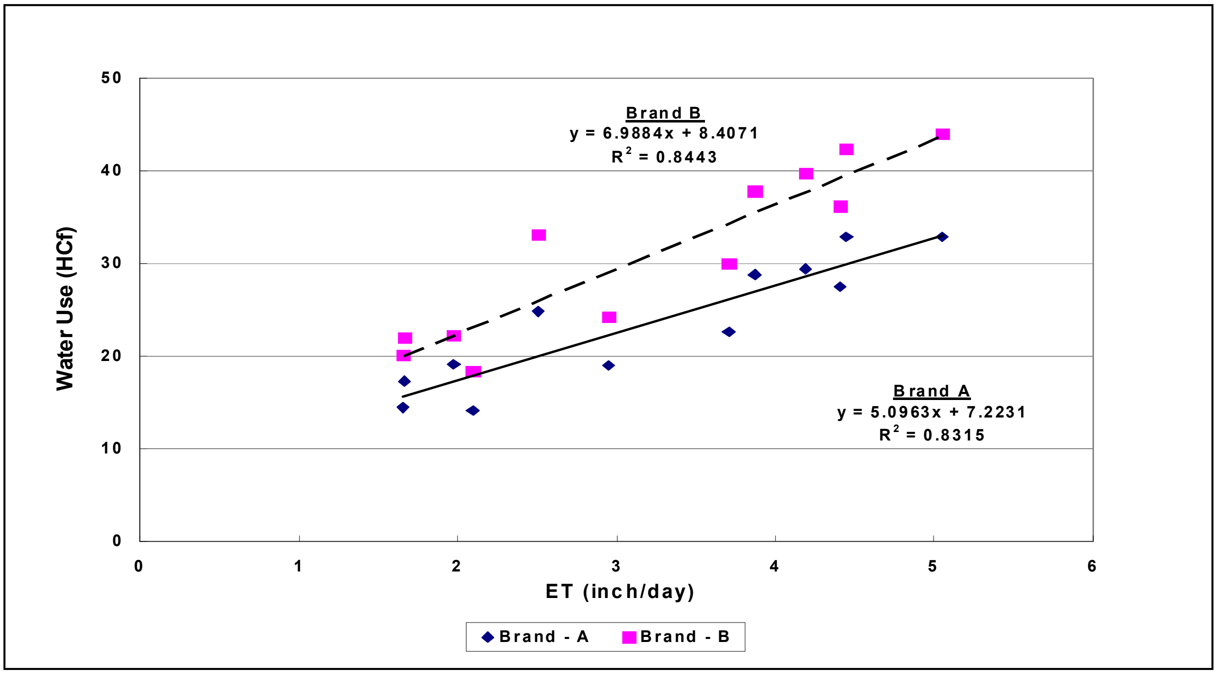


Figure 24: Pre-installation Regression Analyses for Smart Timer Brands in Foothill Zone for SFRs Water Use and ET.

Table 20: Foothill Zone Average Monthly SFR Water Conservation by Smart Timers Brands

	Net reduction in water use (HCF)	
Month	**Brand A**	**Brand B**
January	3.39	2.47
February	2.40	1.74
March	3.40	0.00
April	-0.88	-4.04
May	2.71	-2.66
June	9.53	2.89
July	0.00	0.00
August	3.95	0.00
September	4.74	0.00
October	0.00	0.00
November	0.00	0.00
December	0.00	0.00
Annual Savings in Water Use (HCF)	**29.24**	**0.40**
Annual Savings in Water Use (gpd)	***59.93***	***0.82***

3.4.3.4 Summary of Performance of Smart Timer Brands in SFRs

Among the various brands of Smart Timers, only brands A, B & E had substantial number of installations (> 15) to obtain statistically representative information in each ET Zone. In the coastal and central zones, Brands A & B conserved substantial amount of water (~ 50 gpd and 30 gpd, in coastal and central zones, respectively). Installation of Brand E, however, either increased water use (16 gpd in coastal zone) or yielded lower water conservation (~ 8 gpd in central). In the foothill zone only brands A & B had more than 15 installations. While Brand A conserved nearly 60 gpd of water, installation of Brand B conserved a significantly lower amount (~ 1 gpd) water.

3.4.4 Commercial Water Conservation by Smart Timer Brands

3.4.4.1 Coastal Zone Water Conservation by Commercial Smart Timer Brand

Only Brands I & G had more than 15 installations in commercial accounts in the coastal zone. Brand I had 15 installations and G had 52 installations (Figure 25). The average pre-installation uses were 42,900 and 26,800 gpd, respectively. Figure 26 shows the relationship between ET and water use for these two brands. Table 21 shows the monthly change in water use for these brands. Analyses indicated that installation of both of these brands resulted in substantial water conservation (3,500 gpd and 1,700 gpd, respectively) in the coastal zone.

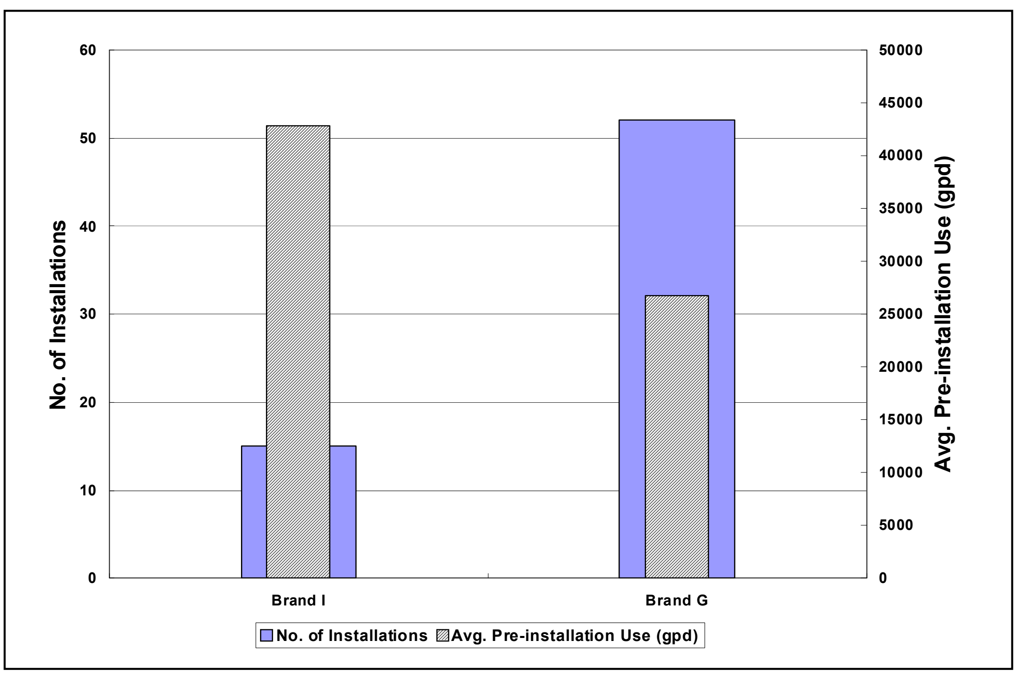


Figure 25: Coastal Zone Commercial Installations and Average Water Use during Pre-Installation Period for Different Smart Timer Brands.

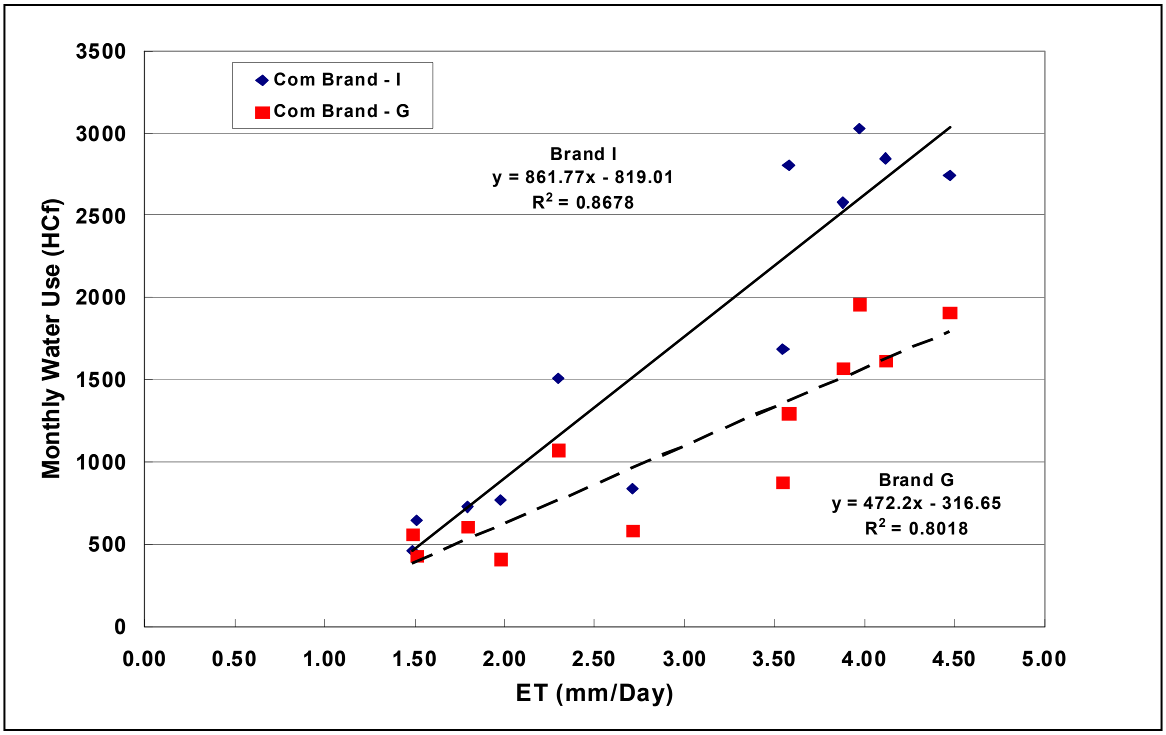


Figure 26: Pre-installation Regression Analyses for Smart Timer Brands in Coastal Zone for Commercial Water Use and ET.

Table 21: Average Monthly Water Conservation of Coastal Zone Commercial Smart Timers by Brands

	Net reduction in water use (HCF)	
	Brand I	**Brand G**
January	472	13
February	230	126
March	0	0
April	-420	-230
May	-470	-262
June	244	277
July	712	390
August	337	185
September	0	0
October	0	0
November	254	139
December	335	183
Annual Change in Water Use (HCF)	1694	821
Change in Water Use (gpd)	***3472***	***1682***

3.4.4.2 Central Zone Water Conservation by Commercial Smart Timer Brands

Only Brand G had more than fifteen installations in commercial accounts in the central zone. The average annual pre-installation use was about 12,900 gpd. Installation of Brand G conserved approximately 300 gpd water in the central zone.

3.4.4.3 Foothill Zone Water Conservation by Commercial Smart Timer Brands

Brands I (16) and G (36) had more than 15 installations (Figure 27). Figure 28 shows the relationship between ET and water use for these brands. Table 22 shows the average monthly water conservation. Installation of Smart Timer conserved approximately 935 and 487 gpd water, respectively.

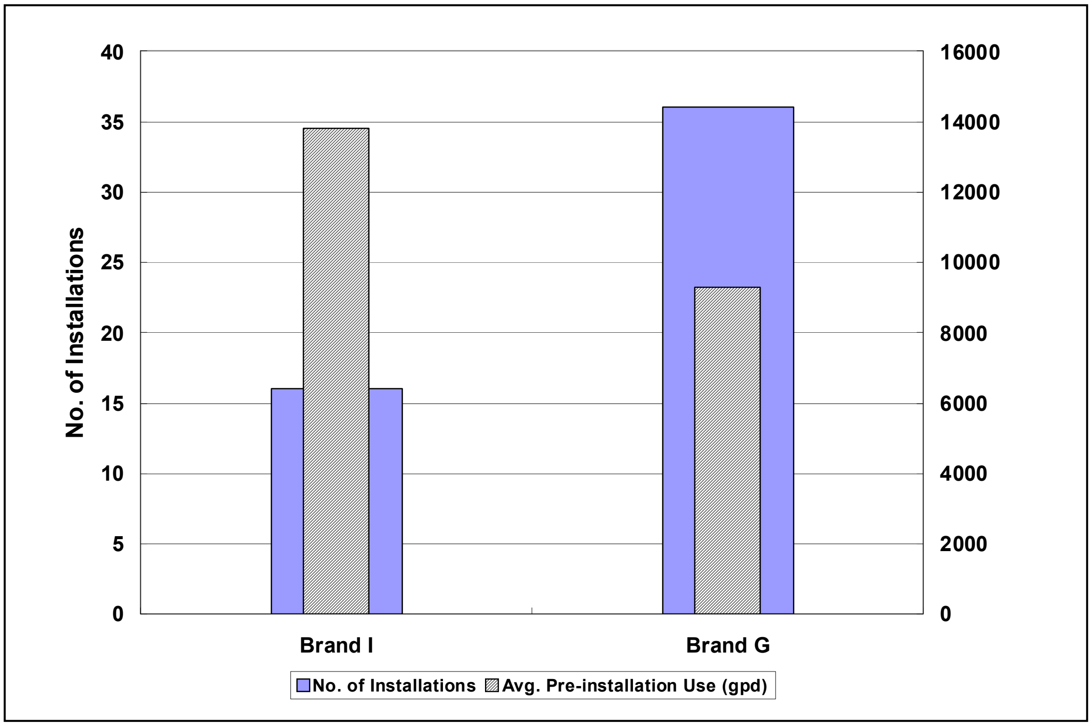


Figure 27: Foothill Zone Commercial Installations and Water Use during Pre-Installation Period by Smart Timer Brands

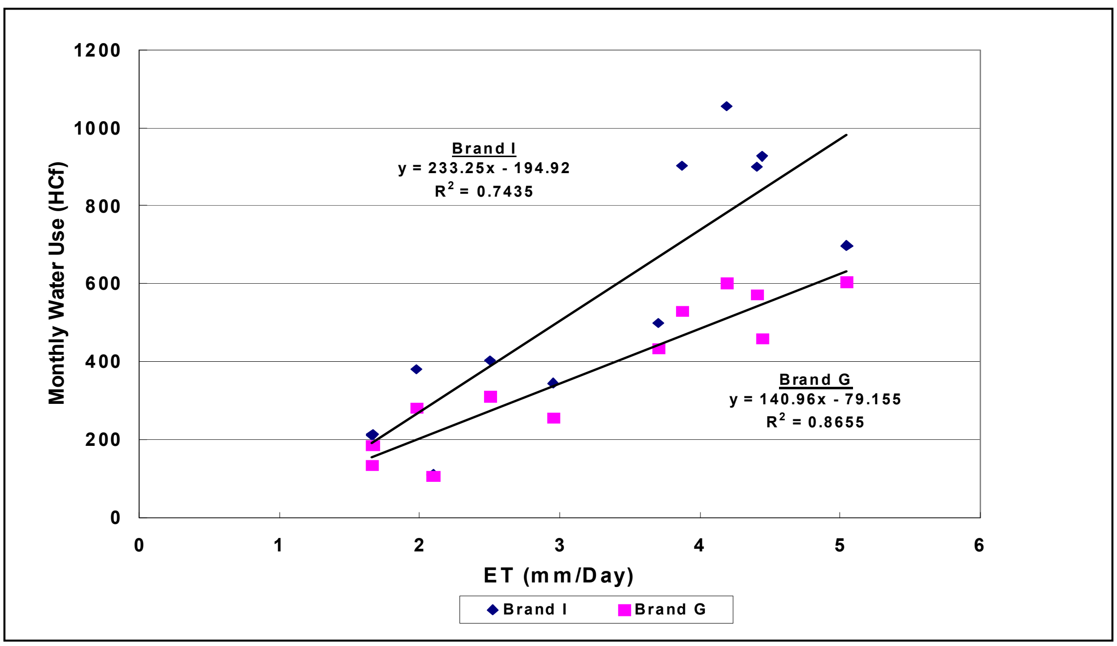


Figure 28: Pre-installation Regression Analyses for Smart Timer Brands in Foothill Zone for Commercial Water Use and ET.

Table 22: Average Monthly Water Conservation of Foothill Zone Commercial Smart Timers by Brand

	Net reduction in water use (HCF)	
Month	**Brand I**	**Brand G**
January	113	68
February	80	48
March	262	120
April	-185	-112
May	-123	-74
June	132	80
July	76	46
August	0	0
September	0	0
October	0	0
November	49	30
December	52	32
Annual Change in Water Use (HCF)	**456**	**238**
Change in Water Use (gpd)	**935**	**487**

3.4.4.4 Summary of Performance of Smart Timer Brands in Commercial Accounts

Among the various brands of Smart Timers, only brands I & G had substantial number of installations (> 15) to obtain statistically relevant information in each ET Zone. In the coastal and Foothill zones, Brands I conserved approximately 5,500 and 900 gpd, respectively. Brand G conserved nearly 50% of the water conserved by Brand I (approximately 1,700 and 500 gpd, respectively) in these zones. Brand G conserved nearly 300 gpd in the central zone.

3.4.5 Effect of Homeowner Vs Manufacturer Installation of Smart Timers on Water Conservation

One of the objectives of this study is to evaluate whether the installer of a Smart Timer made a difference in water savings. This evaluation was performed only using the program-wide SFR water use data. Table 23 summarizes this information and indicates that 333 accounts were installed by homeowners and about 566 accounts were installed professionally. A chi-square test was performed including all the Smart to evaluate the relative performance of homeowner installed and professionally installed timers. This test indicated that the Smart Timers installed by homeowners performed better than those installed professionally. However, this analyses does not include the effect of various other factors such as installation ET, city, existing non-timer related conservation program on the performance of timers installed by homeowners and those installed professionally. Subsequent evaluation of individual brands indicated that for only one Brand (Brand G), those timers installed by homeowners resulted in significant water savings than those installed professionally. However, further evaluations are required to better understand the installer effect on water savings.

Table 23: Performance of Program-wide Smart Timers Installed by Homeowners or Professionals

	Installed by Home Owner			Installed by Professional		
Smart Timer Brand	**Total Number of Timers**	**No. of Smart Timers with significant savings**	**Timer with significant savings (%)**	**Total Number of Timers**	**No. of Smart Timers with significant savings**	**Timer with significant savings (%)**
Brand A	136	46	**38**	113	43	**38**
Brand B	62	27	**43.6**	235	86	**36.6**
Brand C	15	6	**40**	4	2	**50**
Brand D	1	0	**0**	6	1	**16.7**
Brand E	33	6	**18.8**	150	25	**16.7**
Brand G	86	33	**38.4**	58	13	**22.4**
Total	**333**	**124**	**37.2**	**566**	**170**	**30**

Section 4: Runoff Reduction Evaluation

4.1 Overview

This chapter presents the statistical analysis of runoff reduction due to installation of Smart Timers in the study area. Specific information includes:

- Description of data collection stations and data collection periods;
- Discussion of the runoff evaluation methods ; and
- Evaluation and discussion of results

4.2 Evaluation Approach

Tables 24 and 25 describe the monitoring stations, data collection periods and frequencies, and the approach used for evaluation of runoff reduction due to installation of Smart Timers.

Table 24: Description of Runoff Stations and Summary of Evaluation Approach

Site	Watershed Area Description	Smart Timers in the Watershed Area	Types of Evaluations
Runoff Evaluation in Common Area Landscape in a Residential Area			
Buck Gully Retrofit Area (Station 3011)	This is a residential area. The irrigated common area at this location is about 85.7 acres.	There are a total of 51 commercial accounts in this area. 32 of these sites were retrofitted with Smart Timers sometime in 2006 or earlier.	1. Area weighted runoff comparison between the retrofit area and control area in year 2006. (Paired t-test). 2. Compare runoff reduction between pre and post retrofit periods in the retrofit and control areas. (Paired t-test). 3. Evaluate relationship between runoff reduction and weather. (Regression analyses)
Buck Gully Control Area (Station 3001)	This study area is very similar (and located adjacent) to the retrofit area (3011). The irrigated common area is about 65.1 acres.	There are a total of 37 commercial accounts in this area. No sites are retrofitted with Smart Timers.	

Site	Watershed Area Description	Smart Timers in the Watershed Area	Types of Evaluations
Runoff Evaluation in Residential Area			
Lake Forest Retrofit Area (J01P08)	This predominantly residential area has about 500 homes in the watershed area. Each residence has approximately 1350 sf irrigated land. There are also some HOA common-irrigated areas in this neighborhood.	About 50 of the 500 residential homes were retrofitted with Smart Timers sometime in 2006.	1. Compare reduction in runoff between pre-retrofit (2005) and post-retrofit (2006) periods. (Paired t-test). 2. Evaluate relationship between runoff reduction and weather. (Regression analyses).

Table 25: Runoff Data Collection Period

Station	Pre-Retrofit Runoff		Post-Retrofit Runoff	
	Period Monitored	Frequency of Recording	Period Monitored	Frequency of Recording
Buck Gully Retrofit Area (Station 3011)	2003 (July – October)	5 minute interval	2006 (May – October)	1 minute interval
Buck Gully Control Area (Station 3001)	2003 (July – October)	5 minute interval	2006 (May – October)	1 minute interval
Lake Forest Retrofit Area (J01P08)	2005 (June – September)	15 minute interval	2006 (June – September)	15 minute interval

The following two distinct types of areas were selected for this study:

- **Buck Gully** area. A predominantly residential area with dedicated HOA landscape accounts. Runoff was monitored in two sub-areas, one partially retrofitted with Smart Timers (Retrofit Station #3011) and the other not retrofitted with Smart Timers(Control Station #3001). Runoff was monitored prior to (2003) and after (2006) installation of Smart Timers in both the monitoring stations.

- **Portola Hills** area. A residential SFR area with water meters serving both indoor and outdoor use. The runoff was monitored prior to (2005) and after (2006) installation of Smart Timers.

Sigma 950 flow monitors were installed at the monitoring stations (Table 24). The flow monitoring period and frequency of flow recording are shown in Table 25. The runoff flows were monitored during summer/fall months during pre- and post-retrofit periods. The post-retrofit runoff data were collected during 2006 for the Buck Gully and Portola Hills locations. However, the pre-retrofit runoff flows for the Buck Gully area were measured in 2003, while it was measured in 2005 for the Portola Hills area. The flow measurement techniques are similar to that described in an earlier MWDOC R3 Study, except that in this study the use of weirs helped to improve measurement of low flows. IRWD staff visited the monitoring stations twice per week to maintain them in good condition.

4.2.1 Data Reduction

Several techniques were used to identify and rectify potential runoff monitoring data quality errors. During preliminary evaluation it was observed that occasionally the runoff flow was recorded as “0” continuously for several hours or days. Secondly, some of the recorded flow data on dry weather days appeared to be unusually high compared with typical flow rate measured during the same period on most days. The following data reduction approach was used to address these issues:

- Only dry weather (non-rainfall) day runoff flows were considered for evaluation.
- Rainfall data recorded at IRWD monitoring stations were used in this study. The recorded data were verified and corrected for accuracy by IRWD staff prior to identify dry weather days for this study.
- The flow data (1, 5 and 15 minute frequency) were converted to hourly average flow.
- All the “0” hourly data were set aside for correction.
- For the remaining data, the differences in flow rate between consecutive hours were estimated. These differences were then compared with the differences for i) the previous and next hours of the same day, and ii) the same hours of the previous and next days. Any data where the difference is more than 5 times the base line data used for comparison were selected for further scrutiny. Subsequently, the data were either retained or deleted.
- Next, from the “0” flow data set aside earlier, for those days that had four or fewer hours of recorded “0” flow data, the data was replaced with the hourly average flow of the previous and next day for the same hour.
- Average daily flows were then calculated for each day.
- Finally, for days with more than four hours of “0” flow data, the daily average flow for the month was used as the daily flow data.

4.2.2 Data Evaluation Techniques

After the data reduction steps were complete, statistical analyses of the data were performed using paired t-test and regression analyses.

- For comparing Buck Gully retrofit and control area runoff for 2006, the daily average flows were normalized to irrigated acreage in those respective areas. Subsequently, paired t-test by matching dry weather days was performed to evaluate runoff reduction.

