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

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Prepared for

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List of Acronyms

α	Alpha, Statistical term which $(1 - \alpha)$ = percent Confidence Interval. ($\alpha = 0.05$ is equivalent to 95 percent Confidence Interval).
ANOVA	Analyses of Variance
DHS	Department of Health Services
EC	Electrical Conductivity
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

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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. These timers, which included eight different brands, have been installed in both residential homes and commercial sites. The installations were done by professionals or homeowners. As part of this program-wide evaluation, water savings were determined from a statistically valid sample by Smart Timer manufacturers, split between residential and commercial installations, seasonal variability, and type of installer.

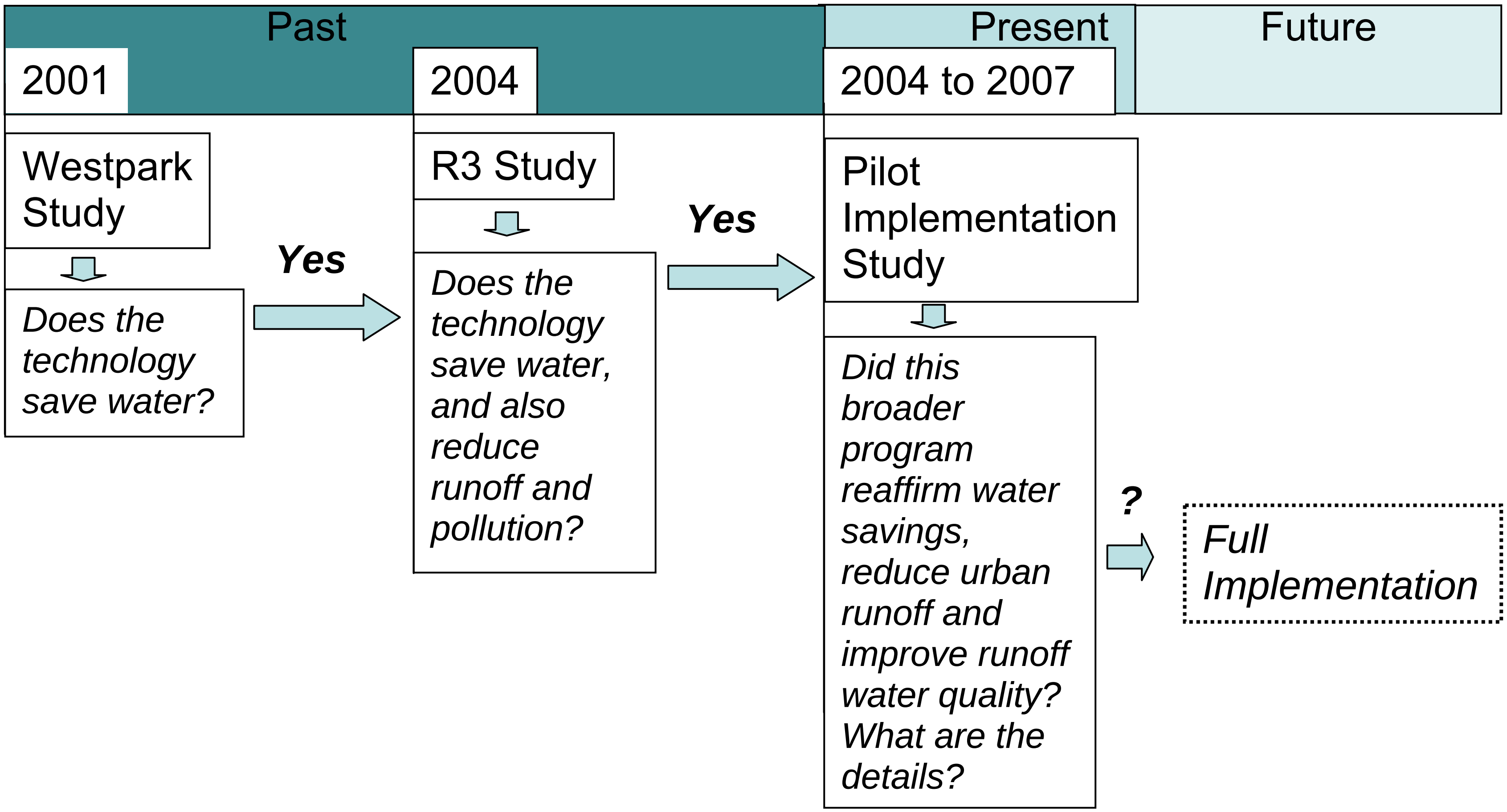


Figure 1: Evolution of Smart Timer Program

The second part of the study was to examine the role of Smart Timers in reducing the quantity of urban runoff and improving the water quality of the runoff. 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 Buck Gully watershed irrigation for the common landscaped areas is fully and separately metered, 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 meters 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 in SFR units resulted in an average water saving of **0.7 HCF/month** (about **18.3 gpd**; 0.0045 gpd/sq.ft irrigated area). This estimate is arrived by calculating the total change in water use in cases where water use changed significantly (increased or decreased, α=0.05) and averaging the net change by all the Smart Timers (899) that were qualified for evaluation. However, the amount of water saving will increase to 1.4

HCF/month (35.7 gpd) if the estimates are made by averaging the net water change (significant increase or decrease) by only those Smart Timers (460) that contributed to significant change in water use.

Three distinct trends were observed in SFRs retrofitted with Smart Timers. In about 33 % of the accounts, the water consumption significantly decreased (α=0.05) after installation of Smart Timers. In about 18 % of the cases the water consumption increased statistically significantly after installation of Smart Timers. In nearly 50 % of the accounts water use did not change significantly upon installation of Smart Timers.

b) Program-wide Water Savings by Commercial Installations

The program-wide installation of Smart Timers in Commercial units resulted in an average water saving of **7.6 HCF/month** (about **190 gpd**; 0.004 gpd/sq.ft. irrigated area). This estimate is arrived by calculating the total change in water use in cases where water use changed significantly (increased or decreased) and averaging the net change by all the Smart Timers (323) that were qualified for evaluation. However, the amount of water saving will increase to 18.5 HCF/month (460 gpd) if the estimates are made by averaging the net water change (significant increase or decrease) by only those Smart Timers (134) that contributed to significant change in water use.

The overall trends observed in Commercial installations were similar to those in SFR installations. In about 30 % of the accounts, the water consumption significantly decreased (α=0.05) after installation of Smart Timers. In about 11 % of the cases the water consumption increased significantly (α=0.05) after installation of Smart Timers. In nearly 60 % of the accounts water use did not change significantly upon installation of Smart Timers.

c) Program-wide Water Savings by Season

Program-wide evaluation of pre- and post-intervention water use in SFR units indicated that significant water savings due to Smart Timers occurred in about six months of the year. These evaluations were performed using approximately four years of pre-intervention data and 1 year of post-intervention data. The water use increased significantly in two to three months (January to March) in SFR units 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. Water use increased during winter months. Figure 2 shows the program-wide SFR observed water use during pre- and post-installation periods. The ET-adjusted water use pattern varied among the Coastal, Central and Foothill regions of the study area. In general, the patterns seem to indicate an existing trend of under irrigation during spring months and over irrigation in the fall season.

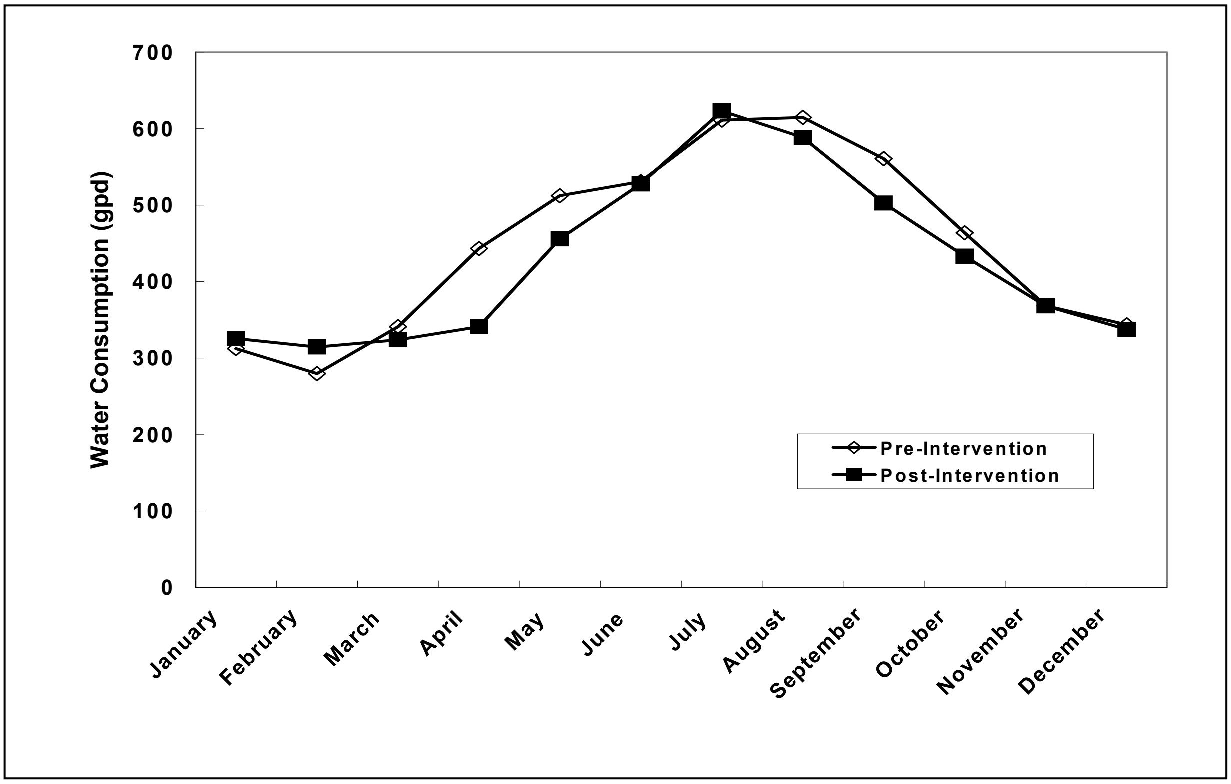


Figure 2: Program Wide SFR Pre- and Post Smart Timer Installation Water Consumption

Water consumption in commercial units 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. As with the SFR installations, the ET adjusted water use pattern varied with the three ET zones evaluated in this study.