- Comparison of pre and post-retrofit runoff for Buck Gully area included the following:

    1. Two sets of data were used: a) the daily average runoff flow, and, b) the daily average runoff adjusted for evapotranspiration for the day i.e.,

    2. Total Flow = Runoff Flow + Portion of water consumed (evapotranspired) by landscape.

    3. The ET data for evapotranspiration adjustment was received from IRWD monitoring stations.

    4. The daily average runoff data in the two stations were normalized to "unit irrigated area" prior to analyses.

    5. Evaluation of runoff reduction (2003 Runoff – 2006 Runoff) in the two stations individually. Paired t-test by matching days was performed for this analysis. The daily average runoff data were normalized to "unit irrigated area" prior to analyses.

    6. Evaluations of relative change in runoff between retrofit and control stations. This was done to selectively identify the impact of Smart Timers on the runoff reduction in the retrofit area. It is assumed in this study that any runoff reduction between 2003 and 2006 in the control area occurred due to various non-Smart Timer factors such as public education, incentives and weather conditions. In the retrofit areas, any observed reduction occurred due to all of the above factors, in addition to the effect of Smart Timers. Hence, the difference in runoff reduction between the retrofit area and control area was assumed as the runoff reduction selectively contributed by the Smart Timer. Table 26 explains this approach.

Table 26: Approach for Runoff Reduction Estimation

Item	Factors Contributing to Runoff Reduction	Estimation Method
Runoff Reduction in Control Area	Include Public Education, Incentives, Weather related issues, etc.	Runoff in 2003 – Runoff in 2006 in control area (1)
Runoff Reduction in Retrofit Area	All of the above + Installation of smart Timers	Runoff in 2003 – Runoff in 2006 in control area (2)
Runoff reduction in retrofit area selectively contributed by installation of smart Timers	Installation of Smart Timers in retrofit area	(2) – (1) above

- Impact of weather on runoff reduction for Buck Gully area was evaluated by i) plotting runoff reduction with respect to the months of the year, and ii) performing regression analyses of runoff reduction with respect to ET (daily, weekly or monthly average) for year 2006.

- Comparison of pre and post-retrofit runoff for Portola Hills area were performed by:
  - Using two sets of data: i) the daily average runoff flow, and, ii) the daily average runoff adjusted for evapotranspiration for the day i.e., Total Flow = Runoff Flow + Estimated evapotranspired flow. Estimation of evapotranspired flow was done using the ET data obtained from IRWD monitoring stations.
  - To evaluate runoff reduction (2005 Runoff – 2006 Runoff). Paired t-test by matching days was performed for this analysis. The daily average runoff data were normalized to "unit irrigated area" prior to analyses.
- Impact of weather on runoff reduction for Buck Gully was evaluated by i) plotting runoff reduction with respect to the months of the year, and ii) performing regression analyses of runoff reduction with respect to ET (weekly or monthly average) for year 2006.

4.3 Evaluation Results

4.3.1 Comparison of Control and Intervened Area Runoff in Buck Gully

Table 28 presents the paired t-test results for comparison of runoff flow for the control (Station 3001) and retrofit (Station 3011) stations in Buck Gully for 2006. The daily average runoff flow in gallons per day (gpd) was normalized to the estimated irrigated area for each station. The results are provided for the duration of the monitoring period (May – October, 2006) as well as for the individual months. There were a total of 95 pairs of dry weather days during the monitoring period.

The paired t-test data indicated that the runoff flow (normalized to irrigated area) in the retrofit area was significantly lower than that of the control area at a 95 percent confidence interval (α=0.05). On an average, the runoff flow in the retrofit area is about 220 gpd/irrigated acre (~52 percent) lower than that of the control area. This is equivalent to a reduction in runoff of about 590 gpd/Smart Timer installed in the Buck Gully area (not program-wide). It is reasonable to attribute the lower runoff rate observed in the retrofit area to the installation of Smart Timers, since the two areas have very similar characteristics and the flow measurements were taken during the same time period. Figure 29 shows the runoff pattern for each month during the monitoring period. Evaluation of results indicated the reduction in runoff was higher in summer months than in late spring and early fall months. This is generally agrees with the consumption data for the area.

Table 27: Summary of Paired T-test Analyses for Runoff in Buck Gully Control and Retrofit Areas in Post Intervention Period (2006). α = 0.05.

Period	Area Weighted Mean Flow (gpd/Acre)		Sample Size (N) – No of dry weather days	T – stat	t-critical (2-tail)	Is Runoff Reduction in Retrofit area significant?	Estimated Runoff Reduction (gpd/Acre)
	Control Station (3001)	Retrofit Station (3011)					
May – October, 2006	420	200	95	14.385	1.986	Yes	220
May 2006	237	163	11	3.347	2.228	Yes	74
June 2006	382	263	26	6.576	2.060	Yes	119
July 2006	543	286	19	7.045	2.100	Yes	257
August 2006	324	135	2	12.706	6.313	No – Sample size too small for determination	189
September 2006	476	122	26	15.922	2.060	Yes	354
October 2006	365	137	11	10.992	2.228	Yes	228

Average Runoff Reduction = 220 gpd/acre
Average Runoff Reduction for the retrofit area = 18,855 gpd
Average Runoff Reduction per Smart Timer = 590 gallons/account/day

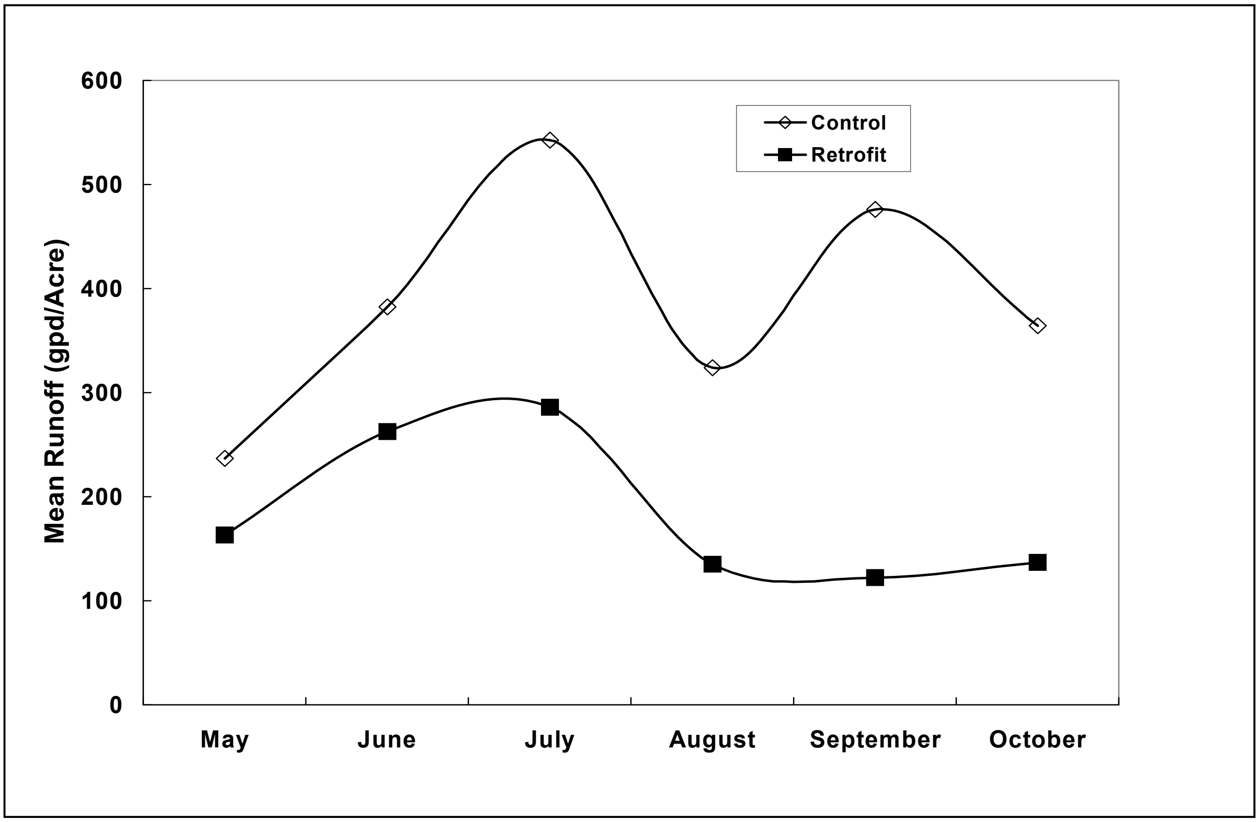


Figure 29: The Area Weighed Runoff in Buck Gully Control and Retrofitted Area in 2006

Figure 29 shows the average runoff in Buck Gully control and retrofitted areas in 2006. The runoff flow for both areas was low in May and gradually increased in summer. Towards the end of summer the runoff flow gradually decreased in the control area. However, in the retrofit area the decrease in runoff flow was more rapid in July and it subsequently leveled off till October. This decrease in runoff is generally consistent with the water consumption pattern of the Buck Gully area landscape irrigation meters.

4.3.2 Comparison of Pre- and Post- Intervention Runoff in Buck Gully Area

Data reduction procedures for these analyses were similar to that described in the above section. Paired t-test were performed by matching the runoff normalized to irrigated area for the same dates for pre (2003) and post (2006) intervention to evaluate differences in runoff. The following paired t-test analyses were performed under this task:

- Comparison of pre- and post- intervention runoff for Buck Gully control station (3001)

- Comparison of pre- and post- intervention runoff for Buck Gully retrofit station (3001)

- Comparison of pre- and post-intervention runoff differences between Buck Gully Control and retrofit area. This analysis was performed after normalizing the flow to irrigated area in the control and retrofit stations.

Figure 30 and Table 28 show the summary of paired t-test results for pre- and post-intervention runoff for Buck Gully control and retrofit stations. During the pre-intervention period, the weighted runoff in the retrofit area (545 gpd/irrigated acre) is significantly lower than that of the control area (669 gpd/irrigated acre; N = 98, t-stat 4.18, t-critical 1.98). In both areas the runoff flow decreased between 2003 and 2006. In the Control Area alone, the average runoff flow decreased from 669 gpd/acre in 2003 to 476 gpd/acre (net decrease of about 190 gpd/acre). Since there are no known Smart Timers in this area, the decrease in reduction may be attributed to other, non-Smart Timer factors such as consumer education, financial incentives or weather-related irrigation reduction. In the Retrofit Area the runoff flow decreased from 545 to 175 gpd/acre (net decrease of 367 gpd/acre). The reasons for decrease in runoff in the Retrofit Area may include all the factors associated with the control station in addition to the effect of Smart Timer installations.

Note that the net reduction in runoff for the Retrofit Area was larger than that for the Control Area by about 175 gpd/acre. This yields a reduction of 465 gallons/day/Smart Timer installed in the Retrofit Area during the evaluation period. In order to verify if this difference is statistically different, a paired t-test was performed to compare the net difference in the Control and Retrofit areas by matching the day. Results (Table 29) indicated that the differences are significant at a 95 percent confidence level ($\alpha = 0.05$). Since the differences in flow between the two areas were measured under identical conditions (except for the Smart Timers), it is reasonable to attribute the reduction observed in this analyses to installation of Smart Timers.

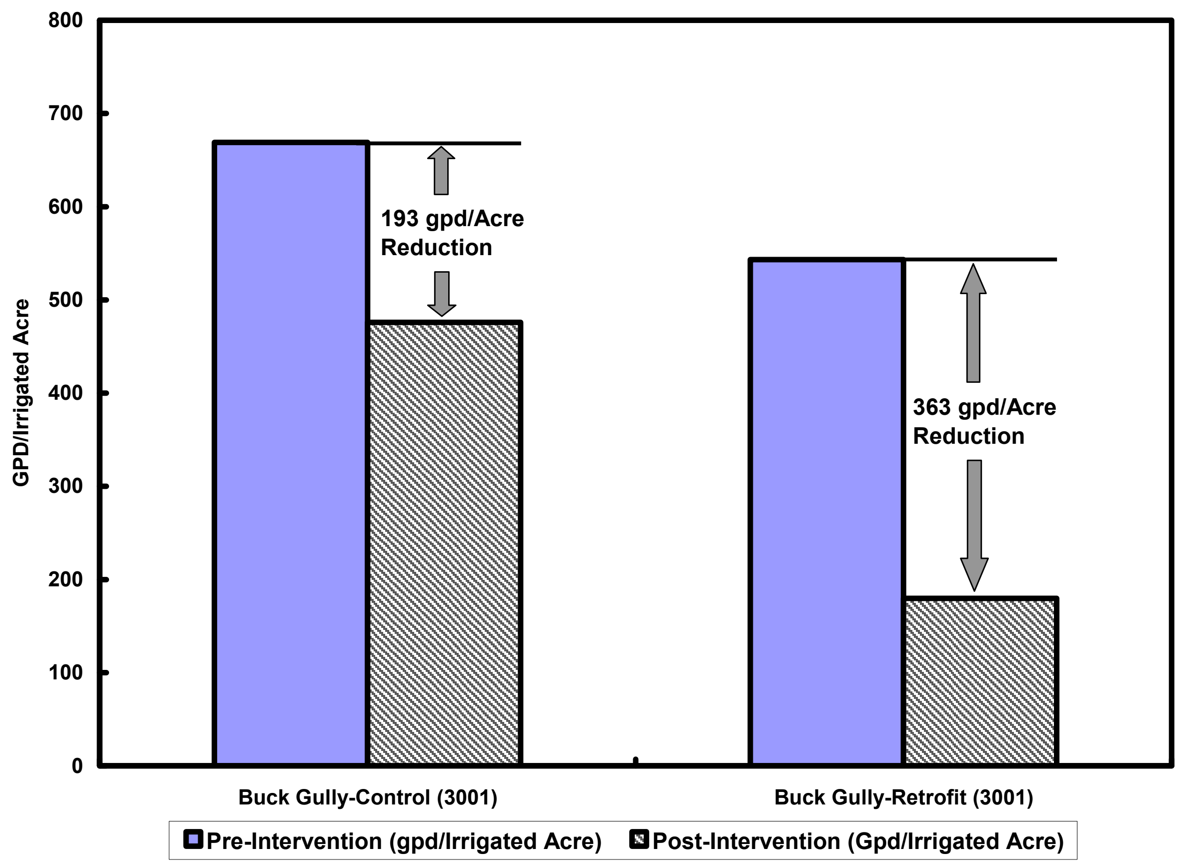


Figure 30: Runoff Reduction in Buck Gully Control and Retrofit Areas Between Pre- and Post-Intervention Periods

Table 28: Summary of Paired T-test Result for Pre- and Post- Intervention Periods for Buck Gully Control and Retrofit Areas

Station/ Flow Type	Mean Flow (gpd) 2003	Mean Flow (gpd) 2006	Sample Size (N)	T – stat	t-critical (2-tail)	Is Runoff Reduction significant?	Estimated Runoff Reduction (gpd/Acre)
Buck Gully Control Area (# 3001)							
Runoff (gpd/Acre)	669	476	51	5.112	2.009	Yes	190
ET Adjusted Flow (Runoff + Estimated ET loss in irrigated area) (gpd/Acre)	4,651	4,277	51	2.26	2.008	Yes	347
Buck Gully Retrofit Station (# 3011)							
Runoff (gpd/Acre)	545	178	52	15.93	2.008	Yes	367
ET Adjusted Flow (Runoff + Estimated ET loss in irrigated area) (gpd/Acre)	4,527	4,096	52	2.756	2.008	Yes	431

Table 29: Summary of Paired T-test Result for Relative Runoff Reduction in Pre- and Post- Intervention Periods for Buck Gully Control and Retrofit Areas

Station/ Flow Type	Runoff reduction between 2003 and 2006 (gpd/Acre)		Sample Size (N)	T – stat	t-critical (2-tail)	Is Runoff Reduction in Retrofit area significant?	Relative Runoff Reduction in Retrofit Area (gpd/Acre)
	Control Station (3001)	Retrofit Station (3011)					
Runoff Reduction from 2003 to 2006	193	367	51	-3.795	2.008	Yes	174

Finally, in order to evaluate the role of weather conditions on the effectiveness of Smart controllers to reduce runoff, runoff reduction in various months in the Control and Retrofit areas was evaluated. Furthermore, regression analyses were performed on the runoff reduction in Control and Retrofit areas with respect to 2006 ET.

Figure 31 shows the runoff reduction in Buck Gully Control and Retrofit areas during various months. In the Control Area, the runoff reduction was the highest in July and August (~ 300 gpd/acre), and then it decreased over time to almost no reduction in the month of October. The runoff reduction pattern in the Retrofit Area was very different than that in the control area, which indicated the influence of Smart Timers. Among the months the runoff was evaluated, the reduction in runoff in the Retrofit Area was the lowest in July (~ 150 gpd/acre). Then the runoff reduction increased to highest volume in August and September (~ 500 gpd/Acre) and slightly declined in October. Determination of selective effect of the Smart controllers in the retrofit area indicated that in the Smart Timers area there was increased runoff volume in July, i.e., “negative reduction.” However, in subsequent months the runoff reduction increased gradually. This is in general agreement with the savings pattern observed in the water meter data (Section 3).

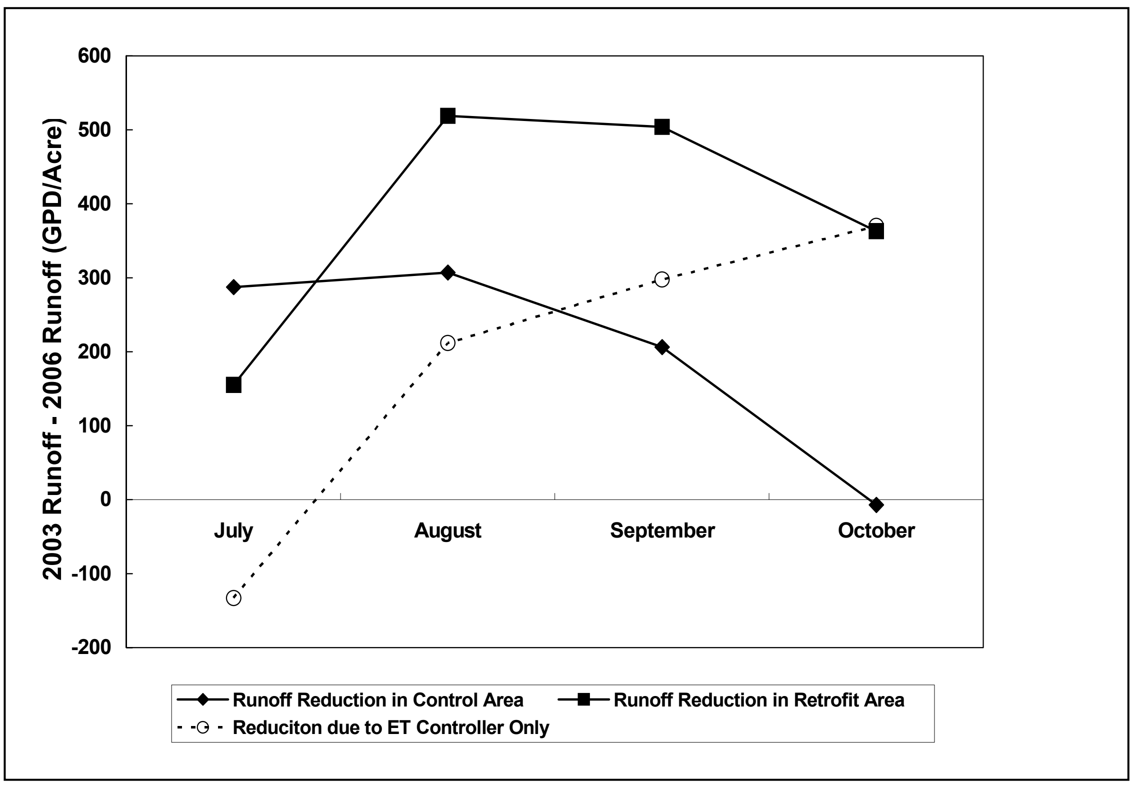


Figure 31: Runoff Reduction Between Pre- and Post-Intervention Months in Buck Gully

Subsequently, regression analyses were performed to relate runoff reduction with 2006 ET values. Analyses were performed using daily ET, weekly average ET and monthly average ET values for all the three cases described above. In general, the regression coefficients were better while using monthly or weekly runoff reduction than daily ET variation. Table 30 shows the regression coefficients for various scenarios. Furthermore, as observed with the monthly runoff relationship, the regression pattern for the Retrofit Area was very different than that for the Control Area, which indicated the influence of Smart Timers. A linear relationship better described the Control Area runoff reduction, while a second degree polynomial regression better described (higher R^2) the runoff reduction in Retrofit Area.

Table 30: Regression Analyses Summary for Buck Gully Area Runoff

Runoff Description	ET Type for Regression	Regression Coefficient	Curve
Runoff Reduction in Control Area	Daily ET	0.213	Linear
	Weekly Average ET	0.655	
	Monthly Average ET	0.9468	
Runoff Reduction in Retrofit Area	Daily ET	0.234	2nd Degree Polynomial
	Weekly Average ET	0.469	
	Monthly Average ET	0.822	
Runoff reduction in retrofit area selectively contributed by installation of smart Timers	Daily ET	0.361	2nd Degree Polynomial
	Weekly Average ET	0.875	
	Monthly Average ET	0.944	

Figures 32 and 33 show the regression using monthly average ET for the three scenarios. In the Control Area the relationship between ET and runoff reduction appears to be a linear one, with higher savings on higher ET days. However, the Smart Timer effect appears to be more pronounced during moderate ET periods (0.12 to 0.14 in), rather than in the higher and lower ET periods. The regression for the Smart Timer effect alone (Figure 14) also indicated a curvilinear relationship, with the greatest reduction occurring during moderate ET periods.

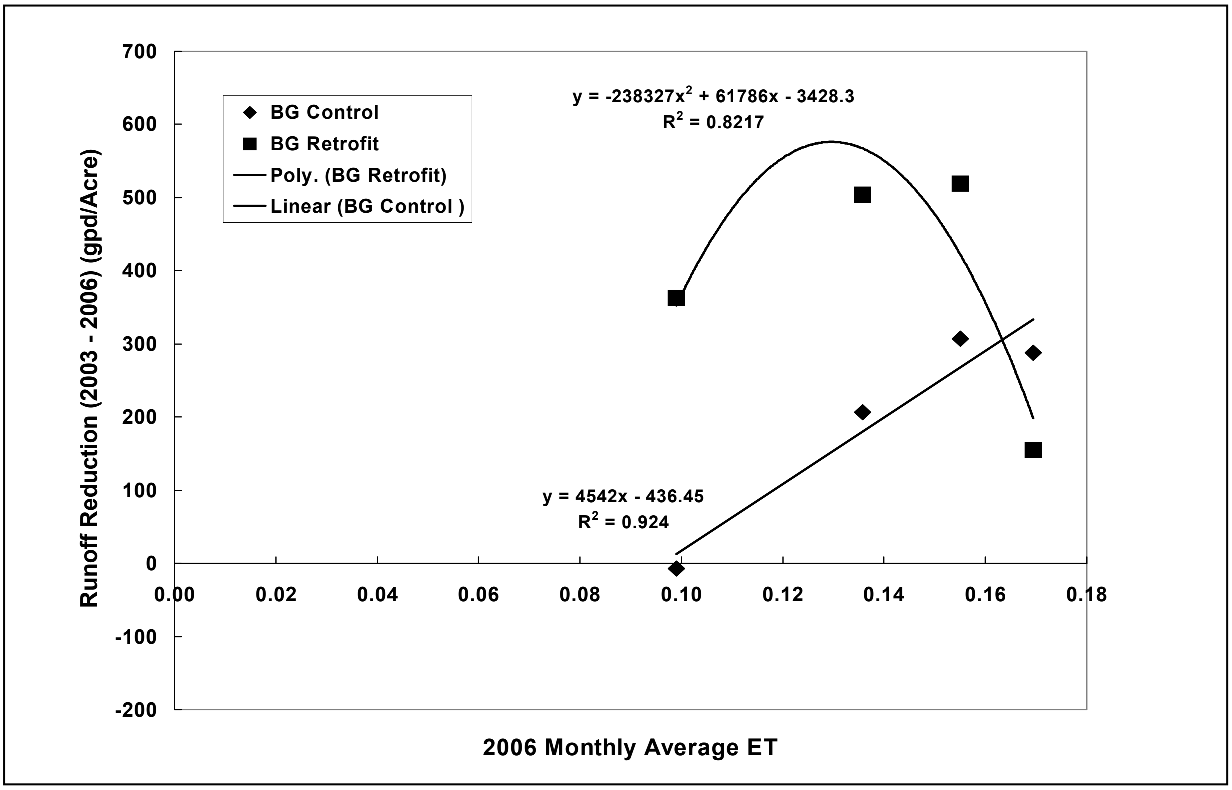


Figure 32: Regression Analyses for Buck Gully Control and Retrofit Area Runoff

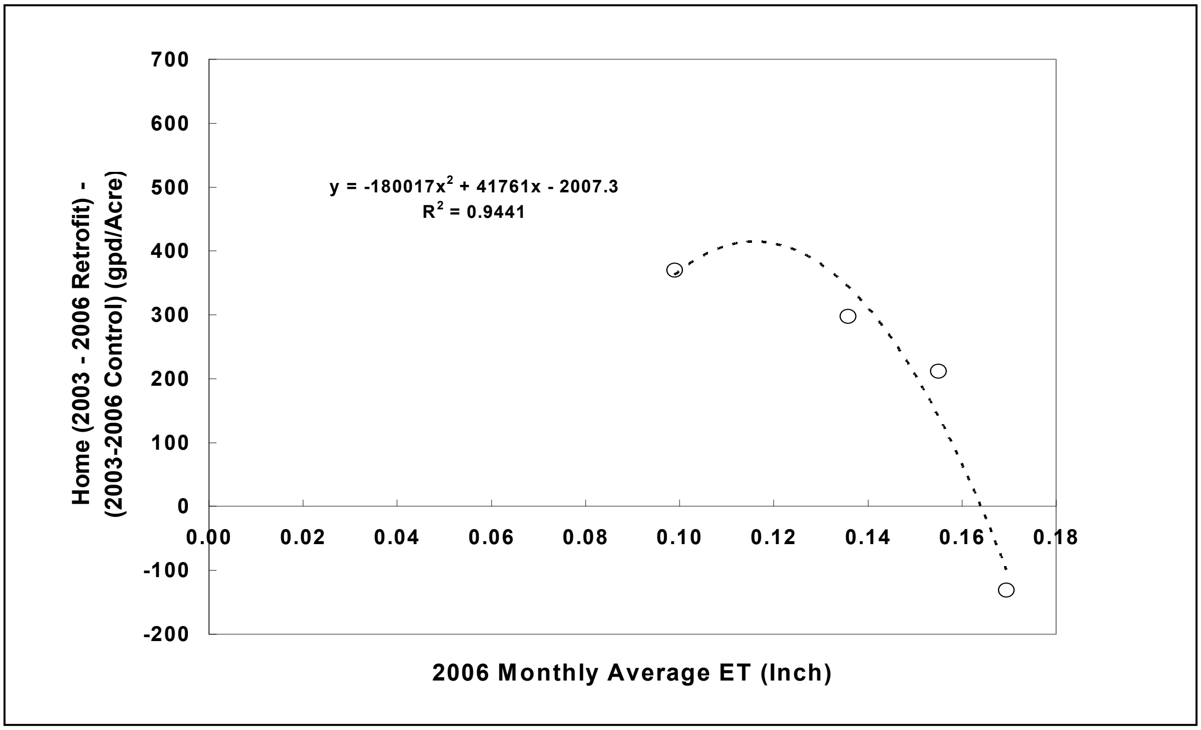


Figure 33: Regression Analyses for Selective Runoff Reduction Due to Smart Timer Installation in Retrofit Area

4.3.3 Comparison of Pre- and Post- Intervention Runoff in Portola Hills Area

Table 31 shows the summary of paired t-test results for pre- and post-intervention runoff for the Portola Hills area. T-test results indicated that the runoff flow decreased between 2005 and 2006. The average runoff flow decreased from 3,511 gpd/acre in 2005 to 1,619 gallons/day/acre in 2006 (net decrease of about 55 percent). Note that the area-normalized runoff flow for Portola Hills is significantly higher than that for Buck Gully. One reason for this may be that the Portola Hills area has some common irrigated areas whose acreage extents are not currently known. Furthermore, the reduction may also be due to non-Smart Timer factors such as public education, incentives, weather, etc.

Figure 34 shows the runoff reduction in various months between 2005 and 2006. The reduction pattern is somewhat similar to that observed in Buck Gully retrofit Area, which indicated the influence of Smart Timer installations and other non-Smart Timer effects. However, regression analyses using daily, weekly or monthly ET values did not yield a significant relationship (Table 32). This may be due to water use patterns in the common irrigated areas of Portola Hills.

Table 31: Summary of Paired T-test Result for Pre- and Post- Intervention Periods for Portola Hills Retrofit Area*

Station/Period	Area Weighted Mean Flow (gpd) 2005	Area Weighted Mean Flow (gpd) 2006	Sample Size (N)	T – stat	t-critical (2-tail)	Is Runoff Reduction significant?
Runoff (gpd/acre)	3,511	1,619	90	23.73	1.987	Yes
ET Adjusted Flow (Runoff + Estimated ET loss in irrigated area)* (gpd/acre)	8,738	7,293	90	9.19	1.987	Yes

* - Portola Hills area also has common irrigated area, whose acreage was not available during the time of this report

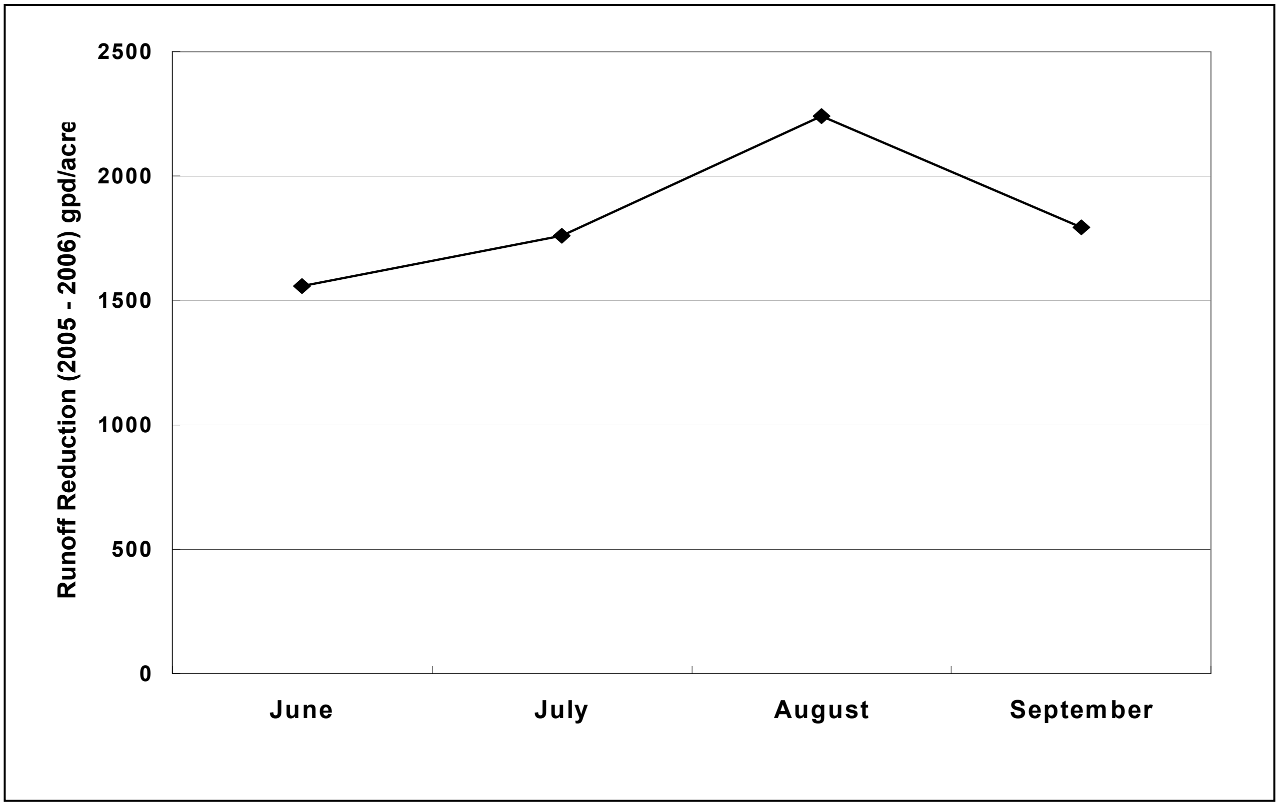


Figure 34: Runoff Reduction Between Pre- and Post-Intervention Periods in Portola Hills

Table 32: Summary of Regression Analyses for Runoff Reduction Between 2005 and 2006 in Portola Hills

ET Type for Regression	Regression Coefficient	Curve
Daily ET (Inch)	0.02	Linear
Average Weekly ET (Inch)	0.008	2^{nd} Degree Polynomial
Average Monthly ET (Inch)	0.229	2^{nd} Degree Polynomial

Section 5: Water Quality Improvement Evaluation

5.1 Overview

This chapter presents the statistical analysis of runoff water quality due to installation of Smart Timers. Specific information includes:

- Description of parameters analyzed and sampling frequency;
- Discussion of data evaluation methods ; and
- Evaluation and discussion of results.

In addition to the analyses presented in this section, additional water quality analyses were performed on the Buck Gully runoff water quality as part of a IRWD study. Those results are presented in Appendix C.

5.2 Evaluation Approach

Tables 33 and 34 describe the water quality parameters, sampling period and sampling frequency for the Buck Gully and Portola Hills areas.

Table 33: Description of Water Quality Data for Buck Gully Control and Retrofit areas

Item	Details
Pre-Intervention Year	2004
Post-Intervention Year	2006
Analytical Parameters	Conductivity, Ammonia Nitrogen, Total Kjeldahl Nitrogen, Nitrate/Nitrite, Ortho Phosphate, Nitrate/Nitrite as N
Sampling Frequency	Approximately once a week from June to October (about 16 sample sets each year)

Table 34: Description of Water Quality Data for Portola Hills Retrofit Areas

Item	Details
Pre-Intervention Year	2003 - 2005
Post-Intervention Year	2006
Analytical Parameters	Several physical, chemical. Bacterial, pesticide and dissolved metal parameters
Sampling Frequency	Limited number of data (3 to 5 per year) for all but three parameters (conductivity, ammonia nitrogen and nitrate nitrogen). Samples were taken from June to October in an inconsistent frequency/schedule.

The following observations are pertinent to water quality data received for analyses:

Buck Gully: For this area, sample sizes received for various parameters were large enough to perform robust statistical analyses. A key limitation, however, is the unavailability of runoff flow data during the pre-intervention sample collection period (2004), due to flow meter malfunction. As a result total mass analyses of water quality parameters could not be performed for pre- and post-intervention changes. Total mass analysis, however, was performed to compare the Control and Retrofit area runoff water quality during 2006.

Portola Hills: While data for several parameters were available for this area, the number of data received was very limited (less than four data per year) for most parameters on most years. Hence, a robust t-test analysis could not be done for these parameters. Furthermore, samples were not collected at consistent frequencies or dates for water quality analyses. Hence, paired t-tests by matching dates were performed for three parameters (conductivity, ammonia nitrogen and nitrate nitrogen) only. Both concentration and total mass analyses were performed to evaluate potential differences. For the remaining parameters, a trend analysis relating water quality over the years were performed.

Sampling Period: For both Buck Gully and Portola Hills, water quality samples were collected during Summer and early Fall seasons. Hence, the observations from the water quality analyses pertain to this sampling period only. Since seasonal variations in water conservation trends were observed due to Smart Timer installation, future studies may include the water quality implications during Winter and Spring seasons also.

5.3 Data Reduction and Validation

First, the normality of data distribution (for parameters selected for t-test) was evaluated to determine potential transformation prior to t-test. This approach was taken to be conservative and safe, although the Central Limit Theory guaranties that the distribution of means will be normal. Results indicated that all of the data evaluated were normally distributed. Furthermore, outlier analyses did not indicate large outliers in the data set. Hence, the data were not further reduced prior to analyses. Table 36 summarizes the water quality data used for analyses.

5.4 Data Evaluation

After the data reduction step, the following data analyses were performed:

- Comparison of water quality for the Buck Gully Control and Retrofit area in post-intervention period by performing paired t-test on i) concentration, and ii) total mass normalized to irrigated area (pollutant flux, i.e. mass of pollutant/day/acre of irrigated area). Pollutant flux was estimated using the flow recorded at the time of sample collection.

- Comparison of pre- and post-intervention water quality by performing paired t-test on measured concentration of parameters. On several occasions the samples for water quality analyses were not taken on the same dates of respective (pre- and post-intervention) years. Hence, paired t-tests were performed using samples collected on days close (± 3 days) to each other in respective years.

- Comparison of water quality for the Portola Hills area runoff by performing t-test on concentration and pollutant flux for conductivity, ammonia nitrogen and nitrate-nitrogen.

Evaluation of general water quality trends over time (time series plot) for the remaining Portola Hills water quality parameters.

Table 35: Water Quality Data Summary

		Pre-Retrofit							Post-Retrofit						
		EC	NO_3-N	NO_2/NO_3	TKN	NH_3-N	Ortho-P	Total P	EC	NO_3-N	NO_2/NO_3	TKN	NH_3-N	Ortho-P	Total P
Buck Gully Control (# 3001) Station	Min	1970		0.04	0.30	0.08	0.04	0.10	1730		0.1	0.3	0.08	0.075	0.2
	Max	2980		2.77	12.00	0.39	1.29	1.25	2440		0.711	1.59	1.06	1.1	1.15
	Average	2294		0.71	1.45	0.10	0.39	0.42	1970		0.122	0.418	0.08	0.43	0.344
	Median	2170		0.16	0.69	0.08	0.32	0.32	1988		0.21	0.51	0.16	0.46	0.44
	Std. Dev	325		1.02	2.93	0.08	0.32	0.34	158.91		0.17	0.32	0.24	0.22	0.24
	No of Samples	13		15	15	15	15	15	17		17	17	17	17	17
Buck Gully Retrofit (# 3011) Station	Min	1710		0.04	0.30	0.08	0.12	0.10	1580		1.18	0.3	0.08	0.236	0.2
	Max	3150		2.86	1.32	0.08	1.24	1.31	3020		3.71	2.49	0.816	1.24	1.21
	Average	2533		1.88	0.72	0.08	0.39	0.42	2610		2.37	0.823	0.08	0.351	0.422
	Median	2720		2.23	0.72	0.08	0.33	0.37	2444		2.24	1.01	0.13	0.49	0.51
	Std. Dev	520		0.94	0.29	0.00	0.30	0.31	473.50		0.59	0.69	0.18	0.30	0.29
	No of Samples	12		14	14	14	14	14	17		17	17	17	17	17
Portola Hills*	Min	1545	0.90			0.04			1090	0.88			0.01		
	Max	2284	3.90			0.29			2248	1.70			1.73		
	Average	1843	1.93			0.19			1505	1.29			0.59		
	Median	1771	1.45			0.21			1340	1.29			0.30		
	Std. Dev	314	1.34			0.11			509	0.46			0.77		
	No of Samples	4	4			4			4	4			4		

* - Additionally, a limited number of additional data on a various other parameters ware also provided for the Portola Hills area. They were used in time series analyses (Section 5.5.4)

5.5 Evaluation of Results

5.5.1 Runoff Water Quality Evaluation of Control and Retrofit Areas in Buck Gully

Tables 36 and 37 show the paired t-test analyses performed for various water quality parameters based on concentration and flux. Analyses based on concentration indicated that the conductivity and the nitrate-related parameter levels were higher in the Retrofit Area runoff than those in the Control Area runoff. This may be expected due to the reduction in runoff volume in the retrofit area. However, no significant increase in concentration of phosphate parameters (orthophosphate as phosphorus and total phosphorus) was observed in the retrofit samples.

When total flux of these constituents was compared, the conductivity of the Retrofit Area was lower than that of the Control Area, whereas the NO_2/NO_3 as N flux of the Retrofit Area was still higher than that of the Control Area. No significant differences were observed in TKN, total phosphorus and orthophosphate.

5.5.2 Pre- and Post- Retrofit Runoff Water Quality Evaluation of Control and Retrofit Areas in Buck Gully

Table 38 shows the results from runoff water quality analyses during pre- and post-intervention periods in Buck Gully. Results indicated that in the Control Area the conductivity and NO_2/NO_3 levels in 2006 were lower than those in 2005. The orthophosphate level increased in 2006. The levels of other constituents did not change significantly for the Control Area. In the Buck Gully area, there was no statistically significant change in the concentrations of any of the parameters analyzed. In general, the analyses of runoff water quality in Buck Gully area did not yield any significant trends in either the Control or Retrofit Area.

5.5.3 Pre- and Post- Retrofit Runoff Water Quality Evaluation for Portola Hills Areas

As observed with Buck Gully area, there were no definite trends observed in the Portola Hills area runoff water quality. One of the possible reasons may be that the sample size (4 pairs) used was significantly small. Although more samples were taken during 2005 and 2006 for these parameters, the sample days were not close enough to each other to allow performance of a paired t-test ($\pm$ 3 days). Comparison of water quality parameter concentrations indicated no significant change between 2005 and 2006 (Table 39). Evaluation of flux trends indicated that only the EC flux decreased significantly between 2005 and 2006 (Table 40). The trend analyses also did not yield any systematic change over time.

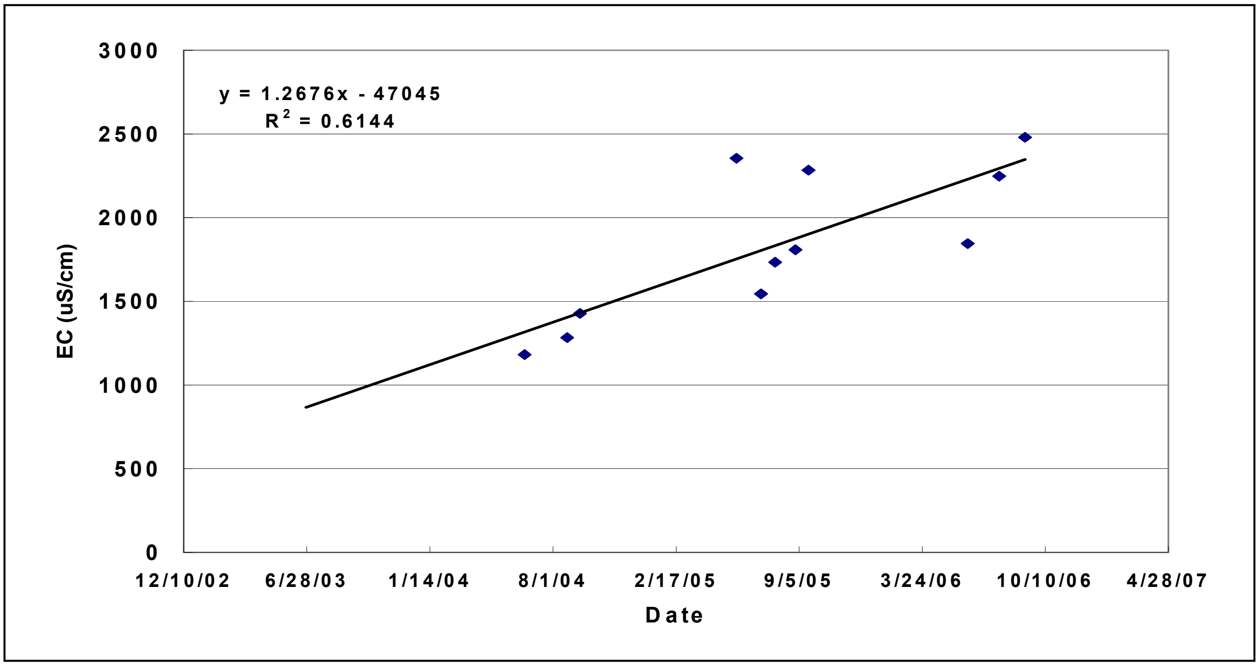


Figure 35: Time series plot and trend line for EC levels in the Portola Hills Area Runoff

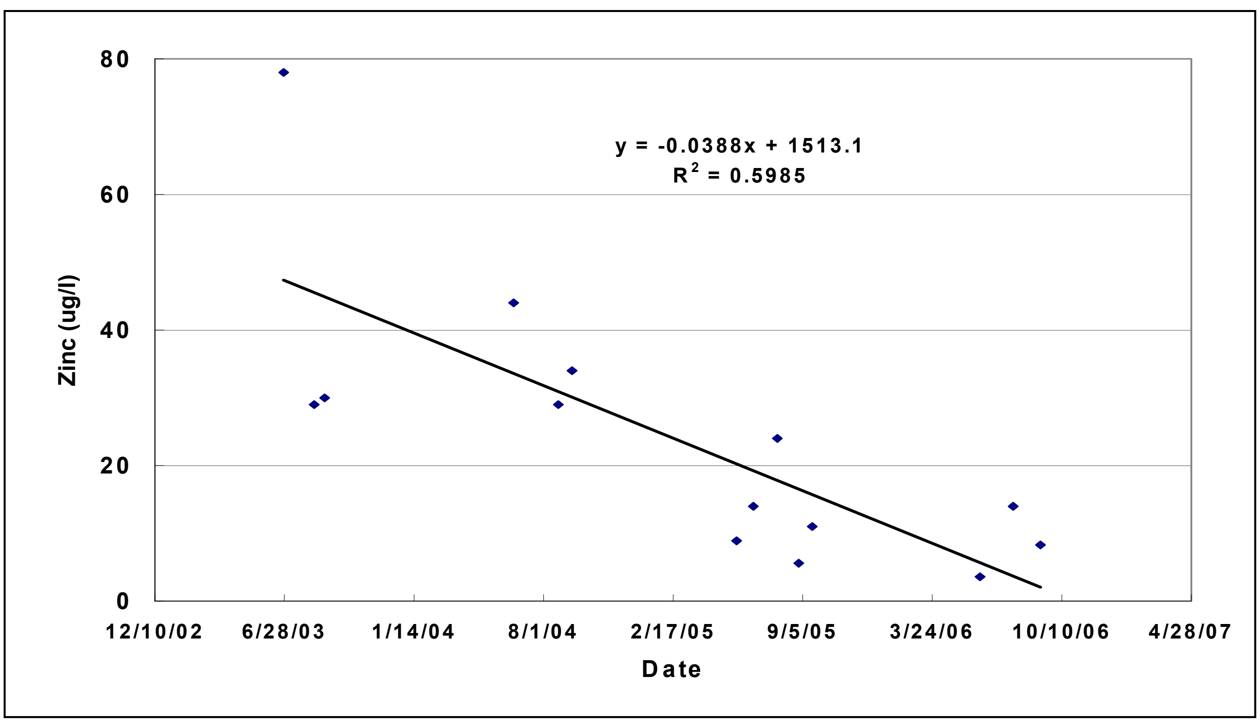


Figure 36: Time series plot and trend line for zinc levels in the Portola Hills Area Runoff

Table 36: Comparison of Buck Gully Control and Retrofit Area Runoff Water Quality During Post-Intervention Period

Parameter	Mean Concentration Control Station (3001)	Mean Concentration Retrofit Station (3011)	Sample Size (N) –days	T– stat	t-critical (2-tail)	Is there a statistically significant difference (α = 0.05)	Estimated Change in water quality
Electrical Conductivity (μmho/cm)	1,988	2,444	17	-3.72	2.12	Yes. EC concentration increased for retrofit area	556
NO_2/NO_3 as N (mg/l)	0.19	2.23	17	-14.32	2.12	Yes. NO_2/NO_3 as N increased for retrofit area.	2.04
TKN (mg/l)	0.477	0.997	17	-2.795	2.12	Yes. TKN increased for retrofit area	0.52
Total phosphorus (mg/l as P)	0.418	0.509	17	-0.865	2.12	No. Differences in Total-P concentrations are not significant.	-
Ortho Phosphate (mg/l as P)	0.46	0.489	17	-0.299	2.12	No. Differences in Ortho-P concentrations are not significant.	-