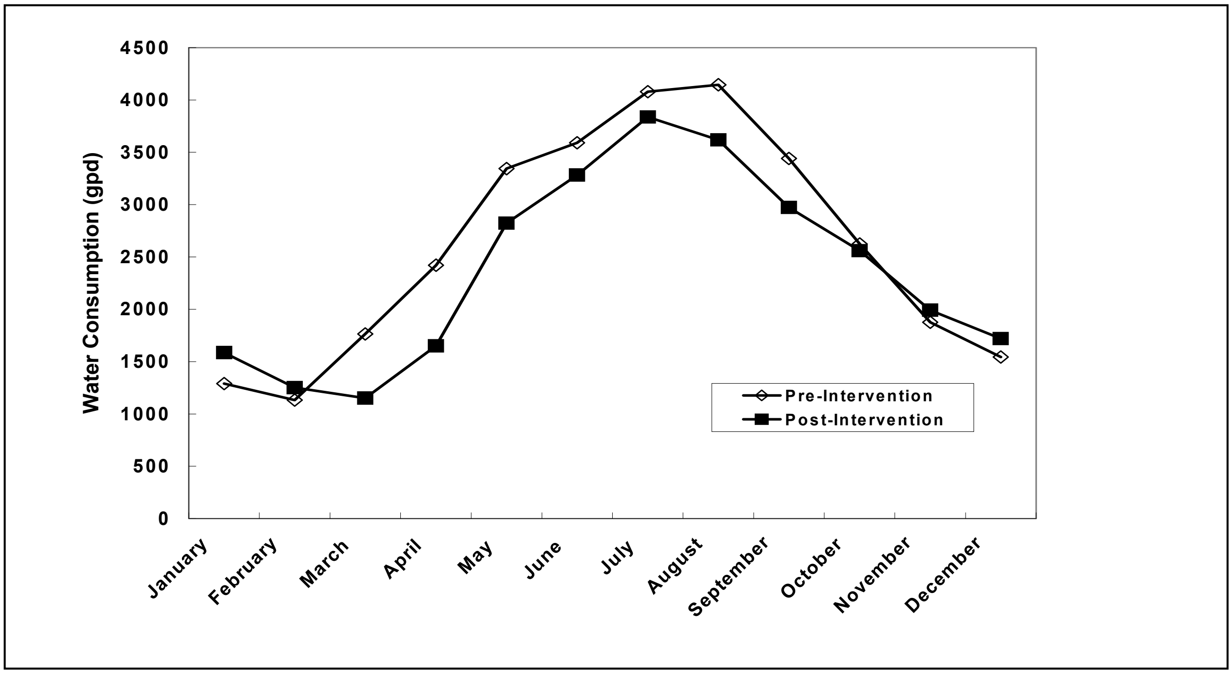


Figure 3: Program Wide Commercial Pre- and Post Smart Timer Installation Water Consumption

d) Program-wide Water Savings by Smart Timer Brand

Seven different brands of Smart Timers were used in SFR units under this study. As a group, three of the brands (Brand A, Brand B, and Brand C) used in the study significantly reduced water consumption in SFR units. In SFR units installed with one brand of Smart Timer (Brand E) the water use increased significantly. Furthermore, in all of these groups, less than 50 percent of the meters yielded statistically significant water savings. Statistically significant water savings occurred in less than 20 percent of the Smart Timers for two groups (Brand D and Brand E). Many factors such as location (ET Zone, City) of installation, ongoing public education, incentive programs, etc. can influenced the differences in the performance of different brands. Additional studies are needed to determine the underlying reasons for the differences of water savings observed in this study.

Nine different brands of Smart Timers were used in Commercial units under this study. However, three brands (Brand B, Brand G, and Brand H) constituted 90 percent of the installations and about 24, 35 and 56 percent of the Smart Timers, respectively, of these brands yielded significant water savings during the study period. Additional studies are needed to determine the underlying reasons for the differences of water savings observed in this study.

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

The performance of Smart Timers in SFRs was evaluated for any differences in Smart Timer functioning due to the installer. There were 336 timers that were installed by 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 significantly saved water. Statistical analysis indicated that a 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. 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.

FINDINGS AND RECOMMENDATIONS

This study showed that installation of Smart Timers resulted in program-wide water savings in SFR (20 gpd) and commercial (254 gpd) areas. However, evaluation of individual meters performance indicated that only about 30 to 32percent of the Smart Timers significantly saved water during the study period. These Smart Timers installed at SFR and commercial facilities saved an average of approximately 80 gpd and 1,200 gpd, respectively.

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 by irrigated area and type of vegetation
- Smart Timer evaluation based on billing rates and structure
- Non-Smart Timer water savings
- Performance by brand of Smart Timer as a function of ET

b) Mid to Long Term Studies

- Inclusion of other water saving database information
- Forensic Smart Timer study
- More than one year post-installation saving analysis
- 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 meters did not meet the criteria needed for inclusion in certain portions of the study. For example, there were only 261 meters 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; MWDOC then provided this information to Kennedy/Jenks Consultants. The information provided was the number of units (each unit is equivalent to 100 cubic feet of water or 748 gallons) for each meter of interest. Water usage for each meter of interest, typically from monthly or bi-monthly meter readings, was provided for years 2002 to 2007.

2.1.3 Evapotranspiration and Rainfall

This data was provided by the IRWD. Daily ET and rainfall data for three IRWD weather stations (Coastal, Central and Foothill) were provided for years 2002 to 2006. 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 Flowmeter. 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 Water Savings

Monthly water savings were 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. This information had to be allocated to the appropriate calendar month using the average usage by day to properly allocate a meter reading that included parts of two months. After this data transformation was performed an average pre-installation monthly average was calculated and used to compare with the post-installation consumption. Furthermore, analyses were performed to determine whether adjustments to the observed water savings to the differences in ET between pre- and post-installation periods were justified.

2.3 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.

2.3.1 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 meters. The Buck Gully study site in Newport Beach had only commercial Smart Timers installed on HOA water meters.

2.3.1.1 Portola Hills

Specifically, the Portola Hills sampling location is at outfall pipe J01P08 located in the Aliso Creek watershed at N 33^{o} 40.700' W 117^{o} 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 Flowmeter. 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.

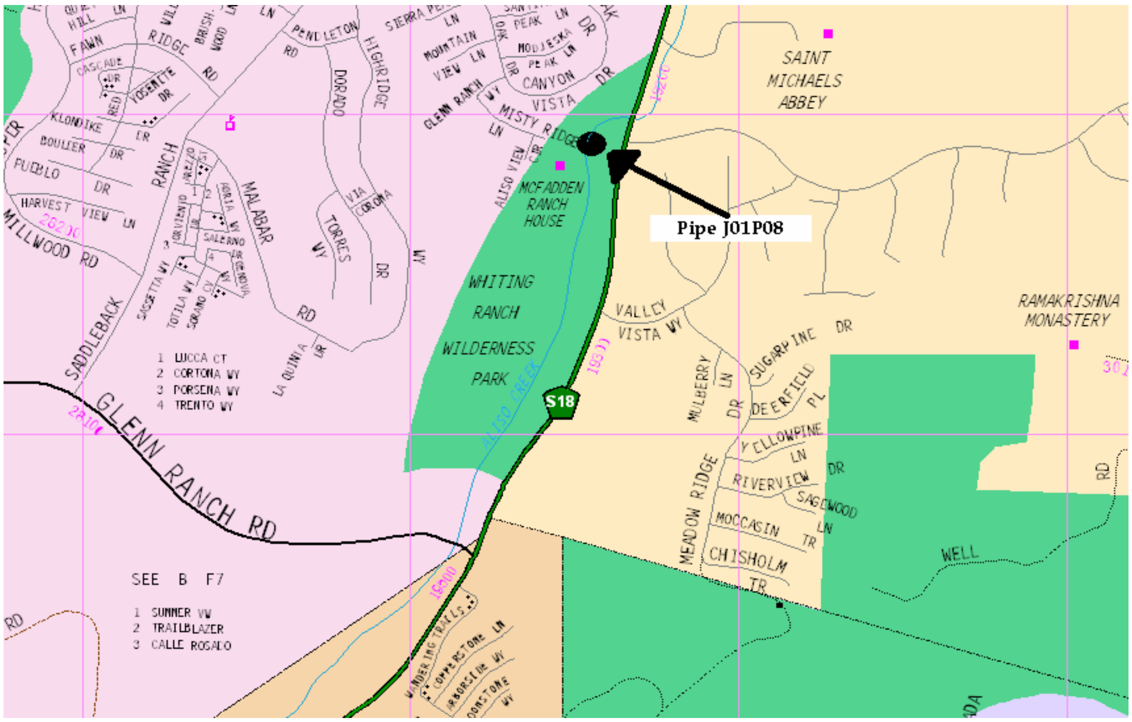


Figure 4: Detailed Map of Portola Hills Study Area

2.3.1.2 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 units are irrigated as part of the common landscaped areas. The backyards of housing units 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.

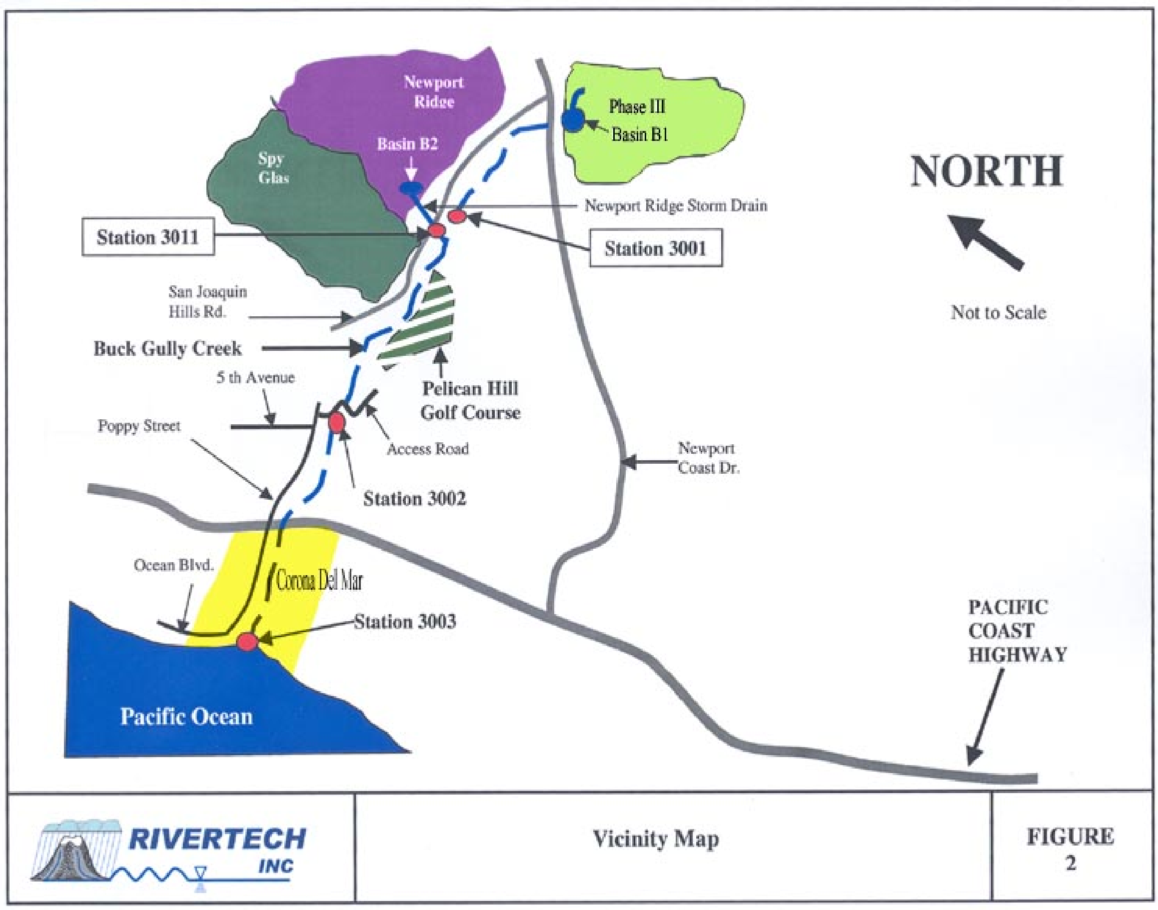


Figure 5: Schematic Map of Buck Gully Study Area

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 units 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 chapter describes the statistical analysis of water savings among customers who installed Smart Timers by evaluating water use before and after Smart Timer installations. Specific information includes (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.