Table 37: Comparison of Buck Gully Control and Retrofit Runoff Pollutant Flux During Post-Intervention Period

Parameter	Mean Flux Control Station (3001)	Mean Flux Retrofit Station (3011)	Sample Size (N)	T – stat	t-critical (2-tail)	Is there a statistically significant difference (α = 0.05)	Estimated Change in water quality
Electrical Conductivity (μmho/cm)	6.32	2.53	17	7.05	2.12	Yes. EC flux decreased for retrofit area.	- 3.79
NO_2/NO_3 as N (mg/l)	0.626	2.37	17	-6.18	2.12	Yes. NO_2/NO_3 flux increased for retrofit area.	1.74
TKN (mg/l)	1.79	1.38	17	0.72	2.12	No. TKN flux is not significant.	-
Total phosphorus (mg/l as P)	1.5	0.83	17	1.47	2.11	No. Ortho P flux is not significant.	
Ortho Phosphate (mg/l as P)	1.57	0.8	17	1.95	2.12	No. Total P flux is not significant.	-

Table 38: Comparison of Pre- and Post Intervention Period Runoff Water Quality in Buck Gully Control and Retrofit Area

Station/ Flow Type	Mean Concentration 2004	Mean Concentration 2006	Sample Size (N)	T – stat	t-critical (2-tail)	Is Runoff quality significantly different?	Estimated change
Buck Gully Control Area (# 3001)							
Conductivity (µmho/cm)	2327	1974	10	3.33	2.62	Yes. EC decreased in 2006.	353
NO_2/NO_3 as N (mg/l)	0.623	0.213	10	1.2	2.26	No	-
TKN (mg/l)	0.737	0.425	10	2.53	2.26	Yes	0.312
Total phosphorus (mg/l as P)	0.326	0.4	10	-0.683	2.26	No	-
Ortho Phosphate (mg/l as P)	0.33	0.47	10	-3.3	2.62	Yes	0.17
Buck Gully Retrofit Station (# 3011)							
Conductivity (µmho/cm)	2492	2272	9	0.77	2.3	No.	-
NO_2/NO_3 as N (mg/l)	1.79	2.28	9	-1.25	2.3	No	-
TKN (mg/l)	0.766	1.05	9	-1.24	2.3	No	-
Total phosphorus (mg/l as P)	0.35	0.59	9	-1.91	2.3	No	-
Ortho Phosphate (mg/l as P)	0.31	0.55	9	-1.6	2.3	No	

Table 39: Comparison of Portola Hills Control and Retrofit Area Runoff Water Quality During Pre- (2005) and Post- (2006) Intervention Periods

Parameter	Mean Concentration Pre-Intervention	Mean Concentration Post Intervention	Sample Size (N) – days	T – stat	t-critical (2-tail)	Is there a statistically significant difference (α = 0.05)	Estimated Change in water quality
Electrical Conductivity (µmho/cm)	1543	1505	4	1.04	3.18	No	_
Ammonia Nitrogen (mg/l as N)	0.185	0.587	4	-0.916	3.18	No	_
Nitrate Nitrogen (mg/l as N)	1.92	1.29	4	1.15	3.18	No	_

Table 40: Comparison of Portola Hills Pre- and Post-Intervention Runoff Pollutant Flux

Parameter	Mean Flux Pre-Intervention	Mean Flux Post Intervention	Sample Size (N)	T – stat	t-critical (2-tail)	Is there a statistically significant difference (α = 0.05)	Estimated Change in water quality
Electrical Conductivity (µmho/cm)	299	109	4	15.55	3.18	Yes. The conductivity decreased in 2006.	190
Ammonia Nitrogen (mg/l)	28.9	71	4	-0.68	3.18	No	-
Nitrate Nitrogen (mg/l)	300	214	4	1.05	3.18	No	-

5.5.4 Time Series Plots for Contaminants in Portola Hills Area

Limited water quality data (~ 3 to 4 data per year) were available for several parameters for Portola Hills. Most of the data were collected June to September of each year. Results from time series plots did not yield a consistent pattern for any group of contaminants. Reasonable correlation were obtained only for EC (R^2 = 0.61) and zinc (R^2 = 0.59) with time. The EC levels showed an increasing trend (1182 µS/cm in June 2004 to 2480 µS/cm in September, 2006) with time. The zinc concentration, however, showed a decreasing trend with time (44 µg/l in June

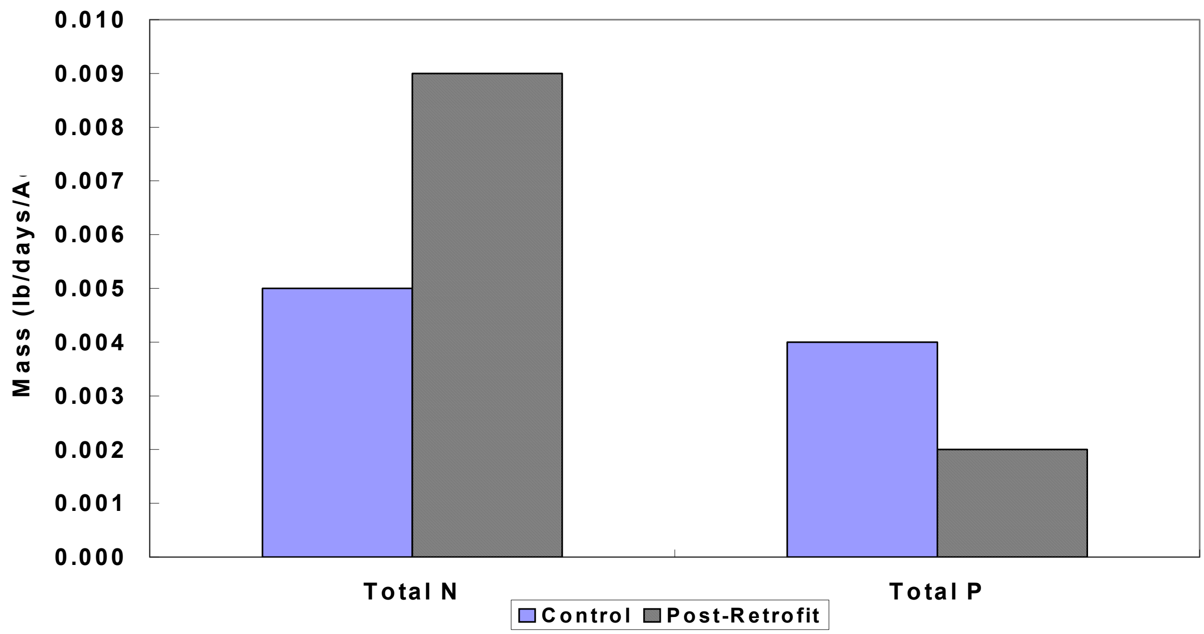
2004 to 8 μg/l in September, 2006). Hardness levels showed an increasing trend (376 mg/l as $CaCO_3$ in June 2003 to 905 mg/l as $CaCO_3$ in September, 2006) with an R2 value of 0.36. The correlation coefficient (R^2) for the other parameters (NH_3-N, NO_3-N, reactive phosphorous, total / fecal coliform, Enterococcus, nickel, copper and cadmium) were less than 0.25.

5.6 Watershed Implications

In general, no definite conclusions could be drawn from water quality analyses of either the Buck Gully or Portola Hills areas. In Buck Gully, the conductivity and concentrations of nitrogen-related parameters appear to be higher in the Retrofit Area than in the Control Area. This is potentially due to the fact that the same amounts of fertilizer were applied to the irrigated areas, while the runoff quantities were reduced, thus increasing the concentrations of nitrogen-related constituents. However, evaluation of total mass indicated that the only nitrate-nitrite as nitrogen mass was higher in the Retrofit Area runoff. The conductivity (and hence, possibly the total dissolved solids) flux was lower in the Retrofit Area.

Figure 37 summarizes the pre and post nitrogen and phosphorus loading at the Buck Gully area for the study period. The total nitrogen (TN) load from control area in Buck Gully was approximately 0.005 lb/day/acre. The corresponding load from the retrofit area during post-intervention period was almost two times of this load (0.009 lb/day/acre). The total phosphorous (TP) load from control area in Buck Gully was approximately 0.004 lb/day/acre. The corresponding load from the retrofit area was about 50 percent of this amount (0.002 lb/day/acre). This data suggested that mechanism of TN and TP transport were different in the Buck Gully runoff flow.

In the Portola Hills area, the TN and TP data for pre-intervention (control) period is not available. The post-retrofit loads for these constituents were 0.025 and 0.006 lb/day/acre, respectively. Note that the irrigated area (15.5 acres) used in mass load estimation for the Portola Hills area does not include the common irrigated landscape. Hence, the actual mass load for TN and TP may be less than the above estimated loads. A more systematic study design must be developed to understand runoff water quality patterns due to installation of Smart Timers.



Area	Nutrient	Flow	[TN]	Irrigated Acreage	TN Load	Watershed Area	TN Load
		gpm	mg/L	acre	lbs/day/irrigated acre	acre	lbs/day/ acre watershed
Control Area	TN	40	0.58	65.1	0.005		
Post Retrofit		17.5	3.0	85.7	0.009		
Control Area	TP	40.5	0.42	65.1	0.004		
Post Retrofit		16.3	0.53	85.7	0.002		

Figure 37: Comparison of Buck Gully Control and Retrofit Area Total Nitrogen (TN) and Total Phosphorous Load Data during post-intervention period

Section 6: Findings, Conclusions and Recommendations

6.1 Overview

This section summarizes the findings of the earlier sections to present them in context to the overall program goals of the study participants and provide guidance for future efforts for water savings and runoff quality improvement for Orange County and other areas of California. Specific information includes:

- Issues concerning the study methods;
- Findings and conclusions on study results; and
- Recommendations for future efforts.

6.2 Study Methods Issues

6.2.1 Water Savings

The statistical analyses used in this study effectively identified program-wide water savings as well as effects of Smart Timer brands on water savings. However, these evaluations did not include water savings based on water use patterns of SFR or commercial accounts. For example, the average monthly water use in SFR accounts varied from 0.3 to 109 HCF, and those in commercial accounts varied from 0.02 to 1120 HCF. In most cases, the distribution of monthly water consumption by the timers did not follow a normal distribution, but a log normal distribution, indicating a large range in monthly water usage. Understanding these relationships may enhance the success of Smart Timer programs.

6.2.2 Runoff Reduction

In general, the runoff flow data quality obtained during this study was much better than the data obtained during the previous study (R3 Study). However, some date quality issues including i) no flow recording over a period of few days, ii) suspect rainfall data for some dry months (e.g. September 2006 for Coastal area) were observed, and iii) impact of residential runoff for Buck Gully and commercial (HOA Accounts) runoff for Portola Hills.

6.2.3 Water Quality

As observed with the previous R3 Study, runoff water quality analyses yielded inconclusive observation. The sample size and number of data sets for statistical evaluation were often too low for key parameters to be considered representative of the scenarios being statistically compared. A number samples collected could not be used due to lack of matching pair data collected around the same time period in other years. Also, time of the day in which samples were collected (low flow Vs peak flow) may also impact the water quality evaluation. A consistent sample collection program with matched runoff flow should be developed to effectively address runoff water quality variations due to Smart Timer installation.

6.3 Study Results

6.3.1 Water Savings

- From an overall programmatic perspective, Smart Timers resulted in a savings of 37.2 gpd/per SFR account and about 556 gpd/account in commercial (HOA) installations.

- Regional (Coastal, Central, Foothill) ET differences exist in the water use pattern and impact water savings. For example, installation of Smart Timers appeared to have increased water use reduction in Coastal area, than in Central and Foothill areas. These effects may be due to the differences in the distribution of different Smart Timer brands as well as the impact of non-Smart Timers in water savings or other anomalies occurred. For example, several factors including, but not limited to irrigation system malfunction such as valve, sprinkler, or piping failures, predisposition to optimizing irrigation prior to installing a smart timer, public education, focusing on lower one's water bills, etc could be responsible for the differences observed.

6.3.2 Runoff Flow Reduction

Findings of this study indicated a significant reduction in the Buck Gully as well as the Portola Hills monitoring areas.

- Runoff flow in Retrofit area of Buck Gully in the post-intervention period (200 gpd/irrigated acre) was significantly lower than that of Control area (420 gpd/irrigated area) during dry weather months of post-intervention period.

- The runoff flow in post-intervention period was significantly lower than that in pre-intervention period. Even in control area, the runoff flow decreased during this period, which indicated the effectiveness of other non-Smart Timer programs, such as public education are also contributing to runoff reduction.

- Assuming the only differences between the Retrofit and Control Buck Gully is the use of Smart Timers, approximately 175 gpd/acre reduction was observed due to Smart Timers.

- The runoff volume in Portola Hills area was significantly lower (by 55 percent) after Smart Timer installation. Since there was only 10 percent Smart Timer installed, this could have resulted to a combination of Smart Timer and non-Smart Timer related factors.

6.3.3 Runoff Water Quality

- Very few consistent results were obtained due to smart controller installation. The conductivity and nitrogen-related parameters concentration in the Buck Gully Retrofit Area was higher than that of Control Area for the same period. However, estimation of pollutant flux yielded a lower conductivity (hence, a lower TDS) and higher nitrate-nitrite as nitrogen level in the Retrofit Area..

- In the Portola Hills area, the flux evaluation also yielded a lower conductivity during post-installation period. The reasons for these poor correlations may be due to complexities in pollutant transport in the watershed as well as the need for more robust water quality sampling program.

6.4 Recommended Additional Studies

The recommended additional studies are divided into two categories. The first category is a short term and can proceed with the current data set and some additional analyses. The second category is long term and generally requires the collection of additional data before performing the analyses.

6.4.1 Near Term Studies

These are studies that can be performed with the current data set already developed for this report and can be targeted for completion in the next six months.

6.4.1.1 Smart Timers analysis normalized to irrigated area and type of vegetation

To qualify to participate in the rebate program an account needs to have a minimum of 1,200 square feet of vegetation that will be controlled by Smart Timer irrigation. During the verification, each valve set is adjusted to the type of vegetation and their corresponding ET. Provided there are enough meters, variable could include irrigated area, type of vegetation, manufacturer, and type of account (SFR or commercial).

6.4.1.2 Role of non-Smart Timer factors in water savings

This study indicated that there were 261 SFR accounts that had 12 months of pre-installation data for 2002, 2003, 2004, and 2005. Each year's monthly average when compared to 2002 was significantly lower. Prior to installation of the Smart Timers, these accounts recognized a monthly water savings of 17 percent when comparing 2002 to 2005. The observation that water usage dropped from 2002 to 2005 influences the calculation of resultant savings, typically less savings were estimated if fewer pre-installation years are used to characterize the average water used prior to installation. This implies that other factors such as education, aggressive enforcement of urban runoff compliance codes, and water rate structures have a role in water savings.

6.4.2 Mid to Long Term Studies

These recommended studies require more time and can be targeted for completion as part of other studies.

6.4.2.1 Inclusion of database information of for other structural changes

MWDOC and the retail agencies have access to databases where rebates have been provided to homeowners that have replaced a vertical axis with horizontal axis washer, high flush toilets with low flush toilets, and low flow shower heads. A study to determine the savings of these devices in combination with and without the Smart Timer could be done.

6.4.2.2 Forensic Smart Timer study

Elements of the study would include, but not be limited to the following:

- Comparing Smart Timers in a retail agency using different basis for water rates. For example, IRWD's rates are based on ET and these Smart Timers could be compared to an agency that does not use ET as part of their rate structure.
- Smart Timers settings;
- Re-inspection of installations to ensure system integrity; and
- Normalization to irrigated area for each category of installation.

6.4.2.3 Study comparing with and without Smart Timers with exterior usage water budgets

This study would control for indoor usage, probably using similar winter month usage for the same size irrigated area and turf and plant mix. An outdoor water budget would then be established for SRFs with and without Smart Timers. Their respective performances would then be statistically compared.

6.4.2.4 More than one year post-installation saving analysis

The post-intervention data for this study that was used for the analysis was less than two years. A study over a longer period can facilitate a more robust analysis of water savings by these Smart Timers.

6.4.2.5 Improved data set for runoff volume and runoff water quality

The runoff analysis did not have enough matching data sets, i.e., run off volumes with corresponding water quality analyses for the same periods. A more systematic study implementation is needed to evaluate runoff water quality effects due to Smart Timers. Also, a monitoring program that involves more frequent verification of field data and more robust quality control can improve efficiency of runoff flow evaluations.

6.4.2.6 Improved data set to estimate percolation

For this project objective a more refined study design and approach is needed in addition to a similar data set that was used on this project. The design may need to consider static ground water levels or contours, accurate watershed boundaries, and percolated water measurements as a cross check of the water balance calculation approach.

Appendix A

Statistical Analyses of Water Savings

Appendix A: Statistical Analyses of Water Savings

I. Independent t-test for Monthly Water Savings

III. Chi-Square Test for Evaluating Performance of Smart Timer Brands

IV. One way ANOVA Test in Conjunction with post hoc (Schaffer) Test to Compare Performance of Smart Timer Brands

V. Student's T-Statistics Analyses for Comparison of Simple Linear Regression Equations

V. References

I. Independent t-test for Monthly Water Savings

Method Description

The t-test is used to determine whether the difference between means of two groups or conditions is due to the independent variable, or if the difference is simply due to chance (Zarf, 1974; Wakelin, D., 2006). The null hypothesis for such test states that the experimental manipulation (e.g. installation of smart timers) has no effect, therefore the means of the groups (e.g. water use before and after installation) will be equal.

The unpaired, or "independent samples" *t*-test is used when two separate independent and identically distributed samples are obtained, one from each of the two populations being compared. In our study, independent t-tests were performed to determine i) if the average water use by the customers for a given month during pre-installation period was same as that during post-installation period, and ii) if the average daily ET for a given month during pre-installation period was same as that during post-installation period.

Data Summary

Table A1. Data Summary for Average Monthly Use by SFR Units in Coastal Zone

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	653	Log Normal	14.59	14.35	2.26	0.023
February	652	Log Normal	14.44	12.52	5.75	1.08E-8
March	654	Log Normal	15.24	16.22	0.84	0.39
April	654	Log Normal	15.83	21.64	10.28	6.8E-24
May	655	Log Normal	21.31	25.68	5.9	3.43E-9
June	656	Log Normal	24.5	26.4	1.9	0.056
July	657	Log Normal	28.92	28.64	0.47	0.64
August	659	Log Normal	27.64	28.42	0.95	0.33
September	656	Log Normal	23.56	21.16	3.47	0.0005
October	656	Log Normal	20.42	20.7	1.17	0.24
November	655	Log Normal	17.12	16.03	2.73	0.006
December	650	Log Normal	15.53	14.45	3.17	0.0015

1. After transformation for distribution.

Table A2. Data Summary for Average Monthly Use by SFR Units in Central Zone

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	137	Log Normal	17.16	15.22	1.6	0.1
February	137	Log Normal	14.27	12.76	1.33	0.18
March	136	Log Normal	13.9	16.3	1.9	0.048
April	136	Log Normal	16.2	22.16	2.45	0.014
May	135	Log Normal	21.54	24.43	1.7	0.08
June	140	Log Normal	28.3	27.44	0.05	0.96

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
July	146	Log Normal	30.82	31.41	0.59	0.55
August	143	Log Normal	29.32	32.14	2.3	0.02
September	146	Log Normal	24.77	28.33	2.28	0.02
October	145	Log Normal	21.57	21.96	0.49	0.62
November	145	Log Normal	18.12	17.6	0.62	0.53
December	141	Log Normal	16.32	16.51	0.32	0.74

1. After transformation for distribution.

Table A3. Data Summary for Average Monthly Use by SFR Units in Foothill Zone

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	90	Log Normal	20.4	18.03	1.57	0.11
February	90	Log Normal	18.18	16.39	0.88	0.38
March	90	Log Normal	20.49	22.34	2.28	0.023
April	90	Log Normal	24.66	26.94	2.28	0.023
May	90	Log Normal	31.33	32.63	1.69	0.093
June	90	Log Normal	34.88	35	1.08	0.28
July	90	Log Normal	39.29	39.59	0.75	0.45
August	89	Log Normal	35.6	39	2.17	0.03
September	91	Log Normal	29.27	34.15	2.73	0.007
October	91	Log Normal	27.07	29.88	1.79	0.07
November	91	Log Normal	21.88	21.77	0.13	0.89
December	91	Log Normal	20.99	21	0.22	0.82

1. After transformation for distribution.

Table A4. Data Summary for Average Daily ET in Coastal Zone

Month	Sample Size (N)	Distribution	Post-Installation ET (mm)	Pre-Installation ET (mm)	t-statistics	Sig. (2-tailed)
January	31	Normal	2.96	1.5	4.5	3.03E-5
February	28	Normal	2.25	1.98	2.93	0.0049
March	31	Normal	2.78	2.71	0.45	0.65
April	30	Normal	3.06	3.54	3.01	0.0038
May	31	Normal	3.56	4.12	2.64	0.01
June	30	Normal	4.47	3.88	2.52	0.014
July	31	Normal	5.3	4.47	5.68	4.1E-7
August	31	Normal	4.36	3.97	3.22	0.0022
September	30	Normal	3.77	3.58	1.09	0.28
October	31	Normal	2.6	2.3	1.88	0.64
November	30	Normal	2.08	1.78	2	0.049
December	31	Normal	1.87	1.49	2.74	0.008

Table A5. Data Summary for Average Daily ET in Central Zone

Month	Sample Size (N)	Distribution	Post-Installation ET (mm)	Pre-Installation ET (mm)	t-statistics	Sig. (2-tailed)
January	31	Normal	2.17	1.66	3.75	0.0004
February	28	Normal	2.37	2.1	2.58	0.012
March	31	Normal	2.83	2.95	0.77	0.44
April	30	Normal	3.02	3.7	3.7	0.0004
May	31	Normal	3.81	4.41	2.75	0.008
June	30	Normal	4.76	4.19	2.35	0.02
July	31	Normal	5.58	5.05	3.72	0.0004
August	31	Normal	4.57	4.45	0.95	0.35
September	30	Normal	4.03	3.87	0.88	0.38
October	31	Normal	2.7	2.5	1.03	0.31
November	30	Normal	2.12	1.96	0.99	0.32
December	31	Normal	1.88	1.66	1.52	0.13

Table A6. Data Summary for Average Daily ET in Foothill Zone

Month	Sample Size (N)	Distribution	Post-Installation ET (mm)	Pre-Installation ET (mm)	t-statistics	Sig. (2-tailed)
January	31	Normal	2.17	1.68	3.7	0.0004
February	28	Normal	2.42	2.08	3.02	0.0038
March	31	Normal	2.86	3.04	1.1	0.28
April	30	Normal	2.96	3.75	3.96	0.0002
May	31	Normal	3.99	4.51	2.2	0.03
June	30	Normal	5	4.44	2.2	0.03
July	31	Normal	5.7	5.4	1.79	0.078
August	31	Normal	4.85	4.8	0.33	0.74
September	30	Normal	4.28	4.08	1.08	0.29
October	31	Normal	2.79	2.61	0.9	0.37
November	30	Normal	2.2	1.99	1.35	0.18
December	31	Normal	1.9	1.68	1.59	0.12

Table A7. Data Summary for Average Monthly Use by Commercial Units in Central Zone

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	81	Log Normal	544	375	2.13	0.03
February	82	Log Normal	485	393	1.23	0.22
March	82	Log Normal	508	510	0.003	0.99
April	84	Log Normal	563	840	1.05	0.29
May	84	Log Normal	1168	1500	1.18	0.23

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
June	84	Log Normal	1357	1436	0.91	0.36
July	83	Log Normal	1678	1649	0.16	0.87
August	84	Log Normal	1723	1753	0.30	0.76
September	84	Log Normal	1318	1304	0.25	0.8
October	84	Log Normal	1101	944	0.42	0.67
November	78	Log Normal	762	501	2.45	0.015
December	79	Log Normal	628	432	2.53	0.012

1. After transformation for distribution.

Table A8. Data Summary for Average Monthly Use by Commercial Units in Central Zone

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	58	Log Normal	541	436	1	0.31
February	58	Log Normal	363	398	0.86	0.39
March	58	Log Normal	340	598	1.42	0.15
April	58	Log Normal	514	773	1.18	0.24
May	58	Log Normal	861	1003	0.66	0.5
June	58	Log Normal	1277	1091	0.20	0.84
July	58	Log Normal	1305	1150	0.07	0.94
August	58	Log Normal	1144	1167	0.11	0.91
September	58	Log Normal	958	968	0.61	0.54
October	58	Log Normal	694	640	0.42	0.67
November	58	Log Normal	559	433	0.95	0.34
December	50	Log Normal	471	325	1.16	0.24

1. After transformation for distribution.

Table A9. Data Summary for Average Monthly Use by Commercial Units in Foothill Zone

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	66	Log Normal	350	293	1.26	0.2
February	66	Log Normal	277	257	1.2	0.23
March	66	Log Normal	259	424	2.8	0.005
April	66	Log Normal	379	568	1.86	0.065
May	66	Log Normal	581	774	0.86	0.39
June	66	Log Normal	772	839	0.36	0.72
July	66	Log Normal	746	773	0.16	0.87
August	66	Log Normal	703	730	0.23	0.81
September	66	Log Normal	622	737	0.59	0.55
October	66	Log Normal	491	476	0.29	0.77
November	66	Log Normal	402	430	0.19	0.85

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
December	66	Log Normal	362	327	0.99	1.66

1. After transformation for distribution.

II. Chi-Square Test for Evaluating Performance of Smart Timer Brands

Method Description

Chi-square Goodness of Fit tests are generally applied to evaluate the hypothesis "If the observed frequency of sample results (e.g. Number of timers that reduced water use Vs those that did not) are different than their expected frequency (e.g. manufacturer claim that 90% will conserve water). In our study, this test was used to evaluate the hypothesis if the observed frequency of results (Number of timers that saved water Vs those that did not) between two brands (e.g. Brand A & Brand B) were statistically different. Chi-square statistics should always involve the frequency of occurrence (i.e. number of timers) rather than the percentage or ratio of occurrence of an outcome. In our study, the analyses was performed by comparing two brands at one time by constructing a 2 X 2 Matrix (e.g. Brand A Vs Brand B, No of timers that conserved water and those that did not conserve). Hence, the chi-statistics for comparison at 95% confidence level is 3.841.

Data Summary

Table A12. Data Summary to Evaluate Smart Controllers Performance by Installers. Chi-square value for comparison of Homeowners and professionals installed timers[1].

Timers Compared	Chi-square Value
All Timers	4.62[2]
Brand A	0.001
Brand B	0.73
Brand E	3.35
Brand G	0.002

1. The chi-statistics for comparison at 95% confidence level is 3.841.
2. More number of homeowners installed timers conserved water. The reason for this trend needs to be investigated. This may be due to factors such as location of these accounts and year of installation, etc.

V. REFERENCES

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Appendix B

Zip Codes and ET Zone Assignements

Appendix B: Zip Codes and ET Zone Assignements

Coastal	Intermediate	Inland
90720	90620	90631
90740	90621	92602
90742	90623	92610
90743	90630	92618
92624	90638	92676
92625	90680	92705
92626	92603	92782
92627	92604	92805
92629	92606	92806
92646	92612	92807
92647	92614	92808
92648	92620	92821
92649	92630	92823
92651	92637	92831
92656	92653	92832
92657	92655	92833
92660	92679	92835
92661	92683	92861
92662	92688	92862
92663	92691	92865
92672	92692	92867
92673	92694	92869
92675	92701	92870
92677	92703	92886
92697	92704	92887
92708	92705	
	92706	
	92707	
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	92868	

Appendix C

Buck Gully Runoff Water Quality Analysis
Supplemental Report

Kennedy/Jenks Consultants

2355 Main Street, Suite 140
Irvine, California 92614
949-261-1577
949-261-2134 (Fax)

Buck Gully Runoff Water Quality Analysis-Supplemental Report

28 November 2007

Prepared for

IRWD
15600 Sand Canyon Avenue
Irvine, CA 92618

K/J Project No. 0753006

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Section 1: Background

In this study analyses were performed to evaluate concentration and mass flux profiles for the following constituents in the Buck Gully Watershed area:

- Electric Conductivity (EC),
- Nitrate/nitrite (NO_3/NO_2),
- Total Kjeldahl Nitrogen (TKN),
- Ortho Phosphate (Ortho-P) and
- Total Phosphorus (Total-P).

Only the data on dry weather days were used in these analyses. Trends were compared between pre- and post-intervention period and also, between control (Station 3001) and Retrofit (Station 3011) stations for the common-area landscape irrigation. Detailed descriptions of the two Stations are presented in the recent Metropolitan Water District of Orange County (MWDOC) report "Pilot Implementation of Smart Timers: Water Conservation, Urban Runoff Reduction, and Water Quality**".** Briefly, the Control Area, with no Smart Timers or other known changes, had the runoff flow measured and sampled for nutrient related water quality parameters at Station 3001. The Retrofit Area, with the addition of Smart Timers, had the runoff flow measured and sampled for nutrient related water quality parameters at Station 3011. Separate monitoring was performed at each of these stations before becoming the flow out of Buck Gully. The common-area landscape in the Retrofit Area is estimated at approximately 85.7 acres. The common-area landscape in the Control Area is estimated at approximately 65.1 acres.

1.1 Data Analyses Methods

The following trend and descriptive statistical analyses were performed for pre- and post-intervention water quality data:

1. Time series plots to visually examine trends
2. Cumulative Frequency and Box Plots to compare pre- and post- intervention trends as well as control and retrofit station trends
3. Paired t-test to evaluate significant differences in concentration and mass flux

1.2 Data Set Used

The time-line for the data used for analyses are presented in Table 1 below. The runoff flow and water quality data for the pre-intervention period were collected in year 2004. The post-intervention water quality and runoff flow data were collected in year 2006. While water quality data collected over a six month period were used for concentration based analyses, only three month data were used for flux analyses. This is due to malfunction with the flow measurement equipment during initial three months of data collection. Only data collected during non-rainfall days during these months were used for the statistical analyses.

Table 1: Data Set Used for Water Quality Analyses

Analyses	Data Collection Period		Types of Analyses
	Pre-Intervention	Post-Intervention	
Concentration-Based	May – October 2004	May – October 2006	Time Series plots, Probability, Box Plots and paired t-test.
Mass-Flux	August – October 2004	August – October 2006	Paired t-test

Section 2: Time Series Analyses

Time series plots for control and retrofit stations were plotted to identify seasonal variation in water quality characteristics. Plots were developed for each of the five constituents considered. Figure 1 to 4 show the time series plots for select constituents. Additional time series plots are shown in Appendix A. In general, the time series plots did not show any apparent differences in water quality during pre- and post-intervention periods for control or retrofit stations.

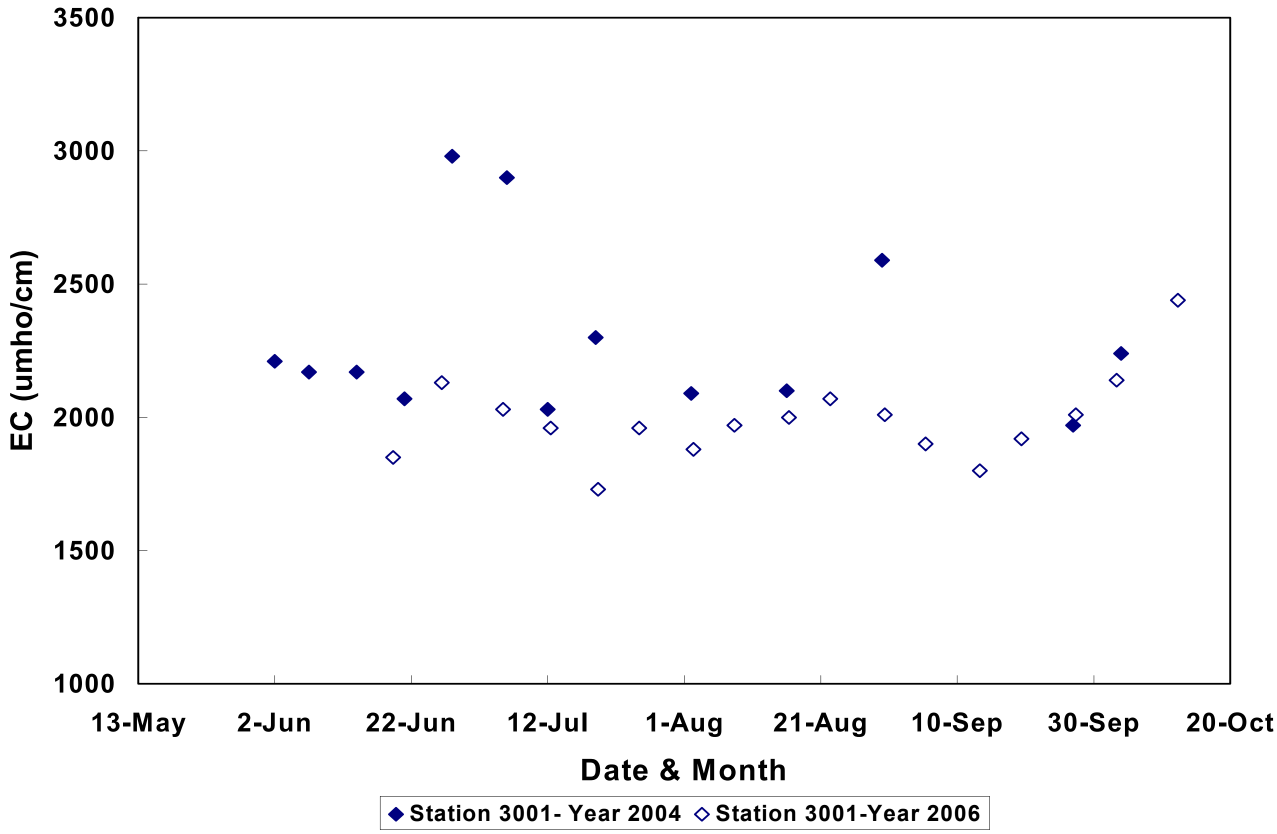

Figure 1: Time Series Plot for Electric Conductivity in Control Station (# 3001) During Pre- and Post-Intervention Periods

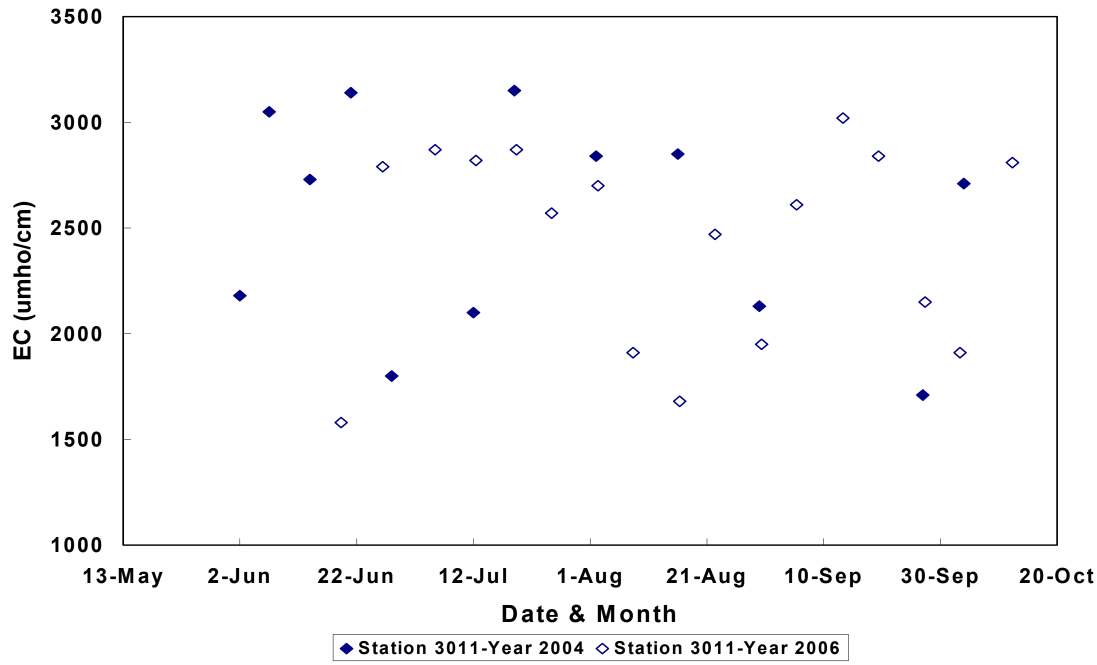

Figure 2: Time Series Plot for Electric Conductivity in Retrofit Station (# 3011) During Pre- and Post-Intervention Periods

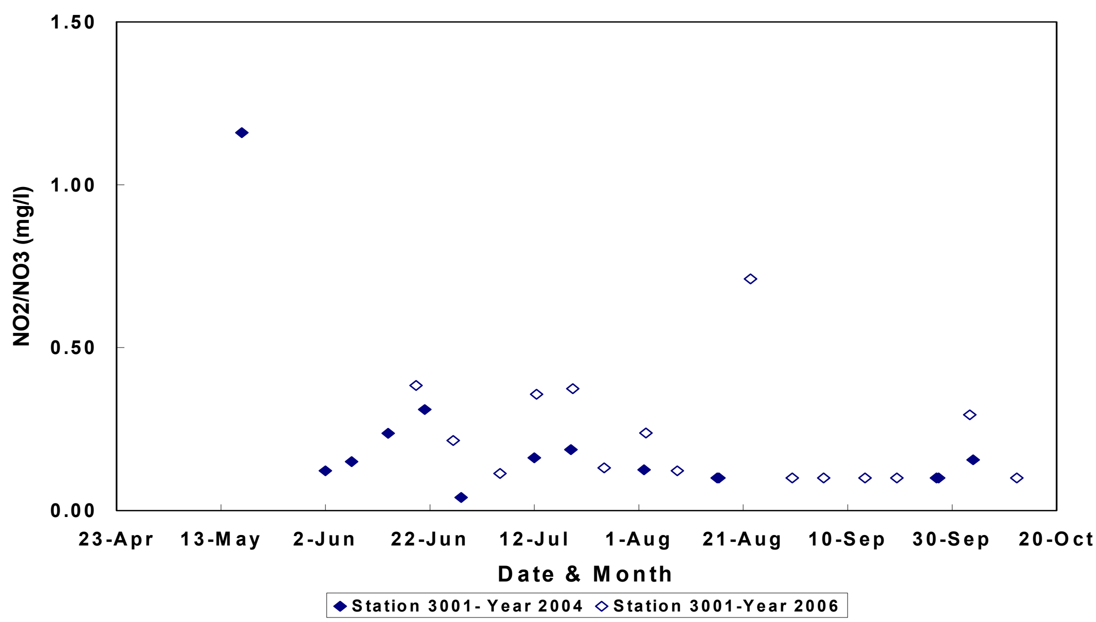

Figure 3: Time Series Plot for Nitrate/Nitrite Levels in Control Station (# 3001) During Pre- and Post-Intervention Periods

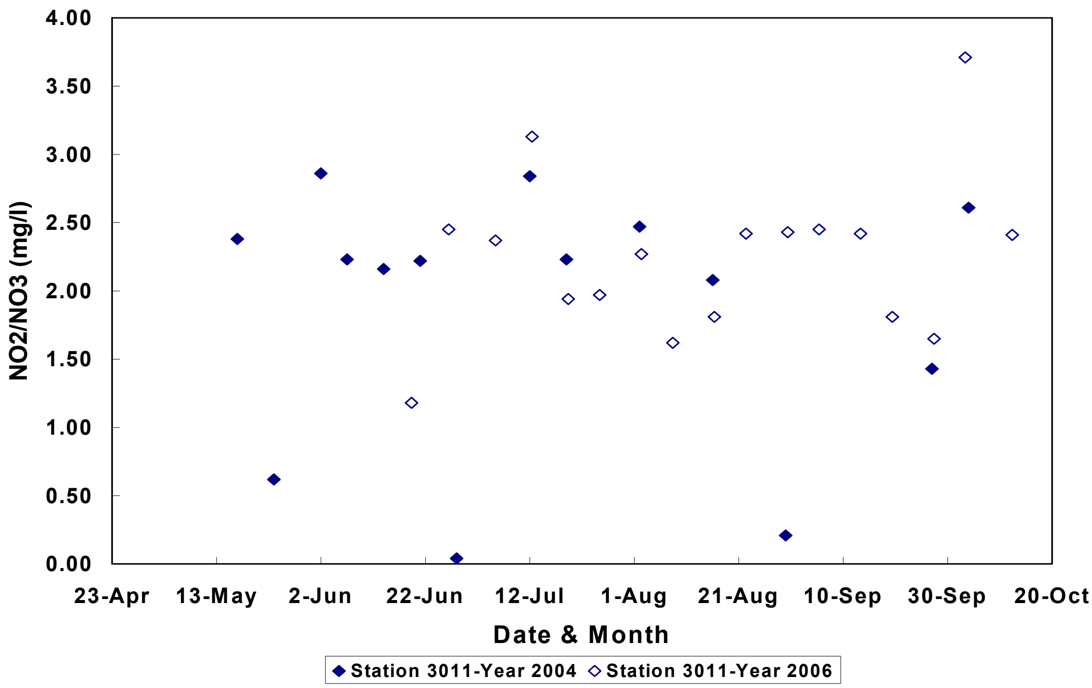

Figure 4: Time Series Plot for Nitrate/nitrite Levels in Retrofit Station (# 3011) During Pre- and Post-Intervention Periods

Section 3: Cumulative Frequency Distribution and Box Plot Analyses

Figures 5 and 6 compare the cumulative frequency distribution of electric conductivity and nitrate/nitrite concentrations for the control and retrofit stations during pre-intervention period. The distribution indicated that the levels of both of these constituents in the retrofit stations were higher than those in control area prior to installation of Smart Timers. The reasons for higher concentrations of EC and nitrate/nitrite are not currently known. The cumulative frequency distributions for other constituents are shown in Appendix B. The distributions for other constituents did not appear to be different between control and retrofit stations.

Figures 7 and 8 show the cumulative frequency plots for EC and nitrate/nitrate levels. Some interesting trends were observed during these analyses. The frequency plots indicated that the EC levels in the control station decreased during the post-intervention period (Figure 7). Furthermore, the variability in concentration also decreased during the post-intervention period for the control station. However, in the retrofit area, the cumulative distribution trend did not vary noticeably between the pre- and post-intervention periods. The EC levels in the retrofit area remained higher than the control area during most of the project period. As discussed in the previous section, the NO3/NO2 levels in the retrofit station prior to installation of Smart Timers were noticeably higher than that of the control station. The NO3/NO2 levels (Figure 8) did not vary substantially during the post-retrofit period for the control or retrofit stations. The post-intervention nitrate/nitrite levels in the retrofit station remained higher than that of the control station. However, the data variability appeared to be less during the post-intervention period. No appreciable differences in the cumulative distribution were observed for TKN, Ortho-P or Total-P between pre-and post-intervention periods (Appendix B).

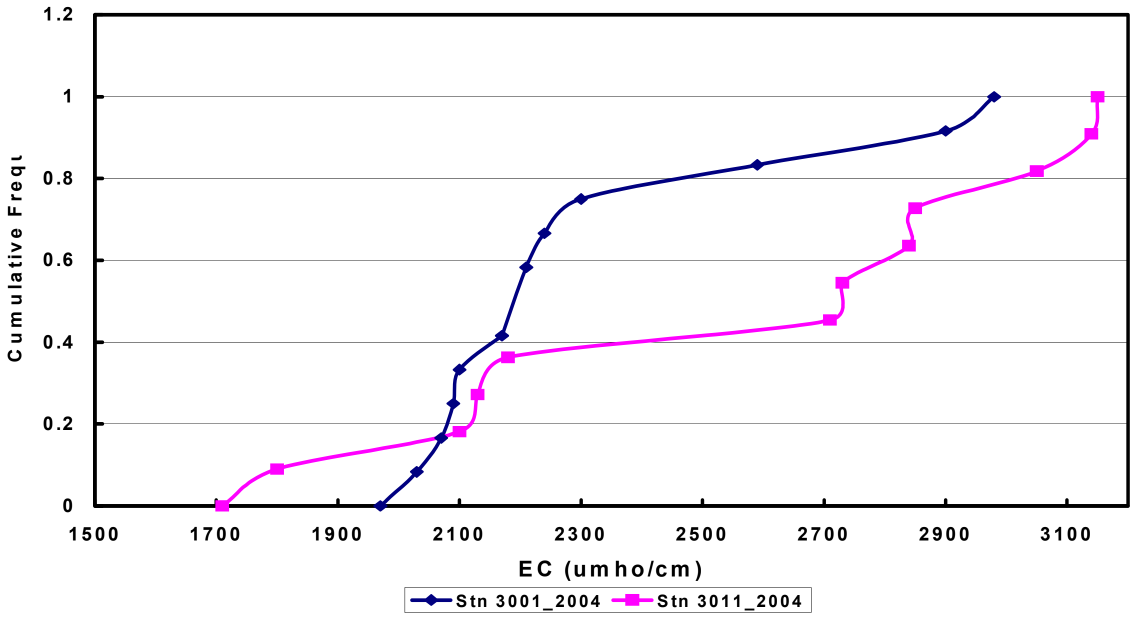

Figure 5: Cumulative frequency Plot for EC Levels in Control and Retrofit Stations Prior to Installation of Smart Timers

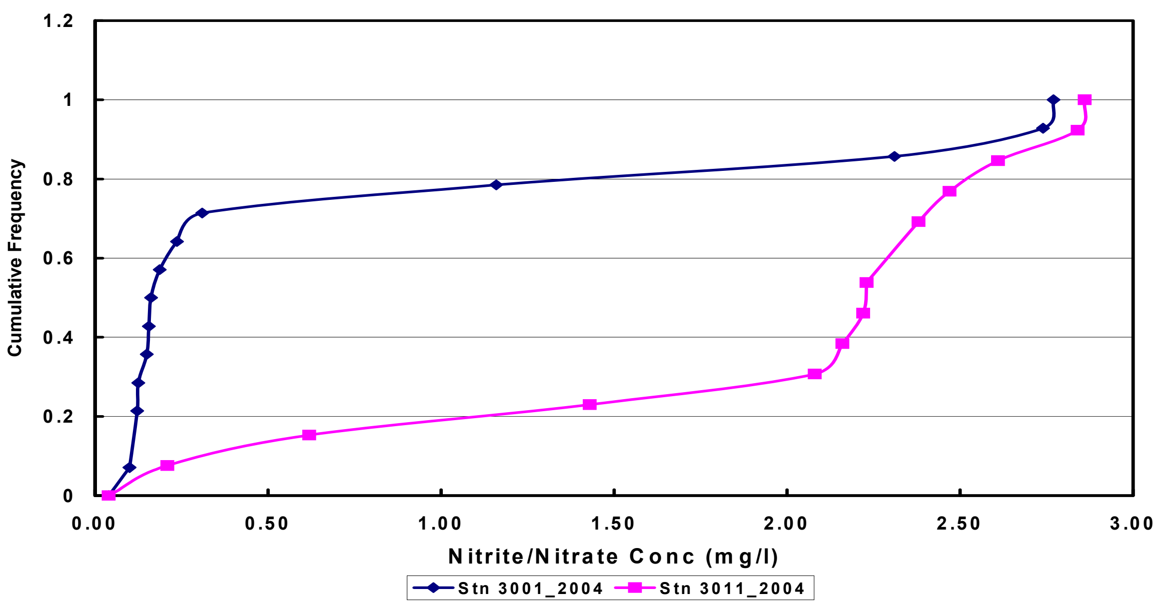

Figure 6: Cumulative frequency Plot for NO_3/NO_2 Levels in Control and Retrofit Stations Prior to Installation of Smart Timers