Water consumption records for participants before and after Smart Timer installations were examined statistically. The hypothesis was that installation of Smart Timers would reduce the 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, about 1,222 Smart Timers qualified after data reduction for statistical evaluation in this study. This included 899 SFRs and 323 commercial Smart Timers. Various types of information required for statistical evaluation on these installations and associated meters were provided by MWDOC. These included type of account, historic water use, billing period, 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 reduce the variability in the water consumption data and 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 units where the Smart Timers were installed on or before April 2006 were considered for further analyses so that there were 12 months of post-installation usage data for comparison.
- Monthly consumption data for some months were reported as “0” for many accounts. These data were verified with MWDOC through the appropriate retail agencies for accuracy.

- Several commercial customers had multiple Smart Timers installed under one account. The combined water consumption data received for these customers were proportionally assigned to each Smart Timer based on the reported irrigated area for each of these timers.
- On some accounts, where the detailed individual Smart Timer information was not available, the total water consumption was assigned to one Smart Timer.
- 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 records were then processed in two different ways:
    i. First, for each meter, the average water use for a given month over the years for which data were provided before the Smart Timer installation was used to represent the pre-installation water use for that month. For example, if the Smart Timer was installed in January 2006, and water use data is available from January 2002, all the January water use data prior to 2006 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 2006 and January 2007 post data were available, an average was generated)
    ii. Secondly, a different data set was prepared in which only one year's (2005) water use data (rather than average of multiple years) was considered for pre-installation water use estimate, and one year's water use (2006) for post Smart Timer installation water use.

  The rationale for these two approaches is as follows: The estimated changes using the average of multiple- year data will reflect the Smart Timer installation effects as well as the non-Smart Timer effect that may occur over a period of few years. On the other hand, the changes in water use pattern using the one year pre- and post- intervention data will mostly reflect the effect of Smart Timer installation. However, limitations in using only a one year's pre- and post-intervention data include 1) a reduction in sample size, and 2) undue impact imparted by anomalies occurring in one year, on the estimated water use.
- After the above steps have been applied, only those meters that had at least three matched pre- and post- installation (months) data were considered for further data evaluation. A limited number of evaluations were also performed using the meters that had matching data for all the 12 months. 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.

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.

- Paired t-tests—and in some cases, Repeated Measures ANOVA tests, were performed to evaluate water conservation due to Smart Timer installation. 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 (reduction) in water use after installation, the savings were assigned to the Smart Timers. Cases where the water use increase was statistically significant were also noted and evaluated further.

- Paired t-tests by matching months of pre- and post-installation periods were performed to evaluate program-wide observed water savings. This was done using two approaches.

    - First, for each selected meter, paired t-tests were performed by matching its pre- and post-installation water use for the months. This analysis provided information on water conservation yielded by an individual Smart Timer.

    - Secondly, a month-by-month water use pattern was evaluated by matching pre- and post-installation water use for all the meters for the given month. This evaluation indicated if the installation of Smart Timers conserved water in a given month of the year.

- Next, regression analyses were performed to adjust the observed water savings to the differences in ET between pre- and post-installation periods. In this approach it is assumed that, while various weather and non-weather factors influenced the water use pattern during pre-installation period, water use was primarily influenced by ET after installation of Smart Timers. Hence, regression analyses were performed to establish the relationship between the monthly average ET and the water use during the post-installation period. This relationship was then used to predict the water use in the pre-installation period had the Smart Timer been in place, i.e., if the water use was controlled by prevailing Smart Timers. The difference between the actual water use in the pre-installation period and that predicted by the ET-based regression equation is considered the ET adjusted water savings.

- The water savings, broken down by individual Smart Timer manufacturer were determined by chi-square analyses, and a one way ANOVA in conjunction with a post hoc test (Scheffe). Furthermore, the mean water consumption (average of pre- and post-intervention use) by individual Smart Timer brands was determined by a Repeated Measures ANOVA procedure.

3.4 Results

Table 4 provides the summary of the nine brands of Smart Timers qualified for statistical analyses after the data reduction process. In summary, 899 residential and 323 commercial Smart Timers were used for paired t-test to determine water savings.

Table 4: Summary of Residential and Commercial Smart Timers Qualified for Various Statistical Evaluations

	Evaluations using average monthly use for pre- and post installation		Evaluations using 2005 (Pre) – and 2006 (Post) water use		Studies using meters with 12 pairs	
Brand/Manufacturer	**Residential**	**Commercial**	**Residential**	**Commercial**	**Residential**	**Commercial**
Brand A[1]	249	6	230	6	178	6
Brand B	297	41	289	37	260	25
Brand C[2]	19	13	19	12	13	10
Brand D[2]	7	1	6	0	5	1
Brand E	183	11	182	11	162	10
Brand G[2]	144	194	139	152	89	179
Brand H	0	52	0	32	0	32
Brand I	0	5	0	5	0	2
Total	**899**	**323**	**865**	**255**	**707**	**265**

1. This includes less than 10 percent of Smart Timers sold under a different name (Brand F) by the same manufacturer.
2. These meters have the same manufacturer but currently sold as separate Brands.

3.4.1 Program- wide Single Family Residence Estimate of Water Conservation

This section presents evaluation results for single-family residence (SFR) customers. Paired t-tests for each Smart Timer were performed by matching their monthly usage for pre- and post- intervention periods. Tests were performed using i) average of monthly water consumption for pre- and post- installation periods, and ii) using only one year pre-intervention data (2005) and one year post-intervention data (2006). The rationale for the two approaches is discussed in Section 3.3. Table 5 summarizes the results from these analyses. In general, three distinct trends were observed in SFRs retrofitted with Smart Timers. In nearly 20 to 33 % of the accounts, the water consumption significantly decreased (α=0.05) after installation of Smart Timers. In about 15 to 18 % of the cases the water consumption increased significantly after installation of Smart Timers. In nearly 50 to 65 % of the accounts water use did not change significantly upon installation of Smart Timers.

Table 5: Paired T-test Results for SFR Smart Timers

Description	Estimates based on Multiple years of Pre-installation Use	Estimates based on one year of pre (2005) and post (2006) water use
Total No. of Smart Timers	899	865
Number of Smart Timers where water use changed significantly[1]	460	307
Number of Timers where water use decreased significantly	294	174
Number of Accounts Water Use Increased Significantly after Smart Timer installation	166	133
Number of Accounts where water use did not change significantly after smart timer installation	439	558
Conservation based on timers where water use changed significantly[1] (gpd/Smart Timer)	35.7 (1.4 hcf/Timer/month)	47 (1.9 hcf/Timer/month)
Conservation based on Total Number of Timers (Program-wide Savings) (gpd/Smart Timer)	18.3 (0.7 hcf/Timer/month; 0.0045 gpd/sq.ft. irrigated area)	16.6 (0.67 hcf/Timer/month; 0.0041 gpd/sq.ft. irrigated area)

1. Change indicates either a significant increase or decrease at α = 0.05.

The number of Smart Timers that conserved water decreased from 294 (33 % of total) average of multiple water use data were used to 174 (20 % of total) when only one year of pre- and post-installation data were used in the analyses. The average water conserved by the Smart Timers that significantly changed the water use is higher when one year data was considered. However, the program wide water consumption was not significantly different between these two cases. On an average 18.3 and 16.6 hcf water were conserved per Smart Timer per month were conserved in these analyses.

The results presented in Table 5 illustrate that the installation and use of Smart Timers in both commercial and residential settings in the Orange County region corrected both the under- and over-irrigation of program participants. Those program participants who increased their water consumption after installation and use of their new Smart Timers were most likely under-irrigating their landscaped areas. Likewise, those program participants who decreased their water consumption after installation and use of their new Smart Timers were most likely over-irrigating their landscaped areas. Therefore, when used properly, the Smart Timer technology used in this study corrected the water consumption of the program participants to an appropriate level that decreased irrigation overspray (and runoff), reduced runoff pollutant levels, and increased water conservation.

Although, program-wide water use decreased during the post-installation period (18.3 hcf/Smart Timer/Month), the amount of water conserved was considerably lower than that reported in the R3 study (~41 hcf/Smart Timer/Month). In order to understand the lower water conservation observed, also to investigate the reasons for the increased water use (or no significantly different water use) observed with a significant number of Smart Timers, further analyses were performed to evaluate i) seasonal variation in water use patterns, ii) impact of ET on water use, iii) role of Smart Timer Brands on water conservation, and iv) differences in water use in Smart Timers installed by home owners and those installed professionally. The results of these analyses are presented in the following sections.

Seasonal (Monthly) impact on water use due to installation of Smart Timers was determined by performing paired t-tests using average water use for all the meters for pre- and post-installation periods. Prior to these analyses, the data distribution for each month was tested for normality, and if required, the data were log transformed prior to performing t-test. Furthermore, outlier data (> 4 standard deviation) were also eliminated.

Table 6 summarizes the results of t-test performed for pre- and post-installation water use for each calendar month. Results indicated that, based on t-test performed using observed monthly average use, installation of Smart Timers resulted in an average water savings of 0.81 HCF/month (about 20 gpd; 0.005 gpd/sq.ft. irrigated area). The net effect of the Smart Timer installation, based on one year pre- and post-intervention data, is a conservation of 0.52 HCF/month (13 gpd; 0.003 gpd/sq.ft. irrigated area). Subsequent paired t-test was performed using the 12 months pre-and post- intervention mean consumption data (i.e., column 2 and 3 of Table 5) indicated that the savings using average monthly usage was not significant at 95 percent confidence level. Relaxing the confidence level to 90 percent converts the findings to a significant difference which resulted in a savings estimate of 24 gpd. The conservation using one year of data was not statistically significant at 95 percent confidence level.

Table 6: Summary of Paired T-test to Estimate Pre- and Post-Intervention Monthly Mean Consumption in SFR.

	Analyses using average monthly data			Analyses using 2005 (pre) and 2006 (post intervention) monthly data		
Month	**Pre-Intervention (HCF)**	**Post-Intervention (HCF)**	**Is the difference significant (α=0.05)**	**Pre-Intervention (HCF)**	**Post-Intervention (HCF)**	**Is the difference significant (α=0.05)**
January	12.71	13.24	Yes	9.98	13.03	Yes
February	11.37	12.79	Yes	9.06	12.84	Yes
March	13.87	13.17	Yes	12.84	12.19	Yes
April	18.02	13.87	Yes	17.88	13.64	Yes
May	20.83	18.54	Yes	20.38	18.38	Yes
June	21.58	21.46	No	21.48	21.32	No
July	24.85	25.34	No	24.90	25.24	No
August	25.00	23.93	Yes	24.63	24.04	No
September	22.81	20.44	Yes	21.89	20.26	Yes
October	18.86	17.62	Yes	18.64	17.58	Yes
November	14.98	14.97	No	15.76	14.85	Yes
December	13.97	13.72	No	15.88	13.70	Yes
Average Monthly Use (HCF)	18.24	17.42	No	17.78	17.26	No

The data from Table 6 is plotted in Figure 5 to illustrate the months that have less, equal, and more water savings during the study period. Savings from the Smart Timer varied over the year. Note that the above differences in monthly use (and hence, the savings) were not normalized for factors such as consumer education, ET differences between the pre- and post-intervention periods, etc. In general, the installation of Smart Timers had the following effects:

- Conserved water for six to eight months of a year;
- Increased water use for two to three months of a year; and
- Did not alter water use during three to four months of a year.

Note that a post-retrofit increase in water use does not necessarily reflect a failure of the Smart Timers. It may well be the case instances where this occurrence involved under-watering in the pre-retrofit period.

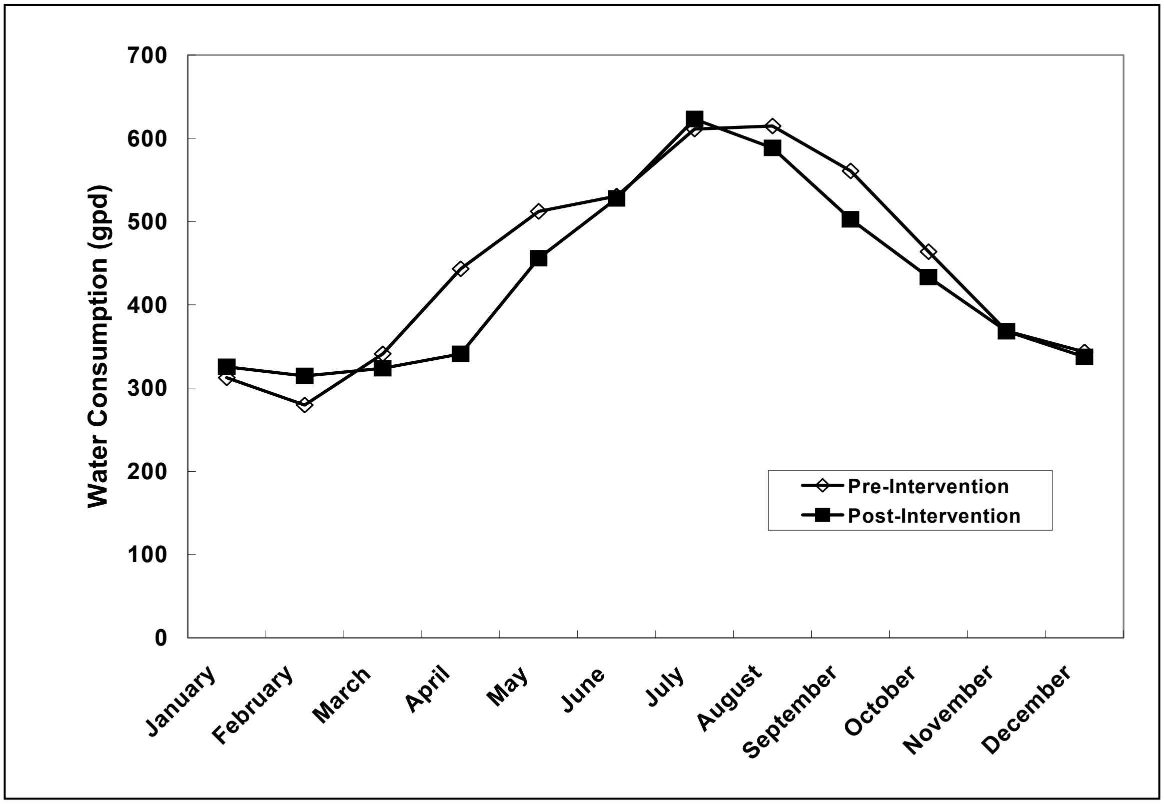


Figure 6: Mean Monthly Water Consumption in SFR During Pre- and Post- Smart Timer Installation Period. Estimated Data Based on Average Monthly Consumption.

Subsequently, in order to identify the effect of ET on water savings, regression analyses were performed for water use and ET in the following manner:

1. The ET values recorded in three IRWD monitoring stations (Coastal, Central and Foothill) were used in this evaluation.
2. Each smart-timer, based on its zip code, was assigned to one of the three monitoring stations. The zip codes assigned to each monitoring station are shown in Appendix B.
3. Relationship between water use and monthly average ET were established using regression analyses.

Figure 7 shows the ET in the three zones for years 2002 to 2006. In 2006 (post-intervention period), the ET in the Central and the Foothill regions were higher than the average ET of the previous years as well as the ET of 2005. The Coastal region ET for 2006 was slightly higher than that of 2005, and lower than the average ET of previous years.

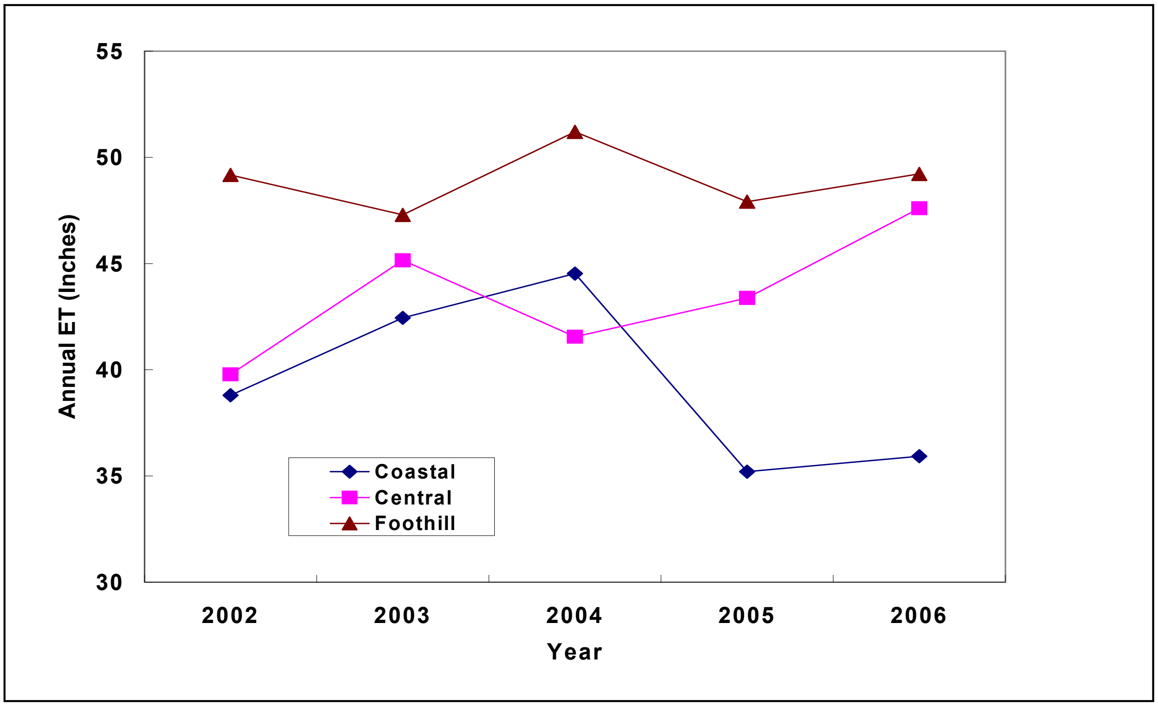


Figure 7: Annual ET Estimates for the Three IRWD Monitoring Stations

Figures 8 through 10 show the regression analyses for monthly water use with respect to ET for the pre and post-intervention periods for the coastal, central, and foothill zones, respectively. The average monthly consumption for all the meters with Smart Timers and monthly ET for pre- and post-intervention periods in SFRs was used for this regression analysis. In general, the "ET – water use" correlation co-efficients ($0.64 < R^2 < 0.82$) for all scenarios were good. Although on closer inspection, more variability is observed at monthly average ET values lower than 0.2 inches/day.

Student's t test statistical analyses (Zar, 1974) were performed to determine if the slopes obtained through regression analyses for pre- and post-installation years were different. As observed with analyses prior to adjustment for ET, the slopes of the regression analyses were not significantly different at a confidence level of 95 percent. The possible reasons for this trend may include the following:

- Water use patterns during pre-intervention periods were controlled by factors other than ET; and
- Landscape water uses were low during cold weather months even prior to Smart Timer installations.

However, the slopes for the Central ET zone were significantly different at a confidence level of 90 percent, and the slopes for the Coastal zone were significantly different at a confidence level of 80 percent.