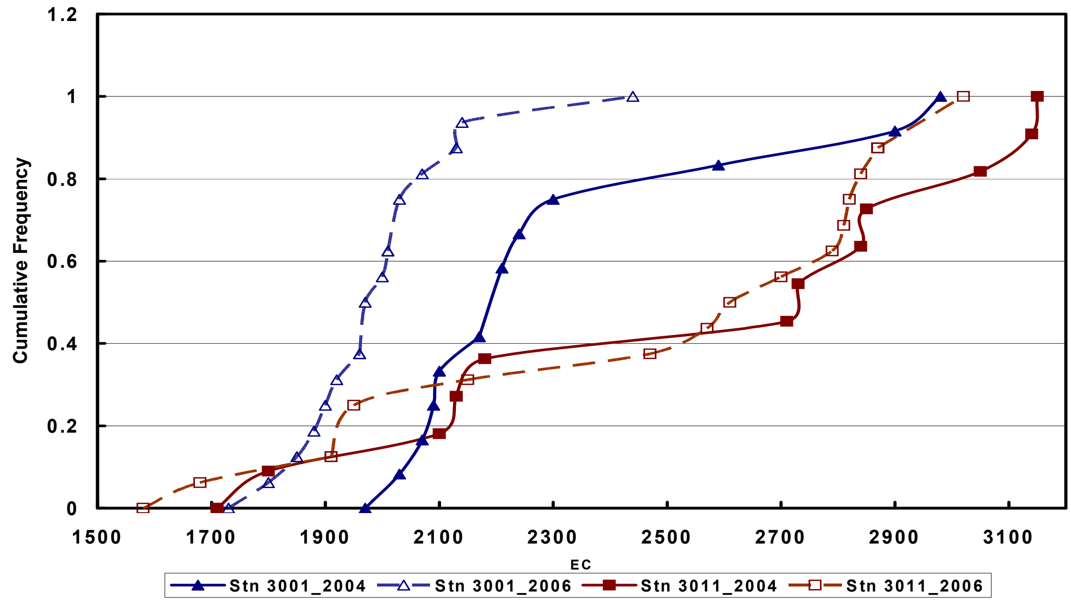

Figure 7: Cumulative frequency Plot for EC Levels in Control and Retrofit Stations Prior to and After Installation of Smart Timers

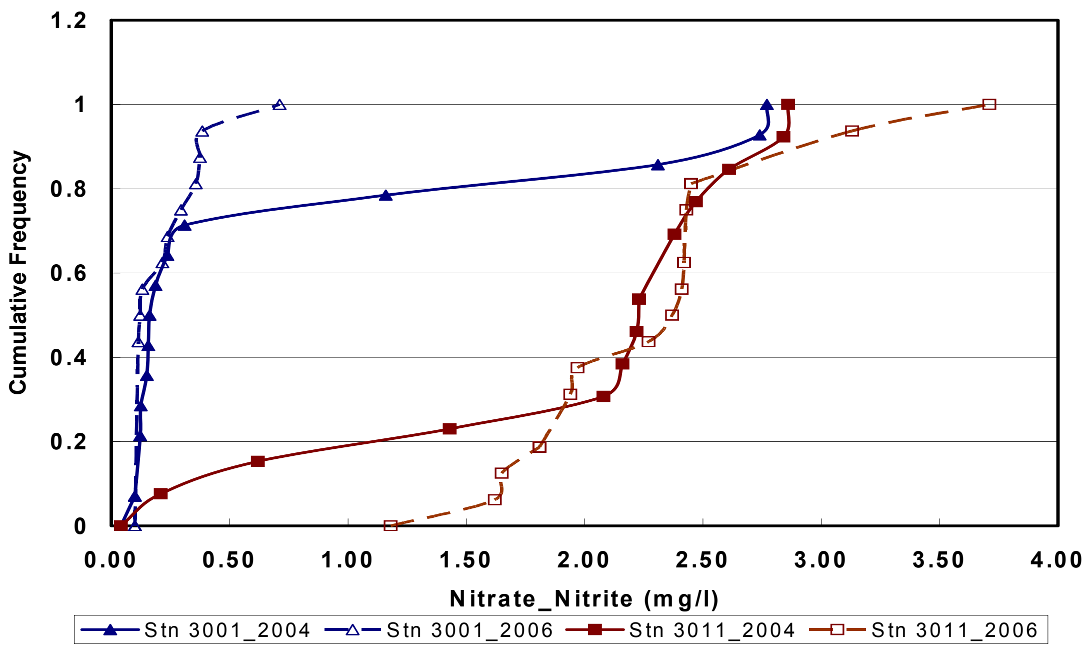

Figure 8: Cumulative frequency Plot for NO_3/NO_2 Levels in Control and Retrofit Stations Prior to and After Installation of Smart Timers

Tables 2 and 3 show descriptive statistics for various water quality parameters for the control and retrofit stations. During the pre-intervention period the measure of central tendencies (mean, median) and variability (standard deviation) for EC and NO3/NO2 concentrations for the control station were substantially different from that of the retrofit station. This suggested that the data arose from different distributions. The trends for other water quality parameters (TKN, Ortho-P, Total-P), however, did not vary appreciably between control and retrofit stations. Only in one case (control station NO3/NO2) the mean value differed substantially from the median value. This suggested that outlier data played only a minor role in the data distribution trends observed.

Table 2: Descriptive Statistics for Control Station (# 3001) Before and After Smart Timer Installation

Statistics	EC		NO_3/NO_2		TKN		Ortho-P		Total - P	
	Yr 2004	Yr 2006	Yr 2004	Yr 2006	Yr 2004	Yr 2006	Yr 2004	Yr 2006	Yr 2004	Yr 2006
N	13	17	15	17	14	17	15	17	15	17
Mean	2294	1988	0.71	0.21	0.70	0.51	0.39	0.46	0.42	0.44
Median	2170	1970	0.16	0.12	0.68	0.42	0.32	0.43	0.32	0.34
Max	29980	2440	2.77	0.71	1.1	1.6	1.29	1.1	1.25	1.15
Min	1970	1730	0.04	0.1	0.3	0.3	0.04	0.075	0.1	0.2
Std. Dev	325	159	1.02	0.17	0.26	0.32	0.32	0.22	0.34	0.24
25^{th} Percentile	2090	1900	0.12	0.1	0.58	0.32	0.19	0.36	0.19	0.28
75^{th} Percentile	2300	2030	1.16	0.29	0.86	0.55	0.42	0.49	0.43	0.58
IQR*	310	130	1.04	0.19	0.29	0.24	0.23	0.13	0.23	0.3

IQR – Inter Quartile Range

Table 3: Descriptive Statistics for Retrofit Station (# 3011) Before and After Smart Timer Installation

Statistics	EC		NO_3/NO_2		TKN		Ortho-P		Total - P	
	Yr 2004	Yr 2006	Yr 2004	Yr 2006	Yr 2004	Yr 2006	Yr 2004	Yr 2006	Yr 2004	Yr 2006
N	12	17	14	17	14	17	14	17	14	17
Mean	2533	2444	1.88	2.24	0.72	1.01	0.39	0.49	0.42	0.51
Median	2720	2610	2.2	2.4	0.72	0.84	0.32	0.35	0.37	0.44
Max	3150	3020	2.86	3.71	1.32	2.49	1.24	1.24	1.31	1.21
Min	1710	1580	0.04	1.18	0.3	0.3	0.12	0.19	0.1	0.2
Std. Dev	520	473	0.94	0.59	0.29	0.69	0.3	0.3	0.31	0.29
25^{th} Percentile	2122	1950	1.59	1.84	0.47	0.51	0.19	0.3	0.22	0.29
75^{th} Percentile	2900	2820	2.4	2.4	0.83	1.45	0.5	0.46	0.53	0.63
IQR	777	880	0.86	0.6	0.36	0.95	0.32	0.16	0.31	0.34

IQR – Inter Quartile Range

Similar comparisons during the post-intervention period indicated that the data distributions were different between the two stations for all of the water quality parameters evaluated. In general, the mean and median values for the retrofit area appeared higher than those for the control station. Finally, outliers appeared to play only a minor role in the post-intervention data also.

Comparison of central tendencies between the pre- and post-intervention data for control station indicated substantial differences for all of the water quality parameters except total-P. This indicated that these data belonged to different distribution. Furthermore, for EC, NO_3/NO_2 and TKN, the mean and median values decreased during the post-intervention period. The mean and median values for ortho-P and total-P slightly increased during the post-intervention period.

The trends in pre- and post-intervention data for the retrofit area differed from those observed for the control station. The EC values slightly decreased and the other parameter levels slightly increased during the post-intervention period. Furthermore, the standard deviation for the pre- and post-intervention periods did not change substantially.

Figures 9 and 10 show the box plot for EC and nitrate/nitrite trends for control and retrofit stations. The box plot trends were generally consistent with cumulative frequency plots and descriptive statistics table. For the control station, mean EC values were lower than those for the retrofit station. Furthermore, the data variability (IQR) for the control station was lower than those for the retrofit station. Similarly, the nitrate/nitrite concentrations for the control stations were lower than the retrofit station values before and after installation of Smart Controllers. The box plots for the remaining parameters are in Appendix B. Unlike the EC and NO_3/NO_2 trends, the box plots for TKN, ortho-P and total-P for the retrofit station were not substantially different than those of control station. The data variability (IQR) for the retrofit station appeared to be high in some cases than those for the control station.

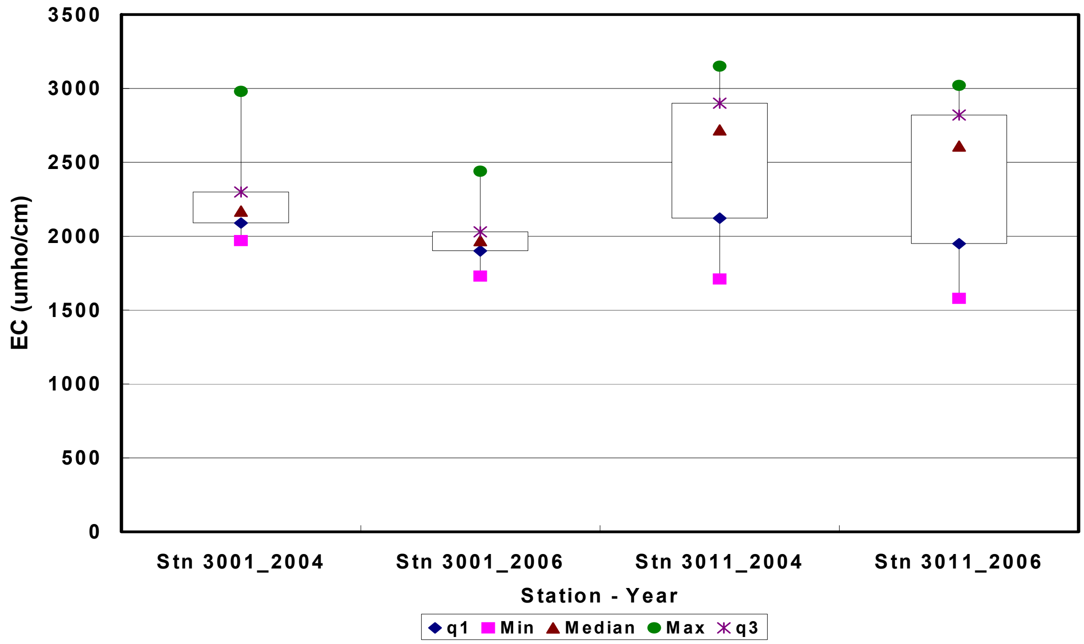

Figure 9: Box Plot for EC Levels in Control and Retrofit Stations Prior to Installation of Smart Timers

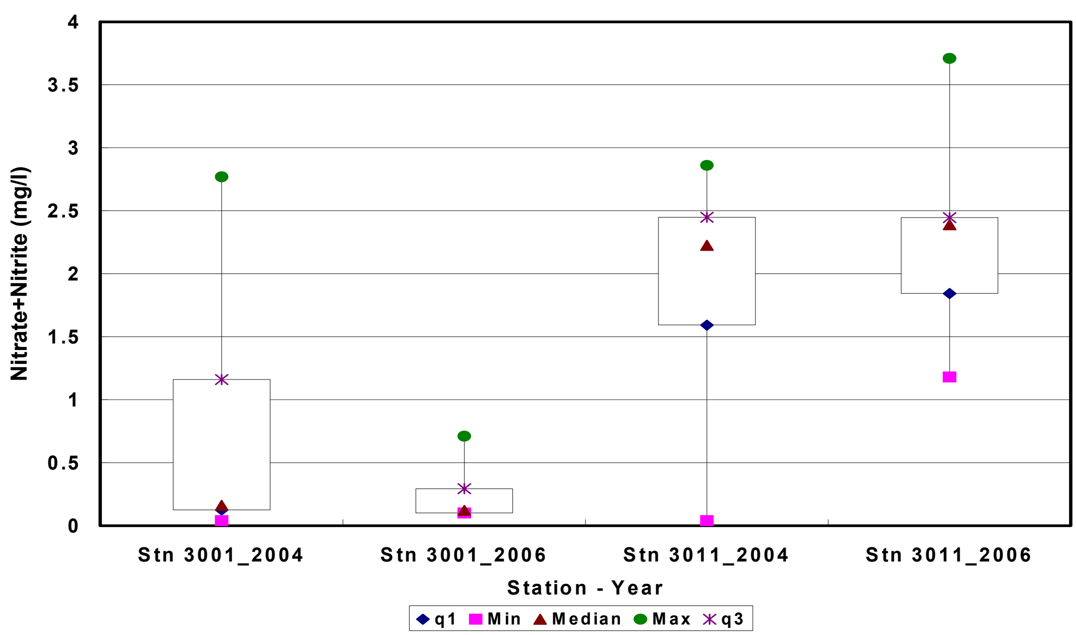

Figure 10: Box Plot for Nitrate/nitrite Levels in Control and Retrofit Stations Prior to Installation of Smart Timers

Section 4: Paired T-test for Comparing Concentrations of Water Quality Parameters

Paired t-tests were performed if significant differences existed in concentrations of water quality parameters under various scenarios. Figures 11 through 14 show the results from the analyses. The solid bars in these figures indicate that the differences are not statistically significant (α = 0.05). The hatched bars indicate statistically significant differences. As shown in Figure 11, the nitrate/nitrite concentrations in the retrofit station were significantly higher than those of the control station prior to the installation of Smart Timers. After installation of the Smart Timers, EC, nitrate/nitrite as well as TKN values for the retrofit stations were higher than those of the control station (Figure 12).

For the control station, significant decrease in EC levels and increase in Ortho-P levels occurred after installation of Smart Timers (Figure 13). For the retrofit station none of the water quality parameters concentrations changed significantly after installation of smart timers (Figure 14).

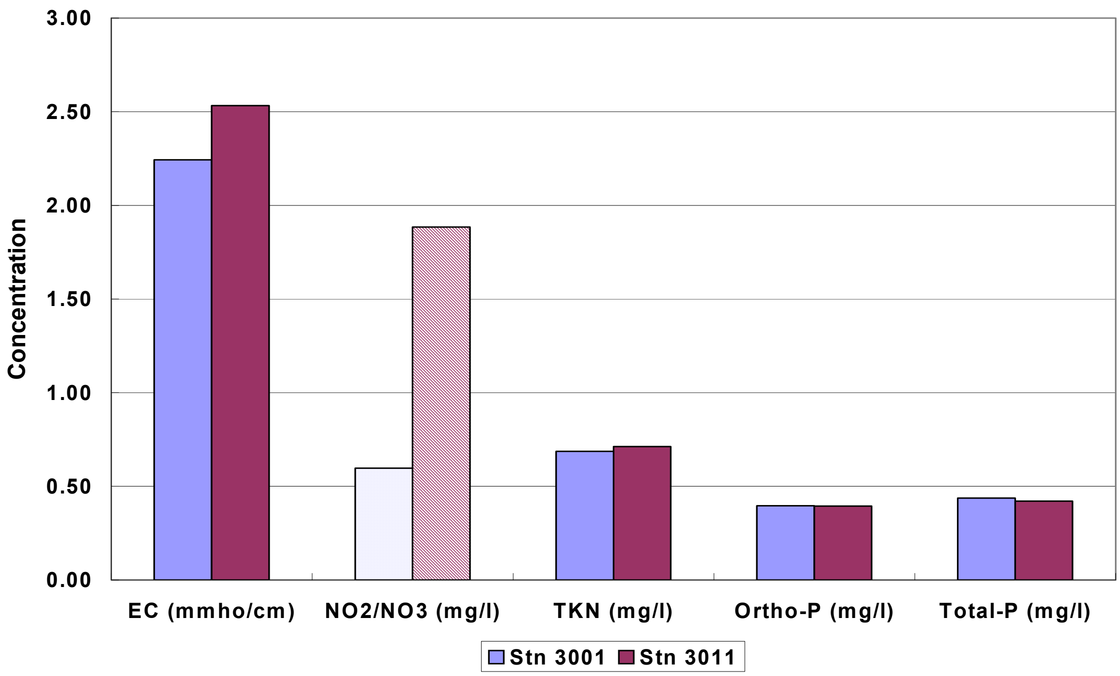

Figure 11: Mean Concentration of Various Water Quality Parameters for Control (# 3001) and Retrofit Stations (# 3011) During Pre-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

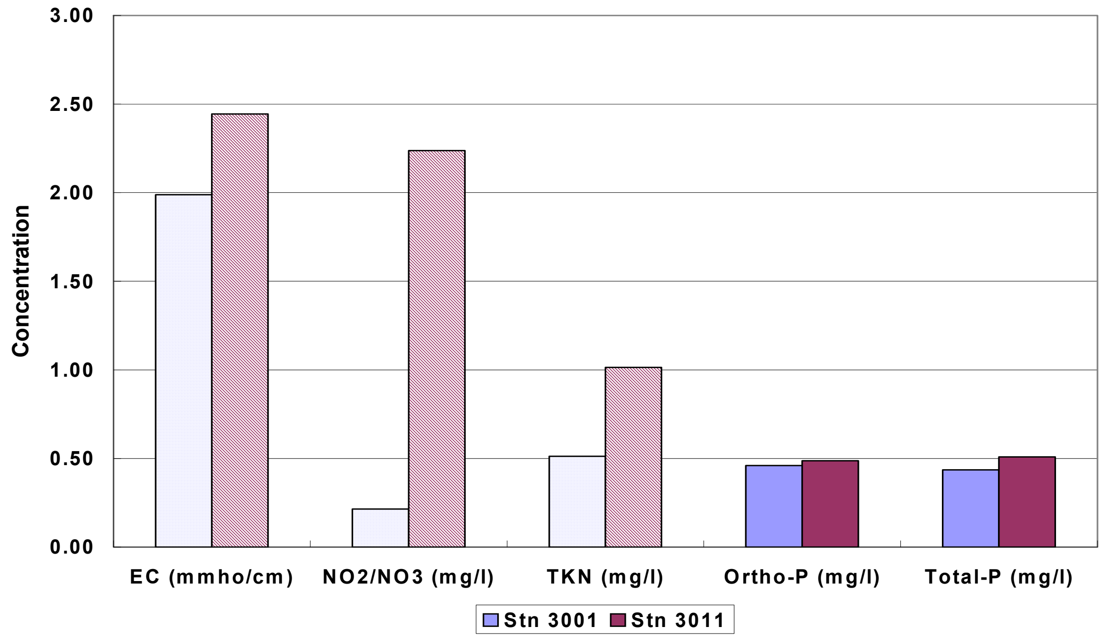

Figure 12: Mean Concentration of Various Water Quality Parameters for Control (# 3001) and Retrofit Stations (# 3011) During Post-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

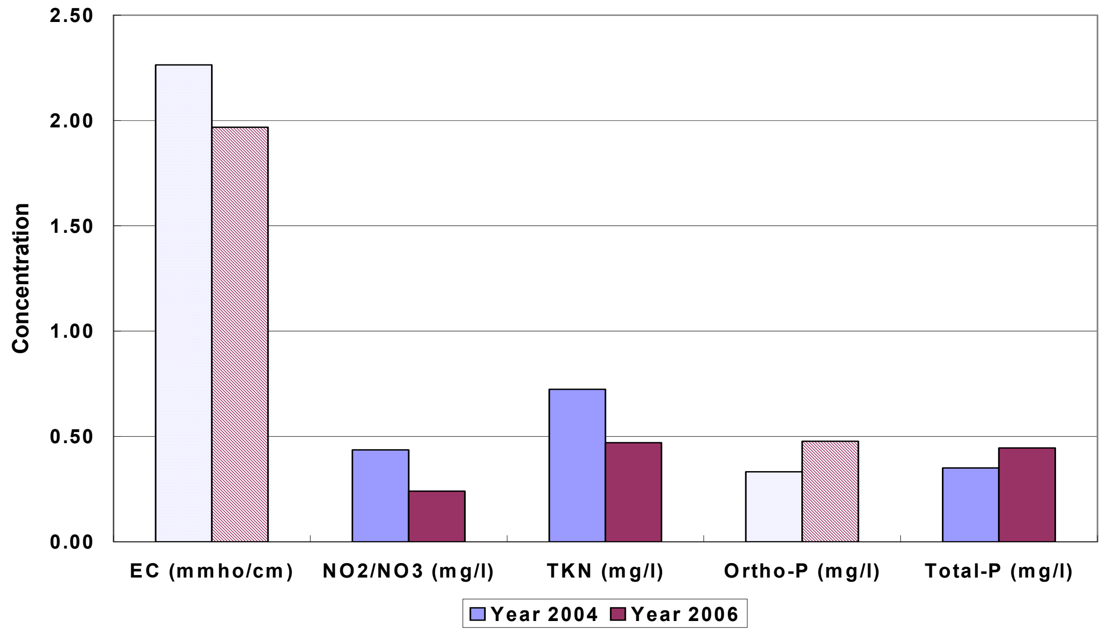

Figure 13: Mean Concentration of Various Water Quality Parameters for Control Station (# 3001) During Pre- and Post-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

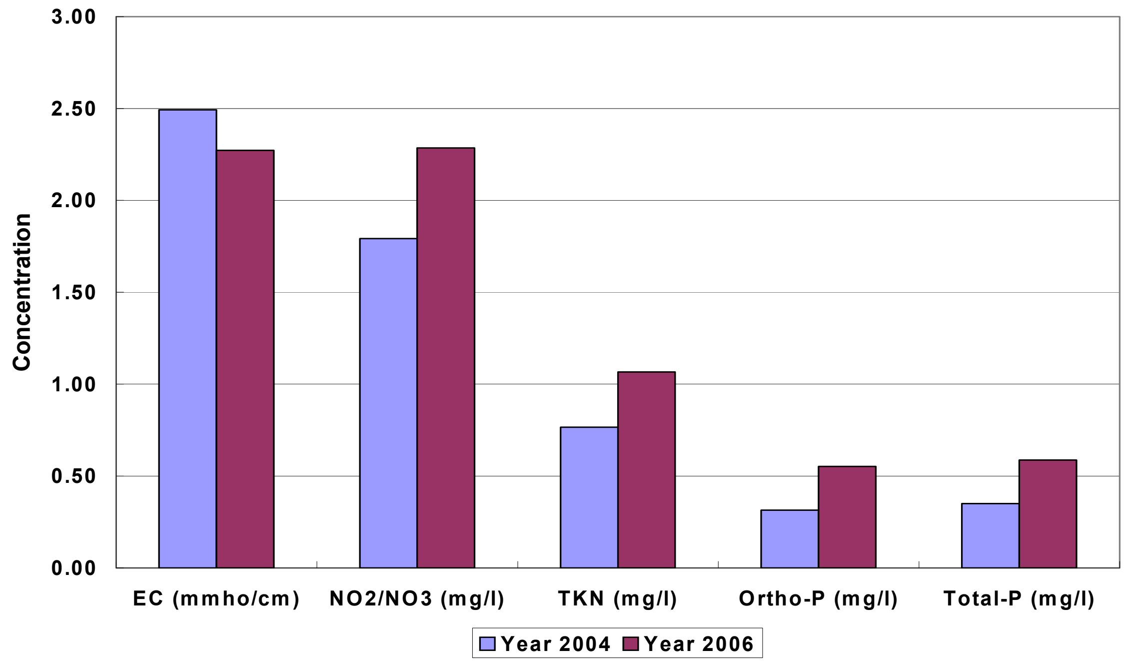

Figure 14: Mean Concentration of Various Water Quality Parameters For Retrofit Station (# 3001) During Pre- and Post-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

Section 5: Paired T-test for Total Pollutant Flux

Paired t-tests were also performed to evaluate mass flux rate for the water quality parameters. The mass flux for the control and retrofit stations were normalized to irrigated area (Mass Flux = [flow X concentration] / Irrigated Area) for comparison. The average flow rates on the date of water quality samples collection were used to estimate mass flux values.