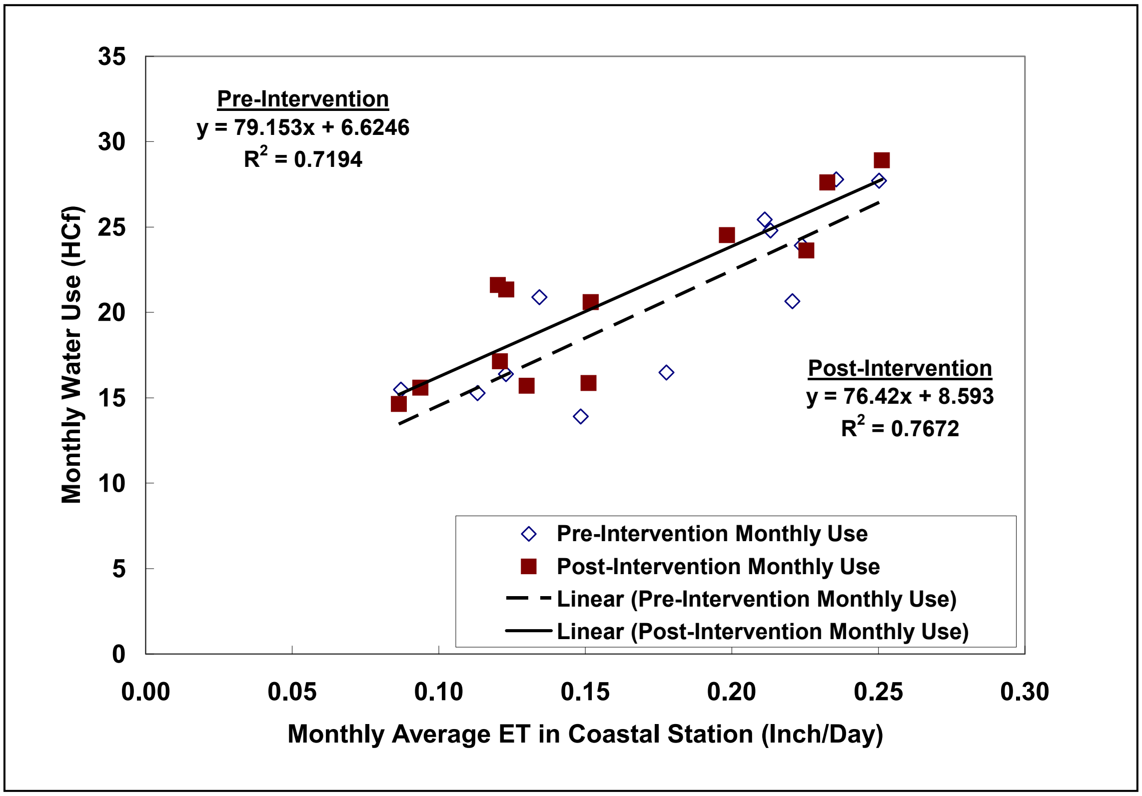


Figure 8: Regression Analyses for Water Use in Coastal Area SFRs with Respect to ET During Pre- and Post-installation Periods.

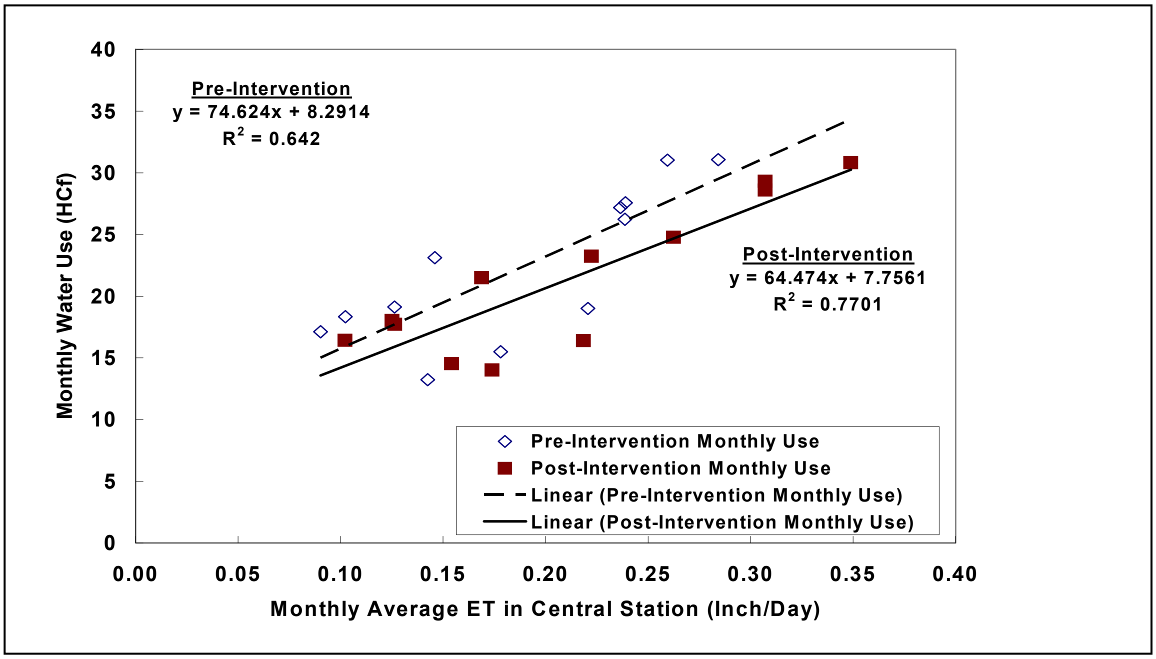


Figure 9: Regression Analyses for Water Use in Central Area SFRs with Respect to ET During Pre- and Post-installation Periods.

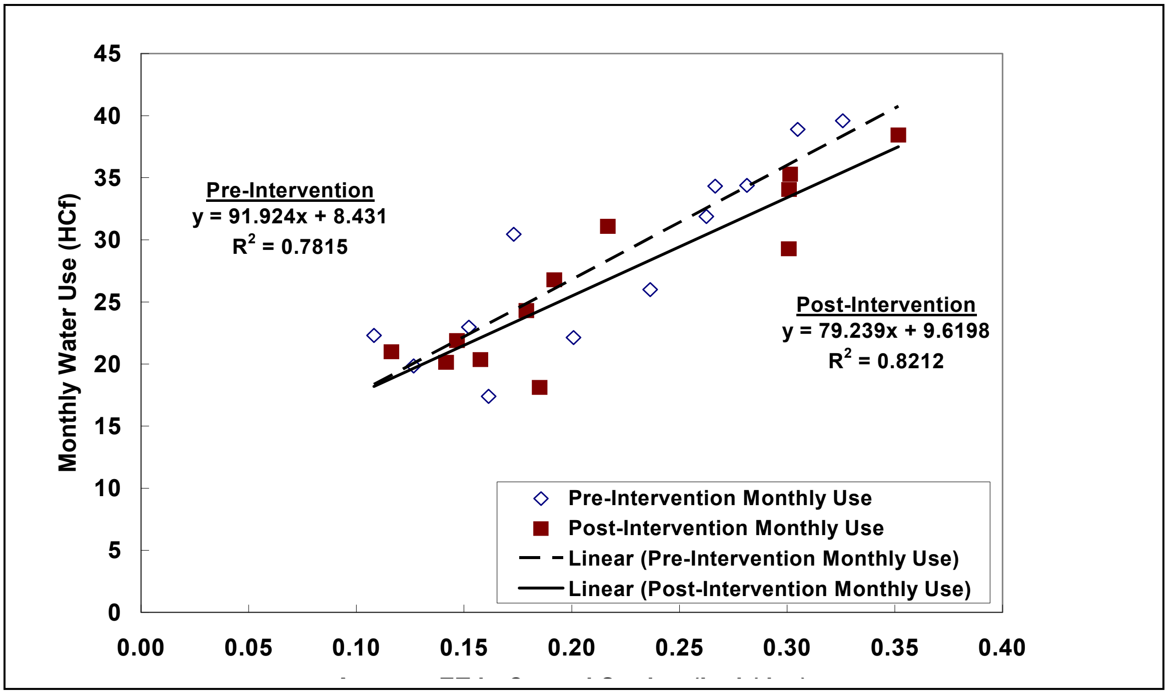


Figure 10: Regression Analyses for Water Use in Foothill Area SFRs with Respect to ET During Pre- and Post-installation Periods.

3.4.2 Summary of Residential Water Savings

Although these results indicate that installation of Smart Timers resulted in water conservation, the amount of water conserved (~ 18.3 hcf) is lower than that estimated (41 gpd) in the R3 study. Furthermore, results indicated that installation Smart Timers decreased water use in only 33% of the SFRs. In 15 to 20% of the cases, water use increased significantly after installation of Smart Timers. Water use did not change in about 50% of the SFRs after installation of the Smart Timers. Subsequent analyses on monthly water use trends indicated that, installation of Smart Timers yielded program-wide savings for six to eight months. Water use increased significantly in two to three months. No changes in water use were observed in about three to four months. The “no significant water use” observed for ~ 50% of the Smart Timers (Table 5) was probably due to such variations in monthly water use. It is also be possible that the early adopting customers of Smart Timer technology may have already been efficient with water use, and hence, have less savings potential using this technology. Subsequently, regression analyses were performed to evaluate the effect of ET on changes in water use trends. The ET vs water use data correlated well for both the pre- and post-intervention periods for all the three ET zones (Coastal, Central, and Foothill area; R2 = 0.64 to 0.82) considered in this study. However, the slopes for the pre- and post-installation periods were not statistically significant at $\alpha = 0.05$. Results using a lower level of statistical significance (α to 0.1 to 0.2), indicated significant differences between the two slopes (i.e. lower ET adjusted water use during post-installation period).

3.4.3 Estimation of Water Conservation in Commercial Sites

There were 323 Smart Timers in commercial sites qualified for analyses using monthly average water use, and 254 units qualified for evaluation using only one year pre- (2005) and post- (2006) installation data. The results from the paired t-tests performed for each Smart Timer are summarized in Table 7. Tests were performed using i) average of monthly water consumption for pre- and post- installation periods. The trends observed for the commercial sites were slightly different than those observed for SFR installations. In general, the results indicated a larger amount of water conservation when multiple year pre- and post-installation data were used, than when only one year of pre- and post-installation data were used for the paired t-test analyses. Irrigation water use significantly decreased (α=0.05) after installation of Smart Timers in nearly 15 to 30 % of the sites. In about 10 to 20 % of the cases the water consumption increased significantly after installation of Smart Timers. In nearly 60 % of the accounts water use did not change significantly upon installation of Smart Timers. Estimates based on only those Smart Timers that significantly reduced water consumption yielded an average conservation of about 1300 to 1400 gpd (52 to 56.6 hcf) per Smart Timer per month. Estimates based on all the Smart Timers that significantly changed water use (increased or decreased) yielded a conservation of 460 gpd (using multi-year data) or increase in water use of 53 gpd (using only one year data). A program-wide water use estimates indicated a conservation of 190 gpd (7.6 hcf) per Smart Timer per month (using multi-year data) or an increase in water use of 19.9 gpd (0.8 hcf) per Smart Timer per month (using only one year of per-and post-installation data). Possible under irrigation in year 2005 due to excessive (nearly double) rain fall may have contributed to the results observed (excess water use after Smart Timer installation) using only one year of pre- and post-installation data.

Table 7: Paired T-test Results for each Smart Timers for Commercial Facilities

Description	Estimates based on Multiple years of Pre-installation Use	Estimates based on one year of pre (2005) and post (2006) water use
Total No. of Timers	323	254
Number of Timers yielded Significant difference	134	95
Number of Timers that Significantly Reduced Water Use	98	41
Number of Accounts Water Use Increased Significantly After Smart Timer Installation	36	54
Number of Accounts Water Use Did not Change Significantly After Smart Timer Installation	189	159
Conservation based on Timers where water use reduced significantly (gpd)	1295 (52 hcf/Timer/month)	1410 (56.5 hcf/Timer/month)
Conservation based on Timers where water use changed (increased/decreased) significantly (gpd)	460 (18.5 hcf/Timer/month)	-53 (-2.1 hcf/Timer/month)
Conservation based on Total Number of Timers (Program-wide Savings) (gpd)	190 (7.6 hcf/Timer/month;0.004 gpd/sq.ft irrigated area)	-19.9 (-0.8 hcf/Timer/month; 0.0004 gpd/sq.ft irrigated area)

As with the SFR Smart Timers, further analyses were performed to evaluate the seasonal variation and the impact of ET on the water use trends observed. Evaluations using monthly average consumption indicated that installation of Smart Timers resulted in conservation of 9.5 HCF/month (about 234 gpd; 0.005 gpd/sq.ft. irrigated area). Paired t-test on the monthly mean (i.e., column 2 & 3 of Table 8) indicated that this difference is statistically significant (α=0.05). However, the net effect of the Smart Timer installation, based upon one year of pre- and post-intervention data showed an increase in water consumption (about 7 Hcf/month; 0.0035 gpd/sq.ft. irrigated area; data not shown), although statistical analyses indicated that this difference is not significant at the 95 percent confidence level. Figure 11 summarizes the water savings in different months due to Smart Timer installation in commercial units.

Table 8: Summary of Paired T-test to Estimate Pre- and Post-Intervention Monthly Mean Consumption in Commercial Facilities

	Analyses using average monthly data			Analyses using 2005 (pre) and 2006 (post intervention) monthly data		
Month	**Pre-Intervention (HCF)**	**Post-Intervention (HCF)**	**Is the difference significant (α=0.05)**	**Pre-Intervention (HCF)**	**Post-Intervention (HCF)**	**Is the difference significant (α=0.05)**
January	52.44	64.47	Yes	28.88	78.74	Yes
February	46.04	50.86	Yes	20.89	48.17	Yes
March	71.77	46.81	Yes	50.70	40.08	Yes
April	98.48	67.11	Yes	79.22	59.41	Yes
May	135.99	114.81	Yes	116.57	111.62	No
June	146.04	133.50	Yes	138.35	135.78	No
July	165.90	156.04	Yes	160.16	168.04	No
August	168.58	147.13	Yes	145.37	149.31	No
September	139.88	120.89	Yes	107.75	108.78	No
October	106.69	104.06	No	84.54	99.61	Yes
November	76.26	80.99	No	66.52	73.49	No
December	62.81	69.92	Yes	65.06	75.48	Yes
Average Monthly Use (HCF)	105.91	96.38	Yes	88.67	95.71	No
Net Conservation	9.5 Hcf (234 gpd)			Not significant @ α=0.05 or 0.1		

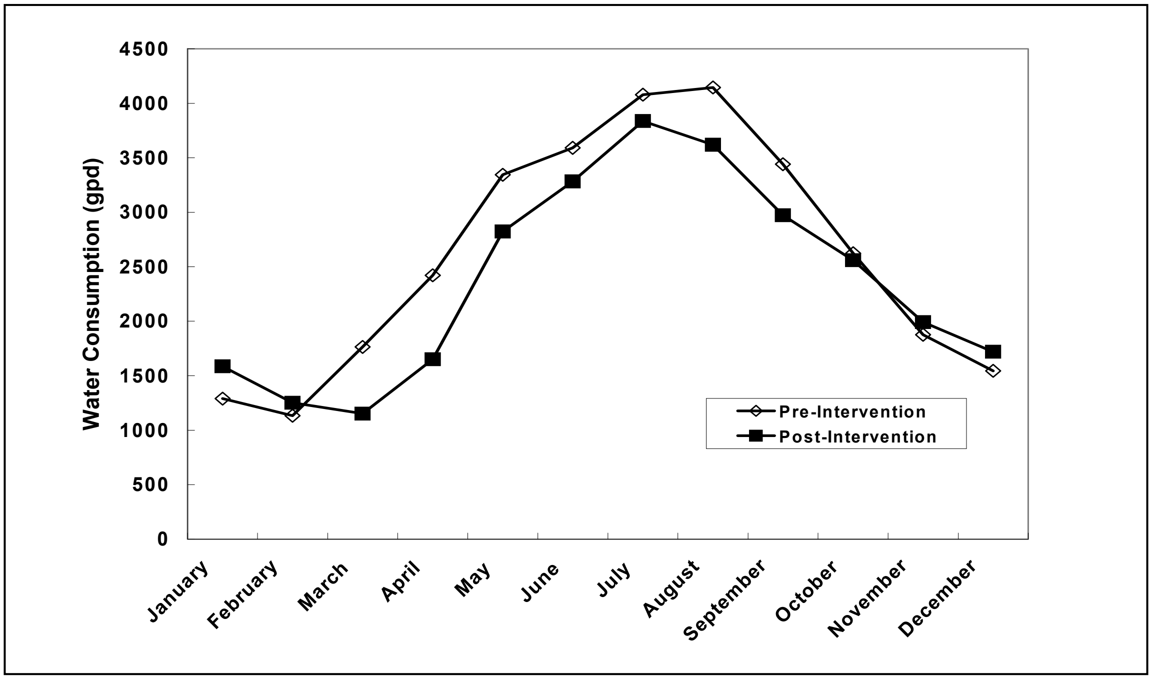


Figure 11: Mean Monthly Water Consumption in Commercial Units During Pre- and Post- Smart Timer Installation Period. Estimated Data Based on Average Monthly Consumption.

Subsequently, the measured water use data were adjusted for differences in ET during pre- and post-intervention periods. Figures 12 through 14 show the regression analyses for monthly water consumption with respect to ET for the pre- and post-intervention periods, using average monthly consumption and monthly ET for pre- and post-intervention periods in commercial area. In general, the "ET – water use" correlation co-efficient (R^2) for all scenarios was good. Upon closer inspection, there was more variability at average monthly ET values lower than 0.25 inch/day.

Student's t test statistical analyses (Zar, 1974) were performed to determine if the slopes obtained through regression analyses for pre- and post-installation years were different. As observed with analyses prior to adjustment for ET, the slopes of the regression analyses were not significantly different at a confidence level of 95 percent. Many become significant only if the confidence level is lowered to 80 to 90percent. The possible reasons for this trend may include the following:

- Water use patterns during pre-intervention periods were controlled by factors other than ET; and
- Landscape water uses were low during cold weather months even prior to Smart Timer installations.
- Heavy rainfall in 2005 resulting in lower irrigation water use

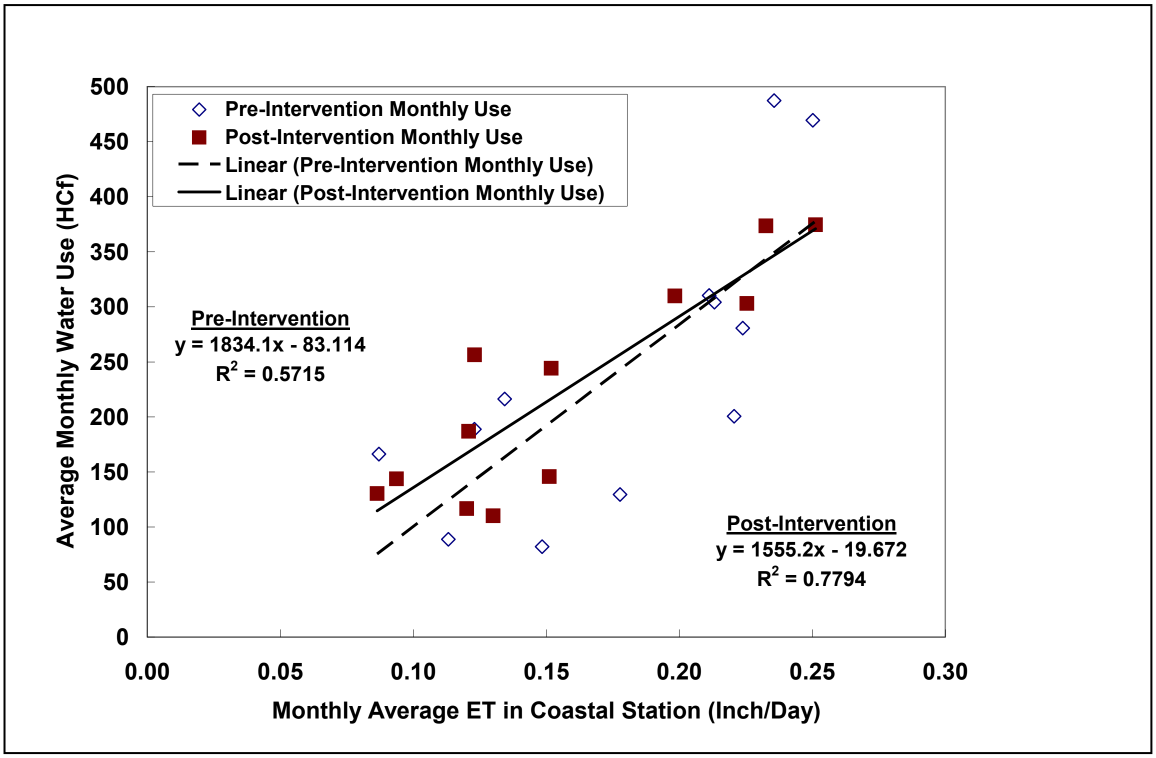


Figure 12: Regression Analyses for Water Use in Coastal Area Commercial Facilities with Respect to ET During Pre- and Post-installation Periods.