First, the t-tests for the flow rates alone are shown in Figure 15. Runoff flows from the water quality sample collection dates alone were used in these analyses. (Detailed evaluation of runoff flow analyses are provided in the recent Metropolitan Water District of Orange County (MWDOC) report “Pilot Implementation of Smart Timers: Water Conservation, Urban Runoff Reduction, and Water Quality”). The mean runoff flow rate for the control station decreased from 0.68 gpm/acre in 2004 to 0.28 gpm/acre in 2006. The mean runoff flow rate for the retrofit station decreased from 1.03 gpm/acre in 2004 to 0.13 gpm/acre in 2006. The decrease in runoff flow were statistically significant for both the stations. Furthermore, the reduction in mean runoff for the retrofit station (0.9 gpm/acre) is significantly larger than the reduction in the mean runoff for the control station (0.4 gpm/acre). The larger decrease runoff flow rate in the retrofit station compared to that in control station can be attributed to installation of Smart Timers.

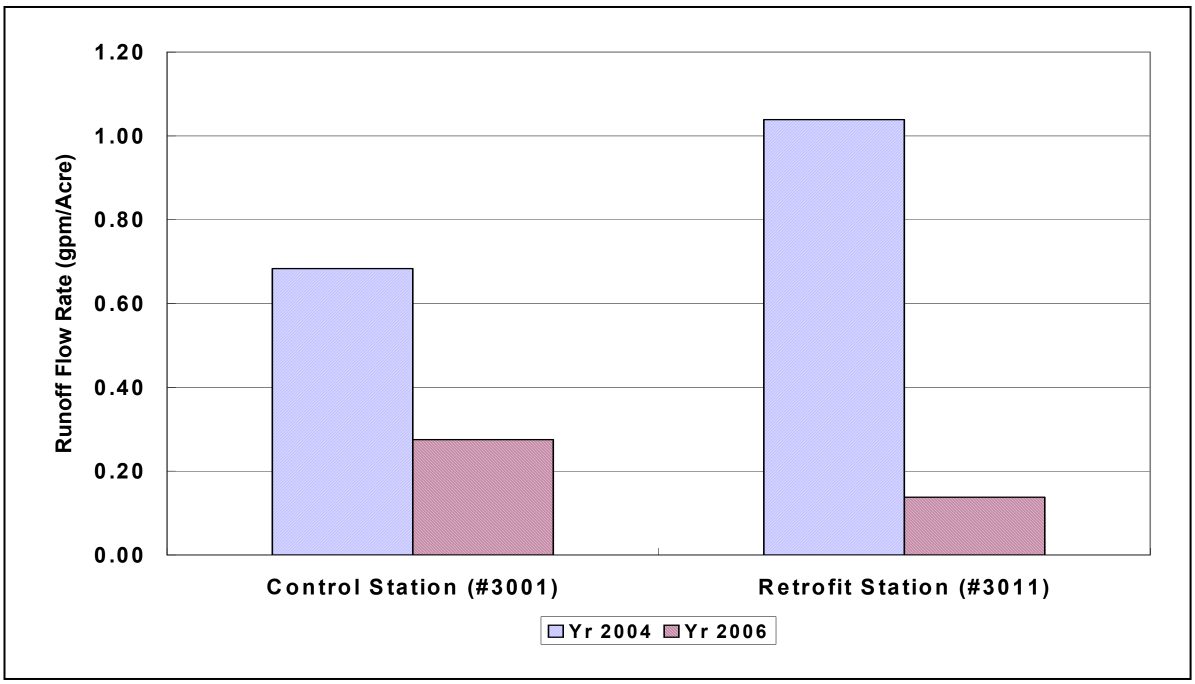

Figure 15: Runoff Flow Rates in Control and Retrofit Areas

Paired t-test results for mass flux are shown in Figures 16 through 18. For the control station, the mass flux for EC and TKN decreased significantly during the post-intervention period (Figure 16). The flux for other parameters were not statistically different during pre- and post-installation period. For the retrofit station, EC, nitrate/nitrite and TKN flux decreased significantly after the installation of Smart Timers (Figure 17). Note that the concentrations of these parameters in the runoff did not decrease significantly after installation of the Smart Timers. Hence, the reduction in flux occurred predominantly due to the reduction in runoff flow.

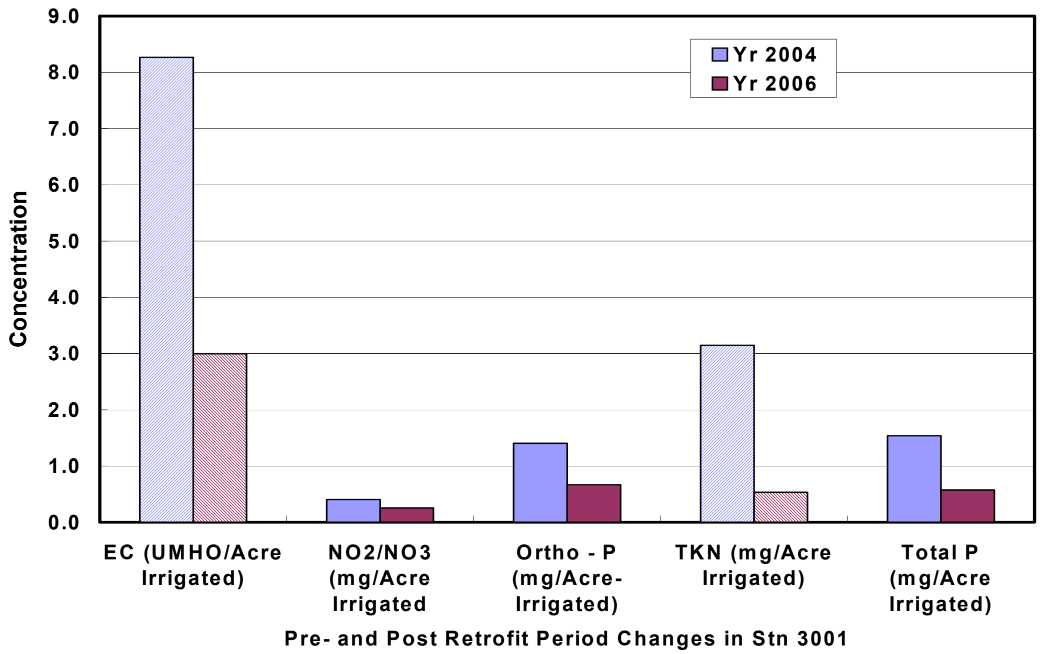

Figure 16: Mean Mass Flux of Various Water Quality Parameters for Control Station (# 3001) During Pre- and Post-Intervention Period. (The doted/stashed bars mean the mass flux are statistically different)

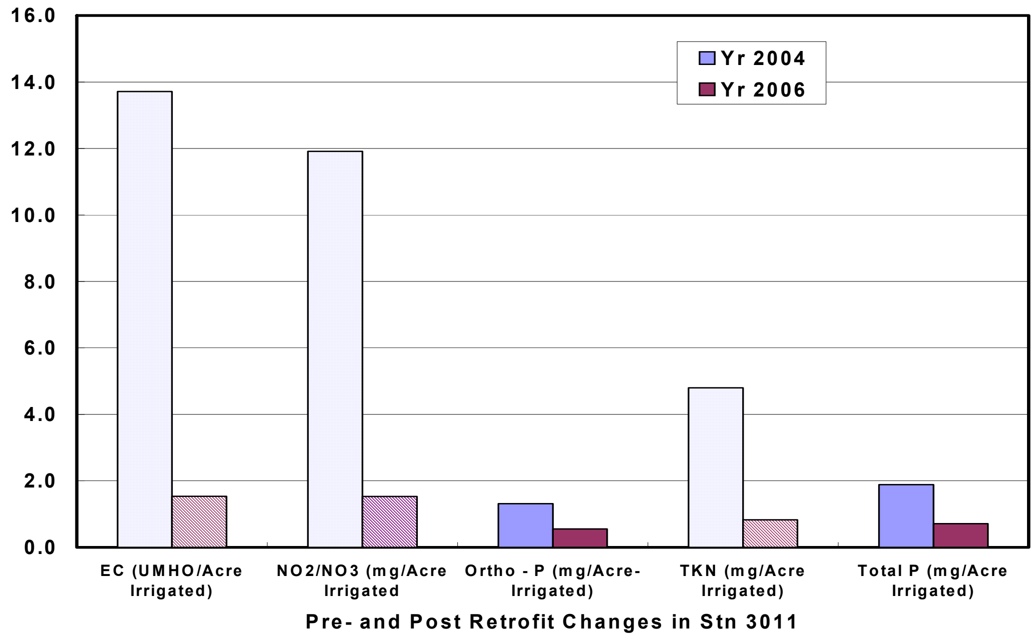

Figure 17: Mean Mass Flux of Various Water Quality Parameters for Retrofit Station (# 3011) During Pre- and Post-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

Finally, paired t-tests were performed to compare the change (= mass flux in 2004 – mass flux in 2006) in mass flux in the control station with that in the retrofit station. Figure 18 shows the results from these analyses. Note that a larger bar in this figure indicates a greater reduction in mass flux. T-test data indicated that, reduction in EC and nitrate/nitrite flux in the retrofit station were significantly greater than those in the control station. Since, the concentration of these parameters did not significantly decrease, the reduction in the mass flux for the retrofit station can be attributed to the reduction in runoff flow rate due to installation of Smart Timers.

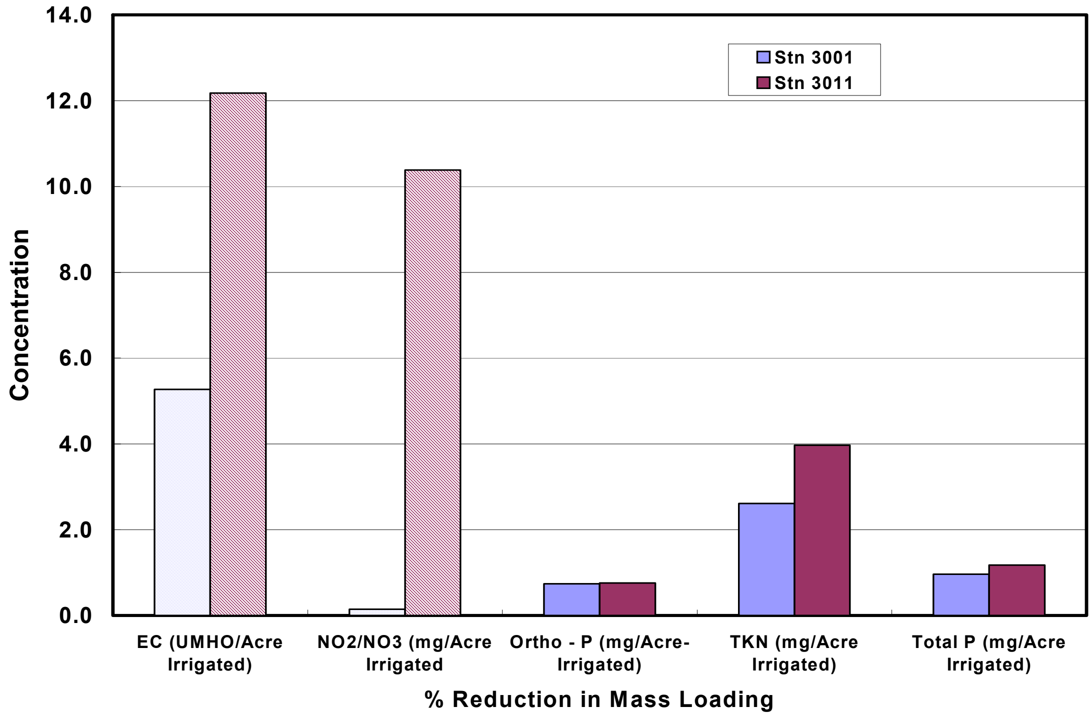

Figure 18: % Reduction in Mass Loading for Various Water Quality Parameters in Control and Retrofit Stations Between Pre- and Post-Intervention Periods. (The doted/stashed bars mean the concentrations are statistically different)

Section 6: Summary

In summary, the data indicated that the nitrate/nitrite concentrations in the retrofit area were higher than that of the control station, before as well as after the installation of Smart Timers. Also, the water quality data for some parameters (EC and nitrate/nitrite) for the control and retrofit stations belonged to different distribution. Reasons for these differences are not currently known. The distribution for the other water quality parameters did not differ substantially between the control and retrofit stations. Concentrations of some parameters (EC, TKN) decreased for the control station during the post intervention period. However, no significant decrease in concentrations was observed for the retrofit station after installation of Smart Timers. The runoff flow rates for both the control and retrofit stations decreased during the post-intervention period. However, the flow rate reduction in the retrofit station was significantly larger than that in the control station. This suggested that installation of Smart Timers significantly lowered the runoff flow in the retrofit area. Mass Flux for some parameters (EC in Control Station; EC, Nitrate/Nitrite and TKN in the retrofit station) decreased during the post-intervention period. However, mass flux reduction in the retrofit area (EC, nitrate/nitrite) was significantly larger than that in the control area. The larger reduction in mass flux in the retrofit area is predominantly caused by reduction in the runoff flow rate caused by the installation of Smart Timers.

Appendix A: Time Series Plots

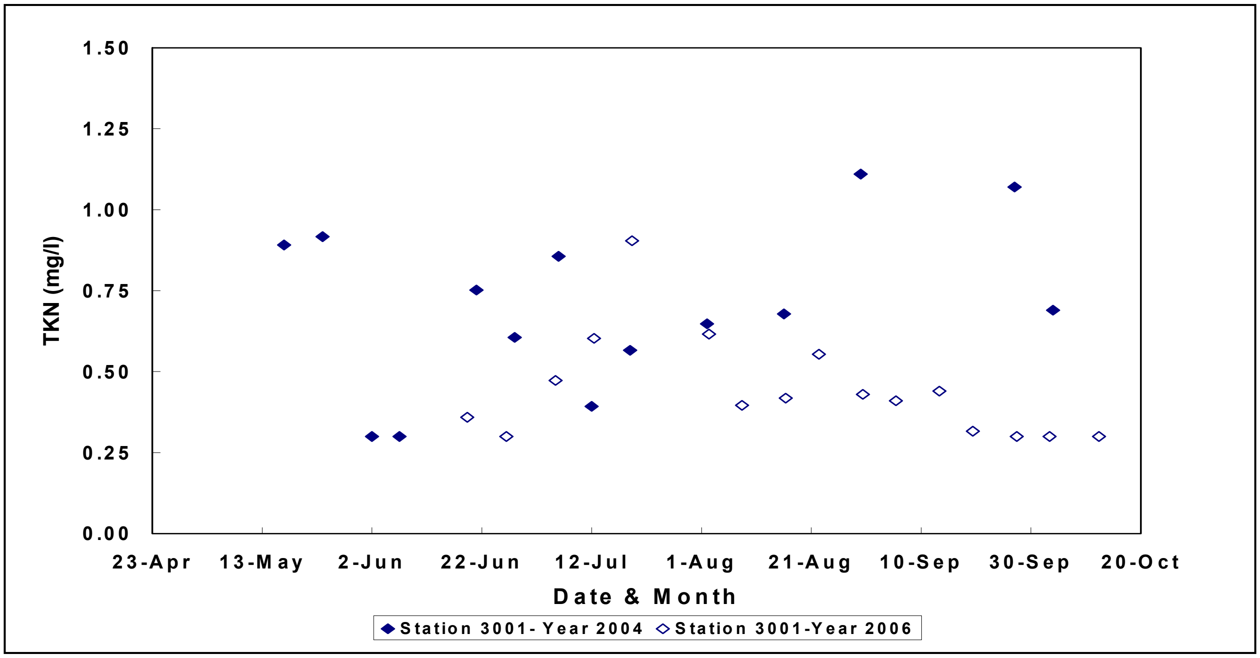

Figure A1. Time Series Plot for TKN in Control Station (#3001) during pre- and post-intervention periods

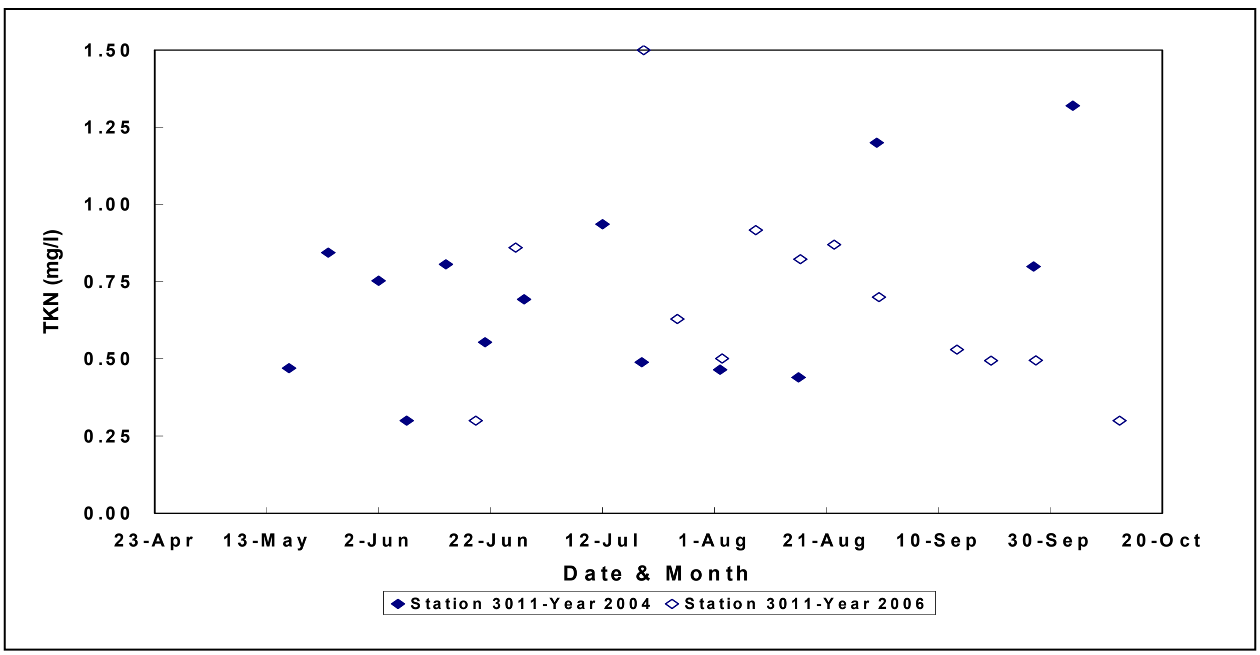

Figure A2. Time Series Plot for TKN in Retrofit Station (#3011) during pre- and post-intervention periods

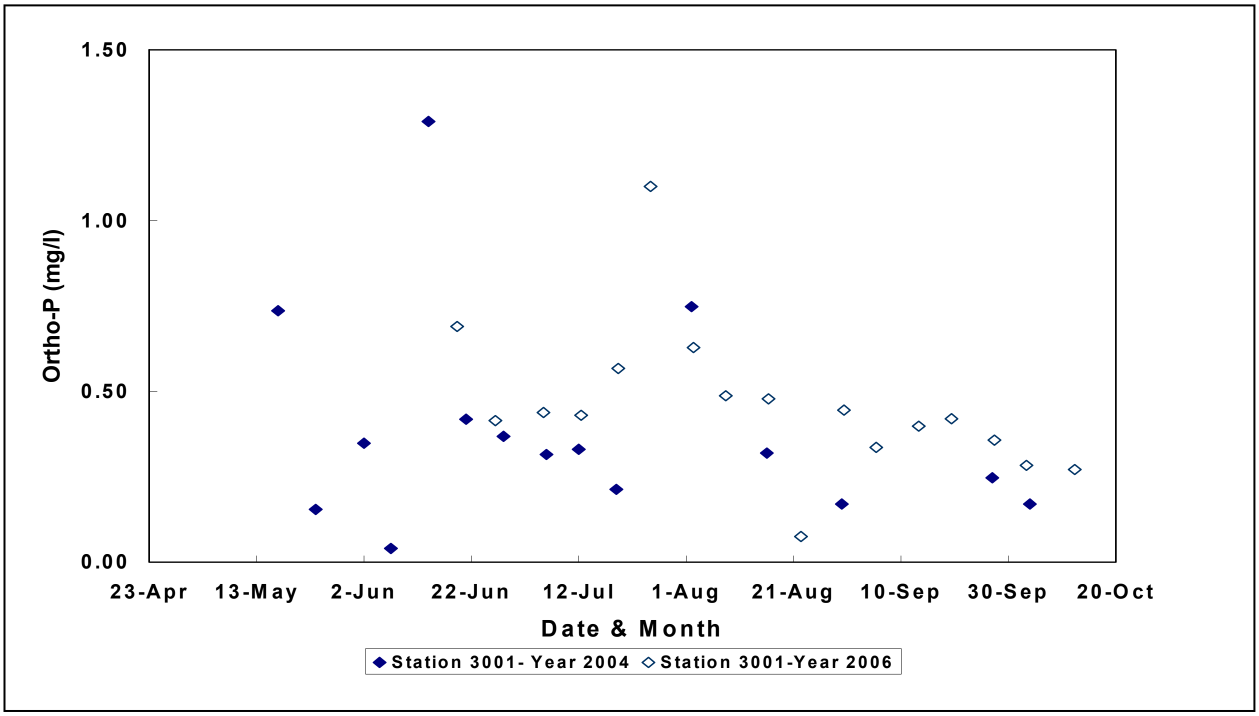

Figure A3. Time Series Plot for Ortho-P in Control Station (#3001) during pre- and post-intervention periods

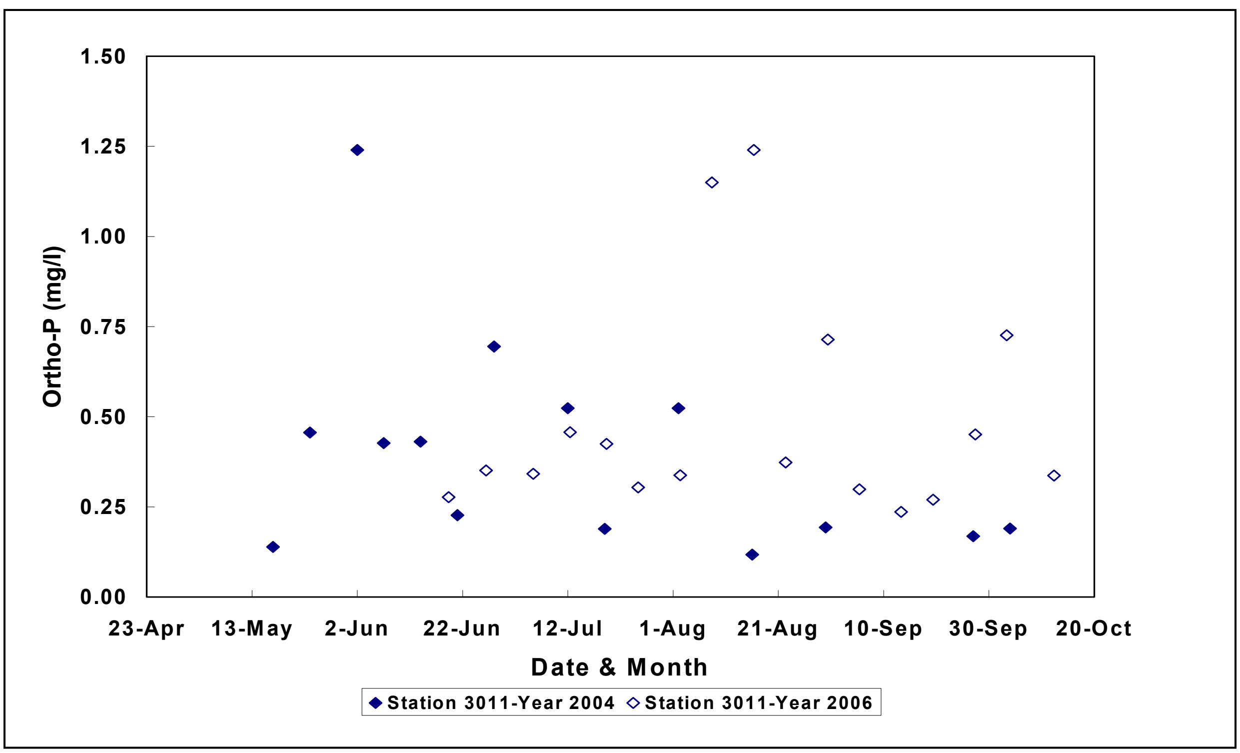

Figure A4. Time Series Plot for Ortho-P in Retrofit Station (#3011) during pre- and post-intervention periods