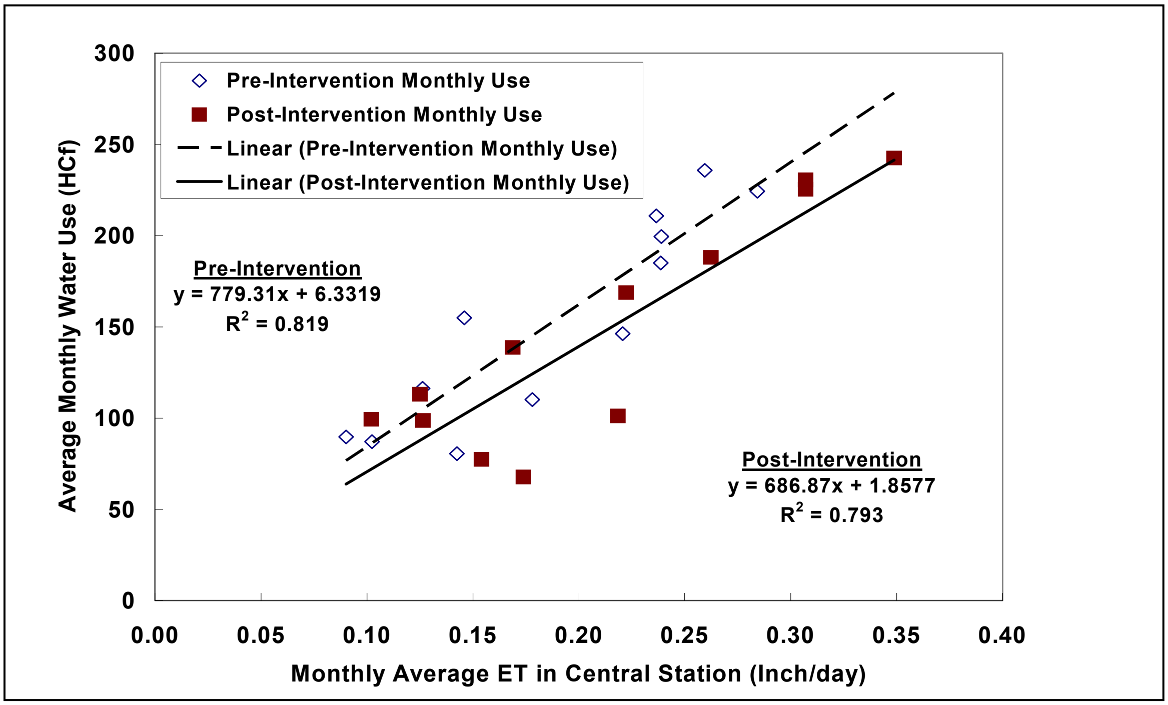


Figure 13: Regression Analyses for Water Use in Central Area Commercial Facilities with Respect to ET During Pre- and Post-installation Periods.

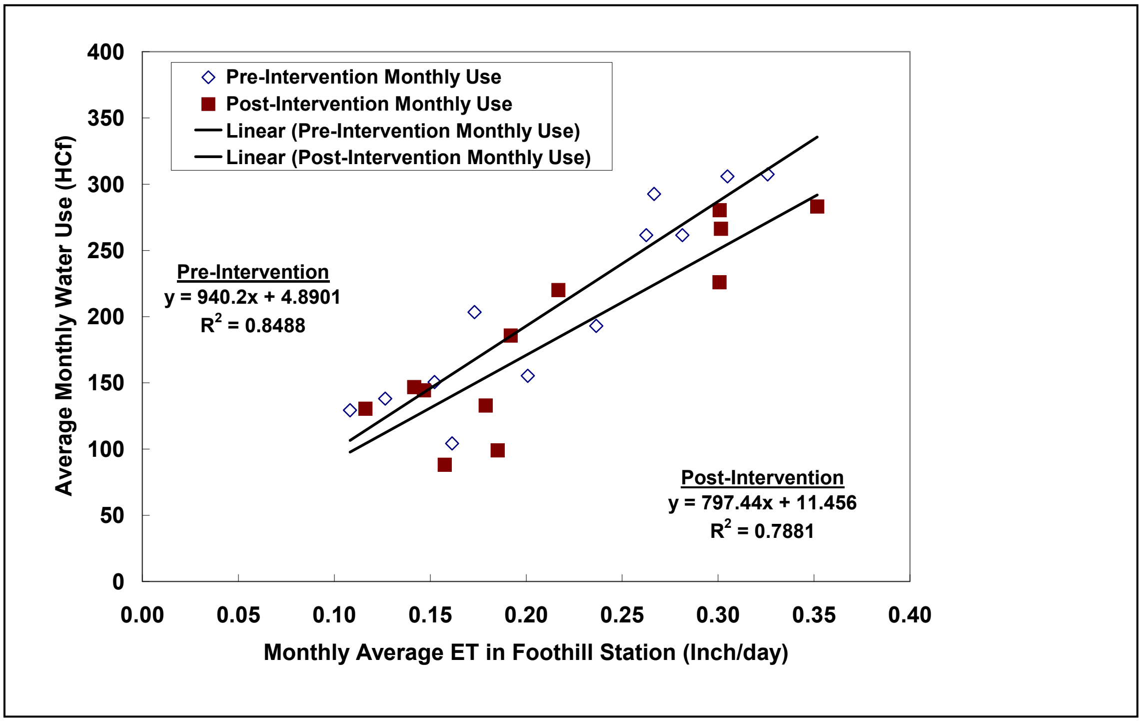


Figure 14: Regression Analyses for Water Use in Foothill Area Commercial Facilities with Respect to ET During Pre- and Post-installation Periods.

3.4.4 Summary of Commercial Water Savings

Analyses using multiple year data indicated that installation of Smart Timers resulted in water conservation of about 190 gpd (7.65 hcf per month) per Smart Timer. Analyses using only one year of pre- and post-installation data indicated a program-wide net increase in water use. This could be due to lower irrigation requirement in year 2005 due to excessive rainfall. Furthermore, results indicated that installation Smart Timers decreased water use in only 15 to 30% of the installations. In 10 to 20% of the cases, water use increased significantly after installation of Smart Timers. Water use did not change in about 60% of the accounts after installation of the Smart Timers. Subsequent analyses on monthly water use trends indicated that water use increased significantly in three to four months after installation of Smart Timers. No changes in water use were observed in two to six months. Water use decreased in two to seven months after Smart Timer installation. Subsequently, regression analyses were performed to evaluate the effect ET on changes in water use trends. The ET vs water use data correlated well for both the pre- and post-intervention periods for all the three ET zones (Coastal, Central, and Foothill area; R2 = 0.57 to 0.85) considered in this study. However, the slopes for the pre- and post-installation periods were not statistically significant at $\alpha = 0.05$. Relaxing the level of significance (α to 0.1 to 0.2), resulted in significant differences between the two slopes (i.e. lower ET adjusted water use during post-installation period).

3.4.5 Effect of Smart Timer Brand (Manufacturer) on SFR Water Conservation

The program-wide evaluation of Smart Timer performance presented in Sections 3.3.1 and 3.3.2 indicated that despite the overall water conservation observed due to Smart Timer installation, only about 33 percent of the timers significantly reduced the water use. Water consumption increased in approximately 18 percent of the SFR installed with Smart Timers. Further analyses of the performance of individual brands of Smart Timers on water reduction also were evaluated.

The effect of Smart Timer brands on water savings was determined by i) paired t-test of for pre- and post-intervention water consumption for each manufacturer, ii) chi-square test to evaluate relative performance of individual timers over the study period, and iii) a one way ANOVA test in conjunction with a post hoc (Scheffe) test.

Table 9 shows the summary of paired t-test for each manufacturer type. A small number (< 10 percent) of Brand A Smart Timers, that were sold as Brand F were not included in these analyses. Results indicated that water consumption significantly reduced in SFR units installed with three brands (Brand A, Brand B, and Brand C) of Smart Timers. Water use did not change significantly in SFRs installed with two brands (Brand D, Brand G). Note that, Brand C, D & G have the same manufacturer and reported have same ET response mechanism. However, water conservation using Brand C was different than Brands D and G. This may be due to fewer number of (7) Brand C Timers installed in the study area. However, water consumption significantly increased in the SFR units installed with one brand (Brand E) of Smart Timer. The three brands where water consumption significantly decreased, together (weighted by total number of installations), conserved 1.81 HCF/Smart Timer/month (about 45 gpd). On the other hand, water use increased by 1.31 HCF/month (32 gpd) in SFRs installed with Brand E. Figures 17 and 18 show the pre- and post-installation water use by Brands A and E, respectively. For the most part the pre-intervention data for the Brand A was almost always higher than the post, indicating a consistent savings. This was not the case in Figure 10 for the Brand E.

Although water use appeared to have increased in SFRs installed with Smart Timer brand E, the reasons for this observation must be further investigated. For example, ET adjusted water use appear to increase in Coastal area (Figure 8). If Brand E is predominantly installed in Coastal area, the increase in water use may be due to factors dictating increased water use (e.g. existing under irrigation, aggressive non-Smart Timer water conservation programs) due to ET adjustment in Coastal area.

Table 9: Mean Change Pre-and Post-Intervention Water Use in HCF for Various Smart Timers Brands at SFRs.

	Brand A	Brand B	Brand C	Brand D	Brand E	Brand G
No of smart Timers	224	292	19	7	182	141
January	-0.28	0.36	0.89	-0.15	-1.60*	-2.71*
February	-0.74*	-0.69*	-0.60	-0.87	-2.50*	-3.32*
March	0.95*	0.83*	5.15*	1.88	-0.21	0.50
April	4.52*	5.32*	8.04*	1.26	2.92*	2.34*
May	4.03*	3.63*	2.88	3.02	-0.51	-0.62
June	1.80*	1.29*	-0.30	-1.72	-3.00	-1.56
July	1.89*	0.28	2.68	-1.33	-4.27*	-1.97*
August	2.54*	1.83*	7.19*	-2.08	-1.99*	0.22
September	3.13*	2.96*	9.33*	-0.79	-0.62	3.02*
October	2.17*	2.32*	6.28*	-2.46	-0.94*	-0.67
November	0.98*	0.16	4.40*	-2.87	-1.76*	0.02
December	0.90*	0.98*	1.45	-3.67	-1.09*	-1.01
Average Annual Savings (HCF)	21.89*	19.28*	47.4*	-9.76	-15.58*	-5.76
Savings (gpd/sq.ft irrigated area)	0.013	0.012	0.02	-0.009	-0.011	-0.001

* = Significantly different

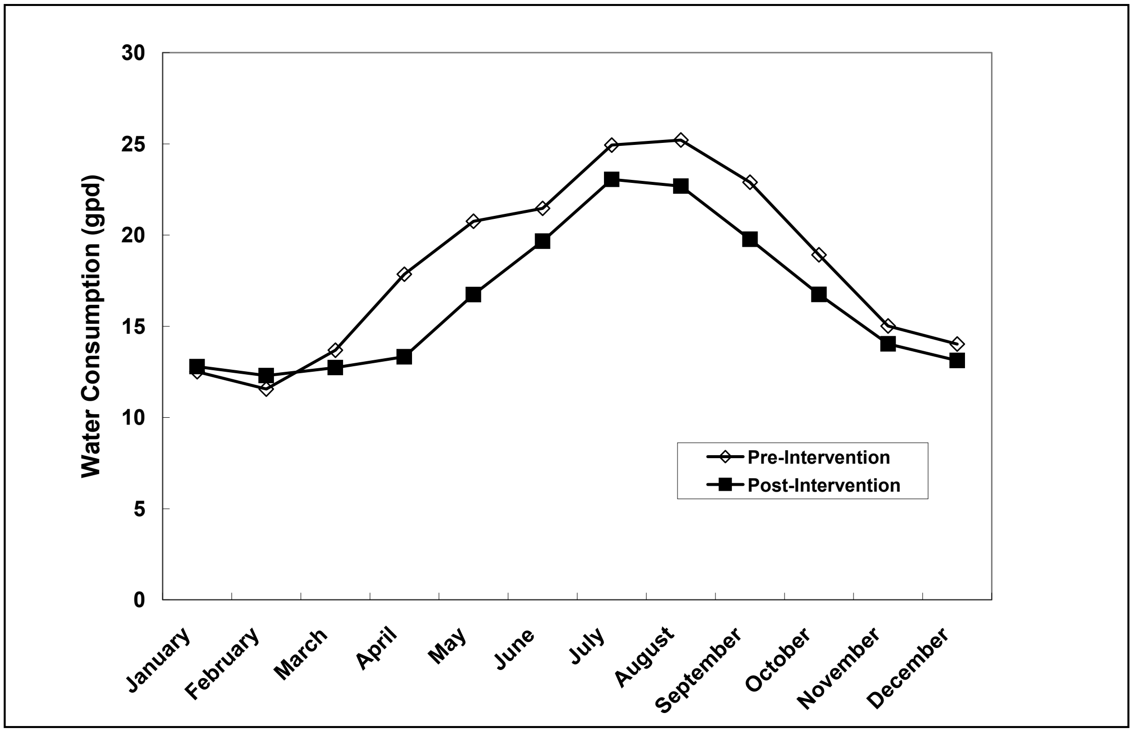


Figure 15: Mean Monthly Water Consumption in SFR During Pre- and Post- Smart Timer Installation Period Using Brand A Smart Timers.