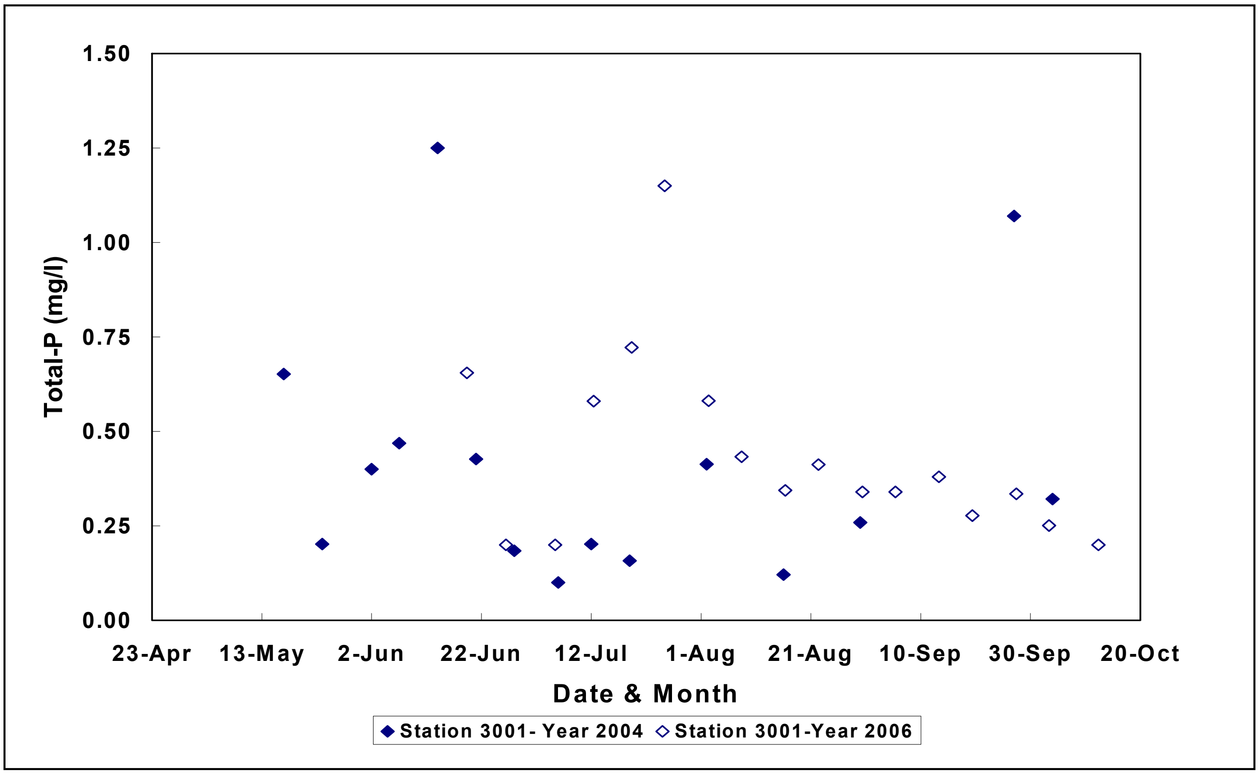

Figure A5. Time Series Plot for Total-P in Control Station (#3001) during pre- and post-intervention periods

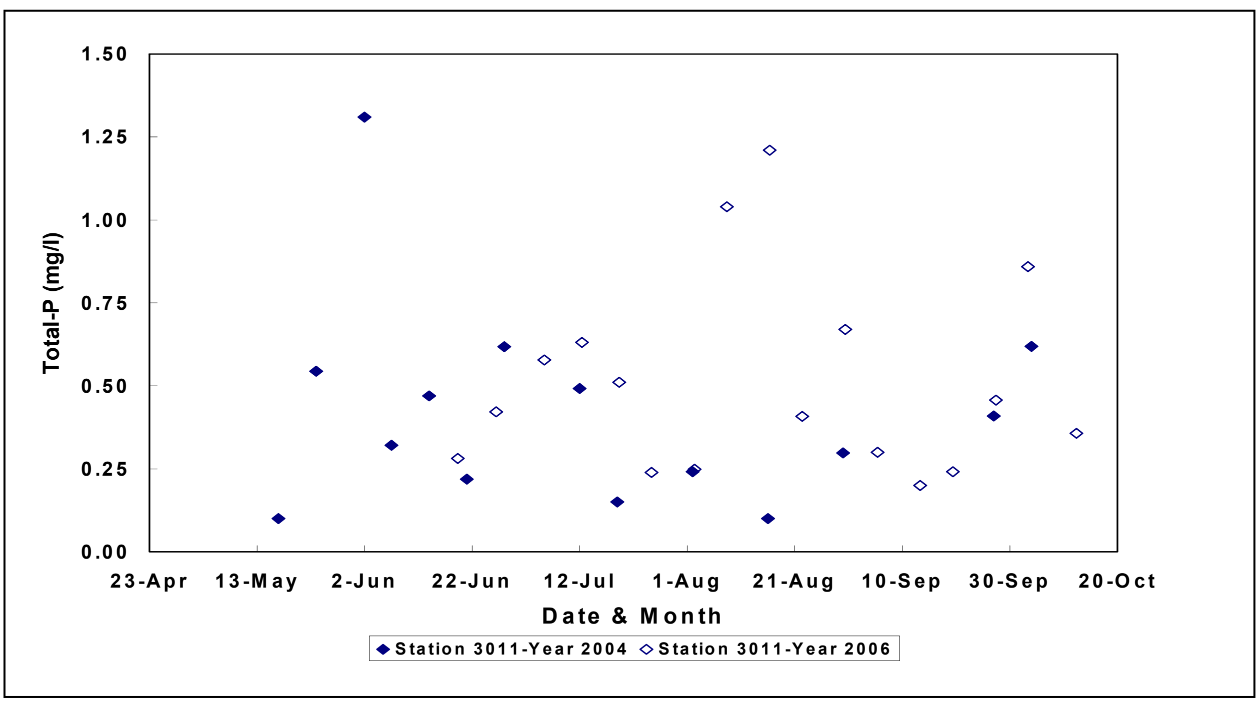

Figure A6. Time Series Plot for Total-P in Retrofit Station (#3011) during pre- and post-intervention periods

Appendix B: Cumulative Frequency and Box Plots

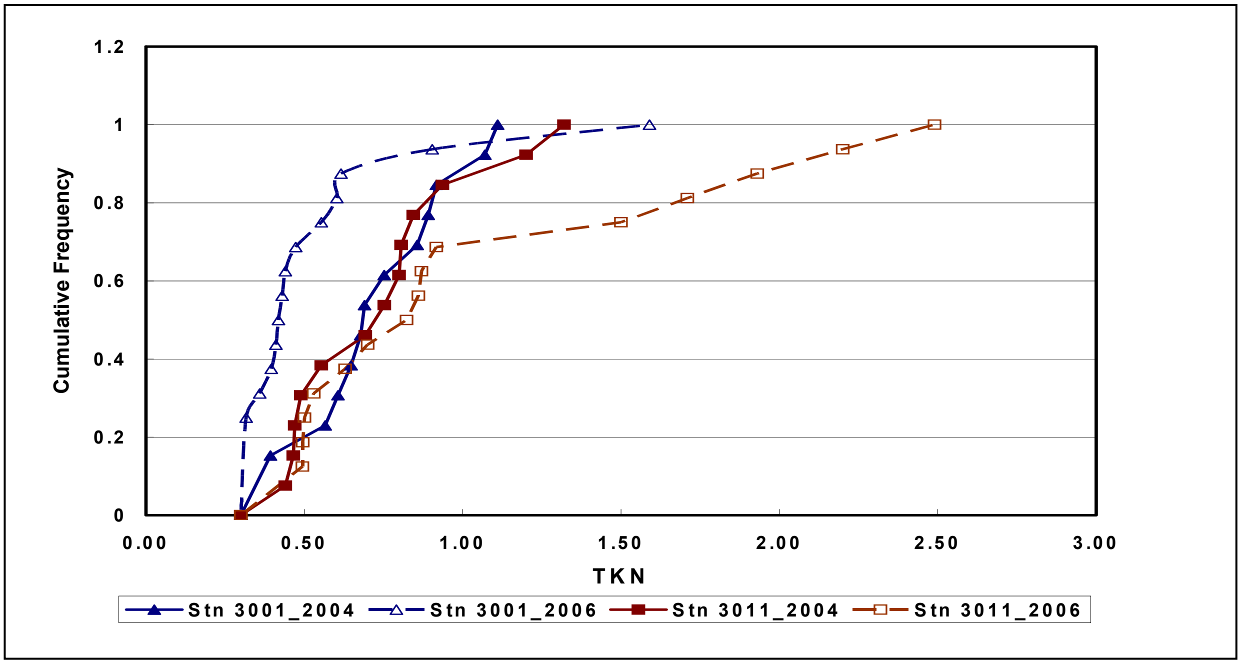

Figure B1. Cumulative Frequency Plot for TKN in Control and Retrofit Stations during pre- and post-intervention periods

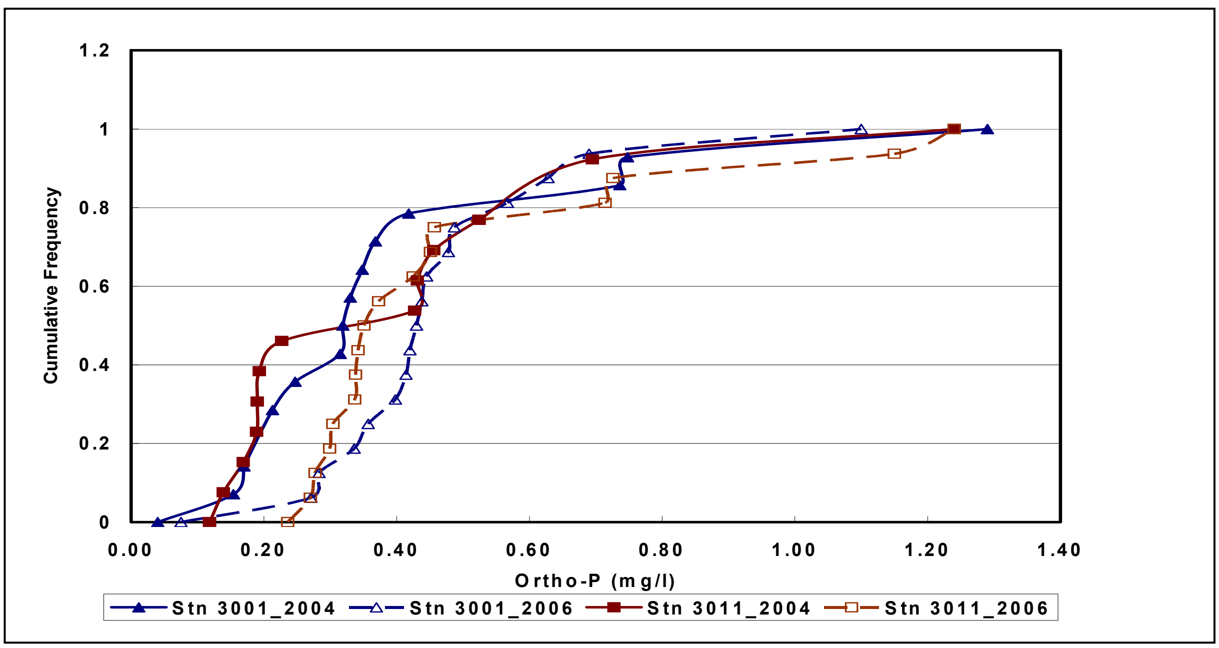

Figure B2. Cumulative Frequency Plot for Ortho-P in Control and Retrofit Stations during pre- and post-intervention periods

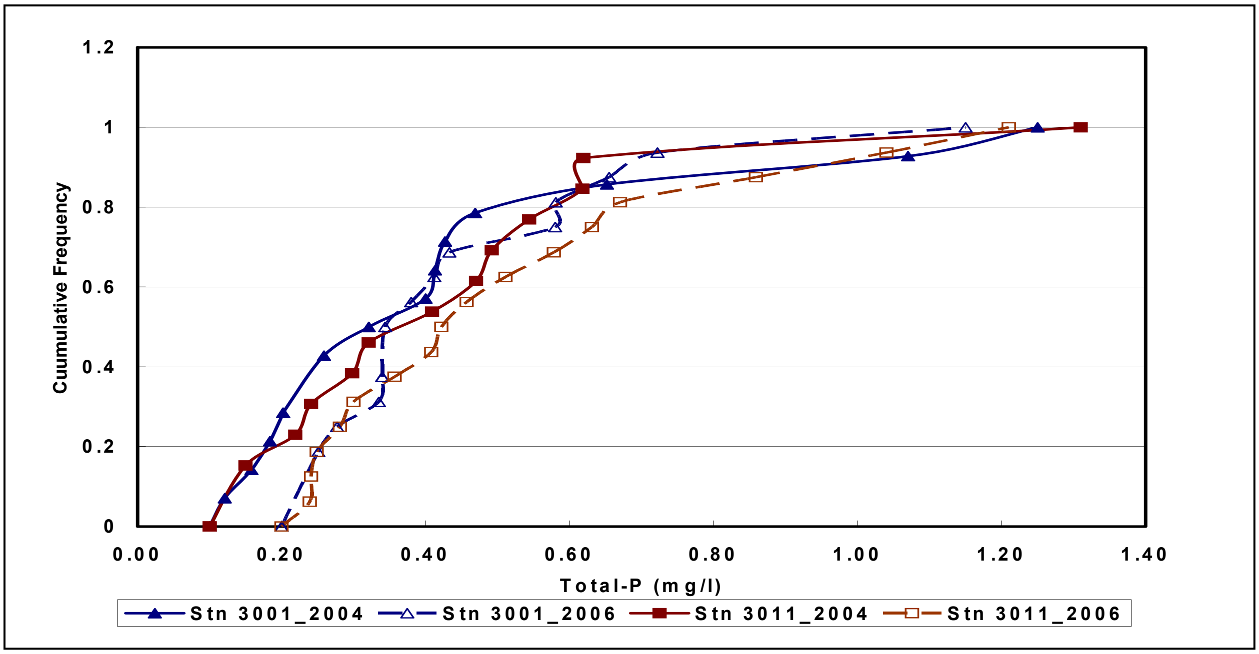

Figure B3. Cumulative Frequency Plot for Total-P in Control and Retrofit Stations during pre- and post-intervention periods

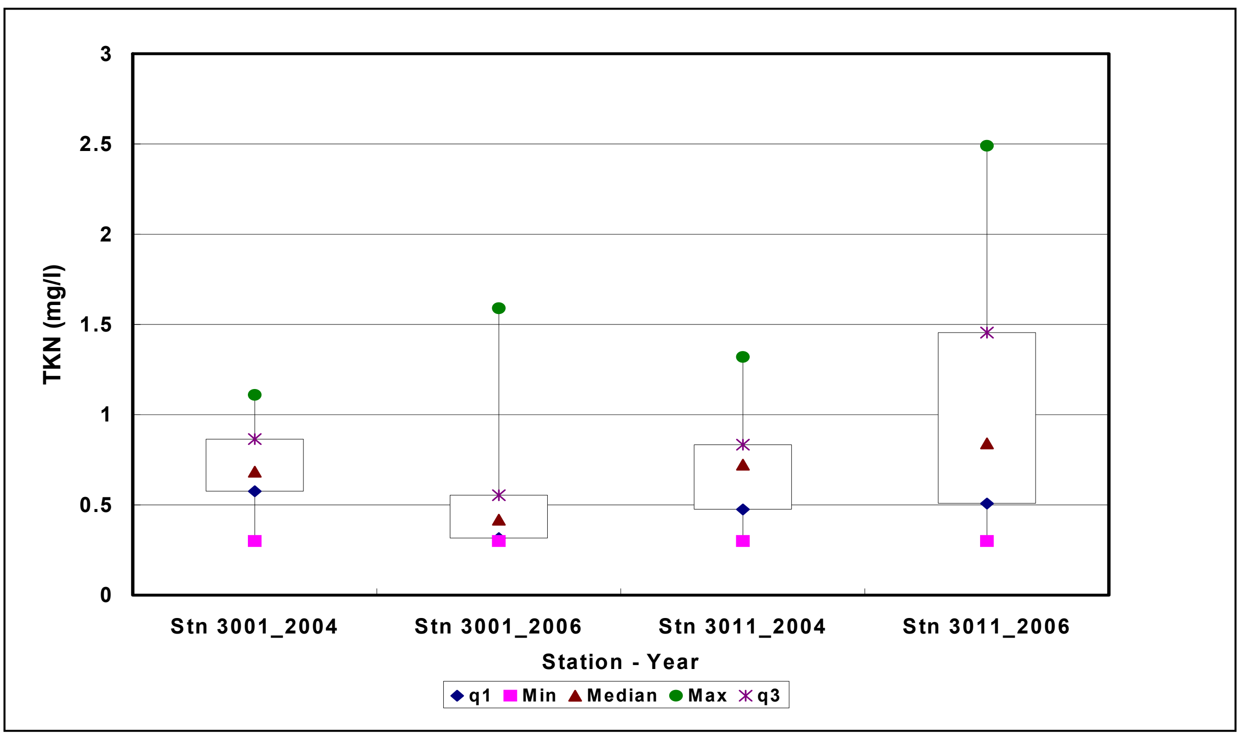

Figure B4. Box Plot for TKN in Control and Retrofit Stations during pre- and post-intervention periods

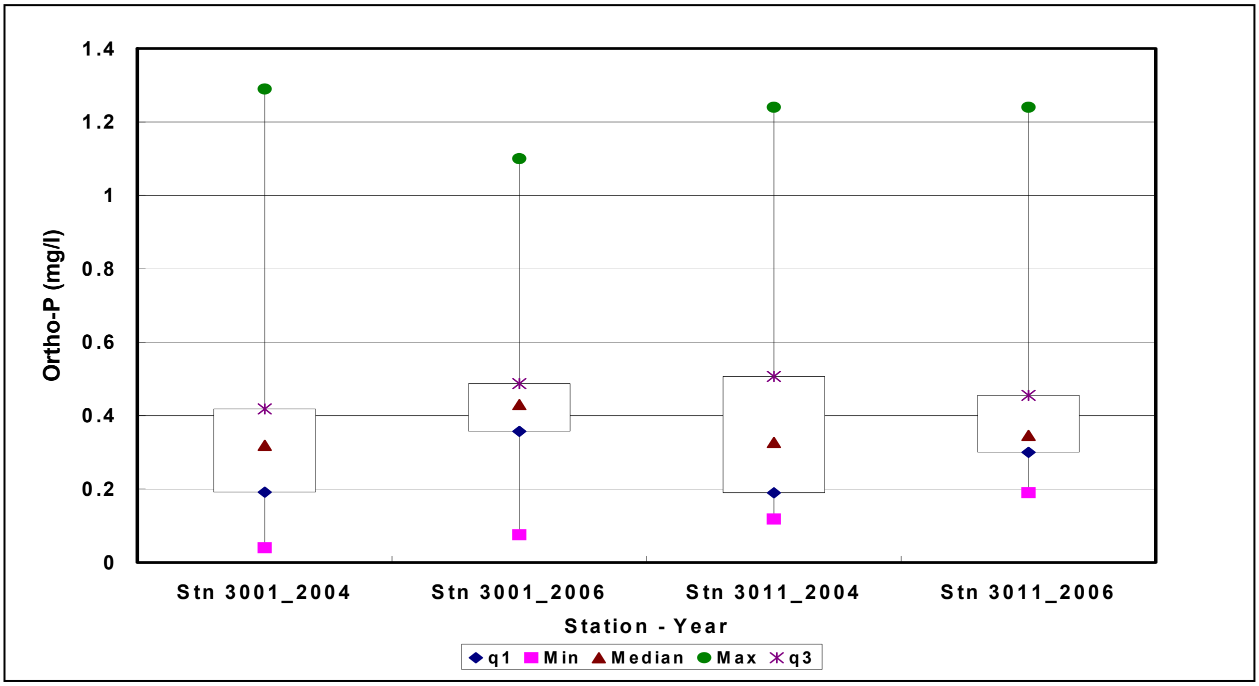

Figure B5. Box Plot for Ortho-P in Control and Retrofit Stations during pre- and post-intervention periods

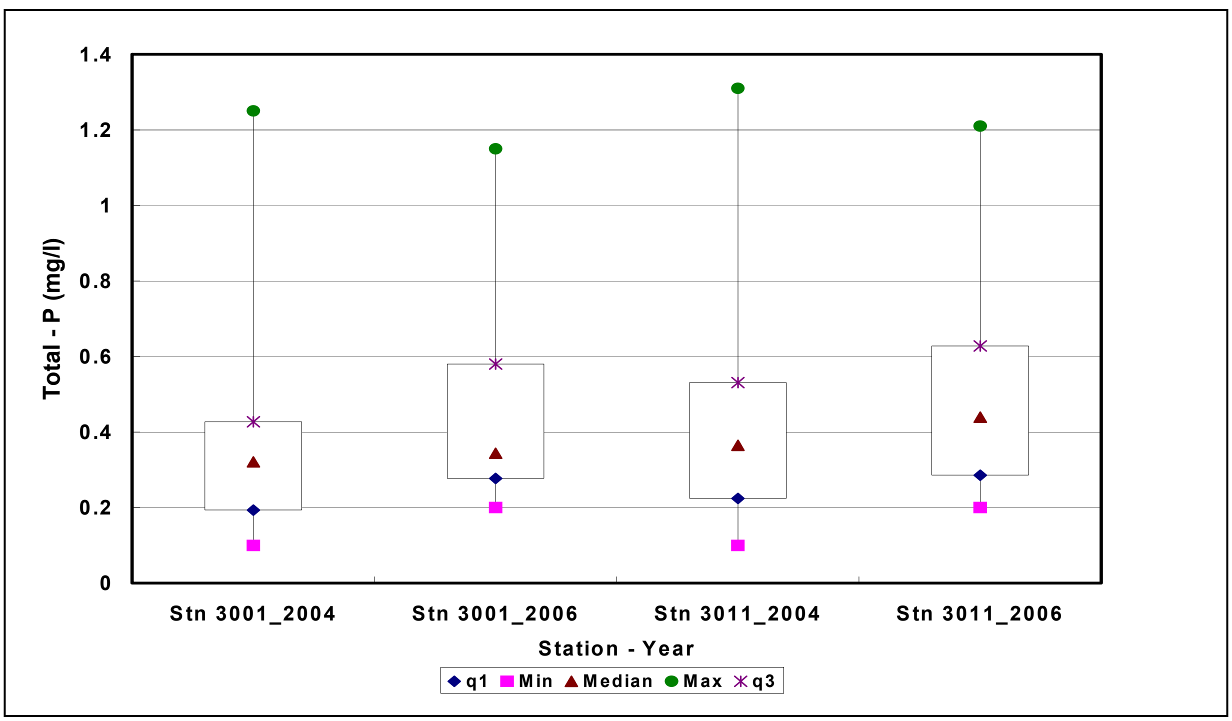

Figure B6. Box Plot for Total-P in Control and Retrofit Stations during pre- and post-intervention periods