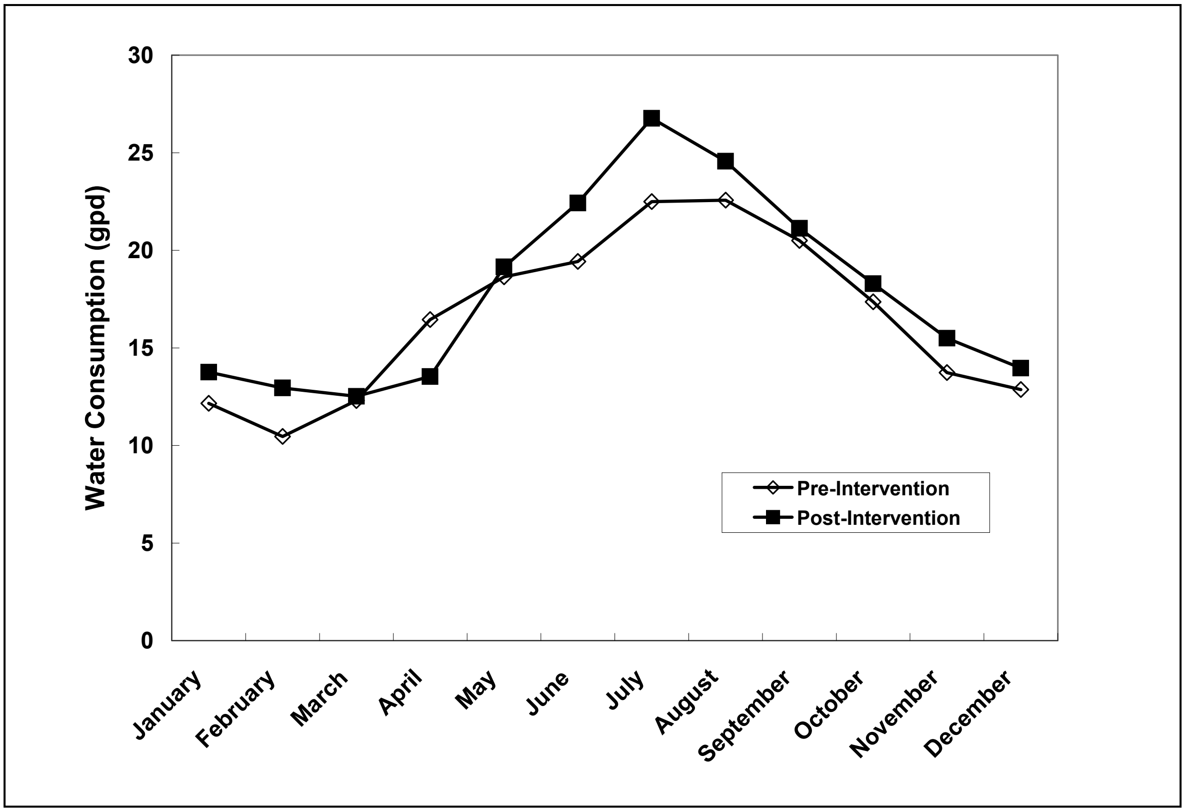


Figure 16: 4Mean Monthly Water Consumption in SFR During Pre- and Post- Smart Timer Installation Period Using Brand E Smart Timers.

These findings are further supported by the analyses of the performance of individual timers over the study period. Table 10 lists these timers by brand. In summary, evaluation of individual Smart Timers indicated that less than 50 percent of the Smart Timers for any brand resulted in significant water reduction. For five brands, about 30 to 50 percent of the Smart Timers significantly reduced water use. The brands that performed poorly include Brand D (14 percent) and Brand E (17 percent) of these controllers yielded significant water reduction.

Subsequently, chi-square tests were performed to evaluate relative performance of each brand. The results of this study are presented in Table 11. Results indicated that the performance of Brand E timer was significantly different (poorer, $\alpha = 0.05$) than all the other brands, except Brand D. More details of these test results are provided in Appendix A. However, month to month performance of various brands using Repeated Measures ANOVA test yielded mixed results (Appendix A). Therefore, further investigations are required to identify the factors responsible for the results observed with respect to each brand.

Table 10: Summary of Statistical Evaluation of Water Use Reduction (HFC) by Various Smart Timers Brands at SFRs

Brand	Total No of Timers	Smart Timers that conserved water	Meters where water use increased	No significant difference	Smart Timers where water use decreased (%)	Meters where water use increased (%)
Brand A	232	87	24	121	37.5	10.3
Brand B	297	113	38	146	38.0	12.8
Brand C	19	8	2	9	42.1	10.5
Brand D	7	1	2	4	14.3	28.6
Brand E	183	31	57	95	16.9	31.1
Brand G	144	46	42	56	31.9	29.2

Table 11: Summary of Chi-Square Test Results Performed to Compare Relative Performance of Each Brand of Smart Timers

Brand	Brand A	Brand B	Brand C	Brand D	Brand E	Brand G
Brand A	-					
Brand B	No	-				
Brand C	No	No	-			
Brand D	No	No	No	-		
Brand E	**Yes**	**Yes**	**Yes**	No	-	
Brand G	*No*	*No*	*No*	*No*	***Yes***	-

The one way ANOVA in conjunction with a post hoc test (Scheffe) test was also performed to compare differences in water conservation among different brands. The results are generally consistent with the chi square test. Brands A, B, C and G conserved significantly (p=0.05) more water than Brand E. Details of the ANOVA/Scheffe tests are presented in Appendix A.

Finally, repeated measures ANOVA test was performed to evaluate if the differences in the conservation trends observed with various brands were due to the differences in the average water delivered (i.e. number of valves activating the Smart Timers). In general, comparison of mean water use by various brands in SFR installations for each month indicated that the average water delivered by Brand G was lower than that delivered by Brands A, B and E in some of the months. No significant differences in the average water delivered were observed among any of the other brands. This suggested that the increase in water use by Brand E was likely not due to differences in the average volume of water delivered by this brand. Appendix A contains more details of the results.

3.4.6 Effect of Smart Timer Brand on Commercial Water Conservation

Evaluation of individual Smart Timer performance indicated that only about 31 percent of the 325 timers yielded significant water use reductions. Water consumption increased in nearly 11 percent of the Commercial units retrofitted with Smart Timers. Table 12 below provides the details of this evaluation for different brands of timers.

Approximately 90 percent of the installed base was made up by three brands, Brand G (60 percent), Brand H (16 percent) and Brand B (12.5 percent). Hence, these three brands were selected for the chi square analyses to evaluate the effect of Smart Timer brand on Commercial water conservation. Among these three brands, the highest percentage of Smart Timers showing significantly different water savings was Brand B (56 percent), followed by Brand H (35 percent), and Brand G (24 percent). Only Brand B was shown to be statistically significantly better by the Chi square test summarized in Table 13.

The ANOVA/Scheffe tests did not yield any significant differences in water conservation among these three major brands. Repeated measures ANOVA for determination of mean water use by each brand indicated that, Brand B had a higher water use than Brands G and/or H from November to February. However, its water use is not significantly different in rest of the months. Brand H had a higher water use than Brand G during most of the year. However, chi-square test data did not indicate any differences in performance between these two brands. Hence, additional investigations are required to identify the factors responsible for the differences observed with various brands.

Table 12: Summary of Statistical Evaluation of Water Use Reduction by Various Brands of Smart Timers in Commercial Units

Brand	Total No of Timers	Smart Timers that conserved water	Meters where water use increased	No significant difference	Meters where water use decreased (%)	Meters where water use increased (%)
Brand A	6	4	1	1	66.7	16.7
Brand B	41	23	3	15	56.1	7.3
Brand C	13	7	0	6	53.8	0.0
Brand D	1	0	0	1	0.0	0.0
Brand E	11	1	1	9	9.1	9.1
Brand G	194	47	24	123	24.2	12.4
Brand H	52	17	8	27	32.7	51.9
Brand I	5	1	1	3	20	20

Table 13: Summary of Chi-Square Test Results Performed to Compare Relative Performance of Each Brand of Smart Timers in Commercial Units

Brand	Brand B	Brand G	Brand H
Brand B	-		
Brand G	**Yes**	-	
Brand H	**Yes**	No	-

3.4.7 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 14 summarizes this information and indicates that 333 units were installed by homeowners and about 566 units were installed professionally. Previously developed paired t-test data using pre- and post-intervention consumption indicated that 124 timers installed by homeowners and 170 timers installed professionally had significant water savings. A chi-square test was performed including all the Smart Timers in the City 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 14: Performance of Program-wide Smart Timers Installed by homeowners and Professionally Installed

	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 15 and 16 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 15: 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.	
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 16: Runoff Data Collection Period

Station	Pre-Retrofit Runoff: Period Monitored	Pre-Retrofit Runoff: Frequency of Recording	Post-Retrofit Runoff: Period Monitored	Post-Retrofit Runoff: 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 meters. 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 17). The flow monitoring period and frequency of flow recording are shown in Table 18. 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:
    i. 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.,

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

       The ET data for evapotranspiration adjustment was received from IRWD monitoring stations.
    ii. The daily average runoff data in the two stations were normalized to "unit irrigated area" prior to analyses.
    iii. 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.

iv. 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 17 explains this approach.

Table 17: 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 18 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 18 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 18: 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/meter/day

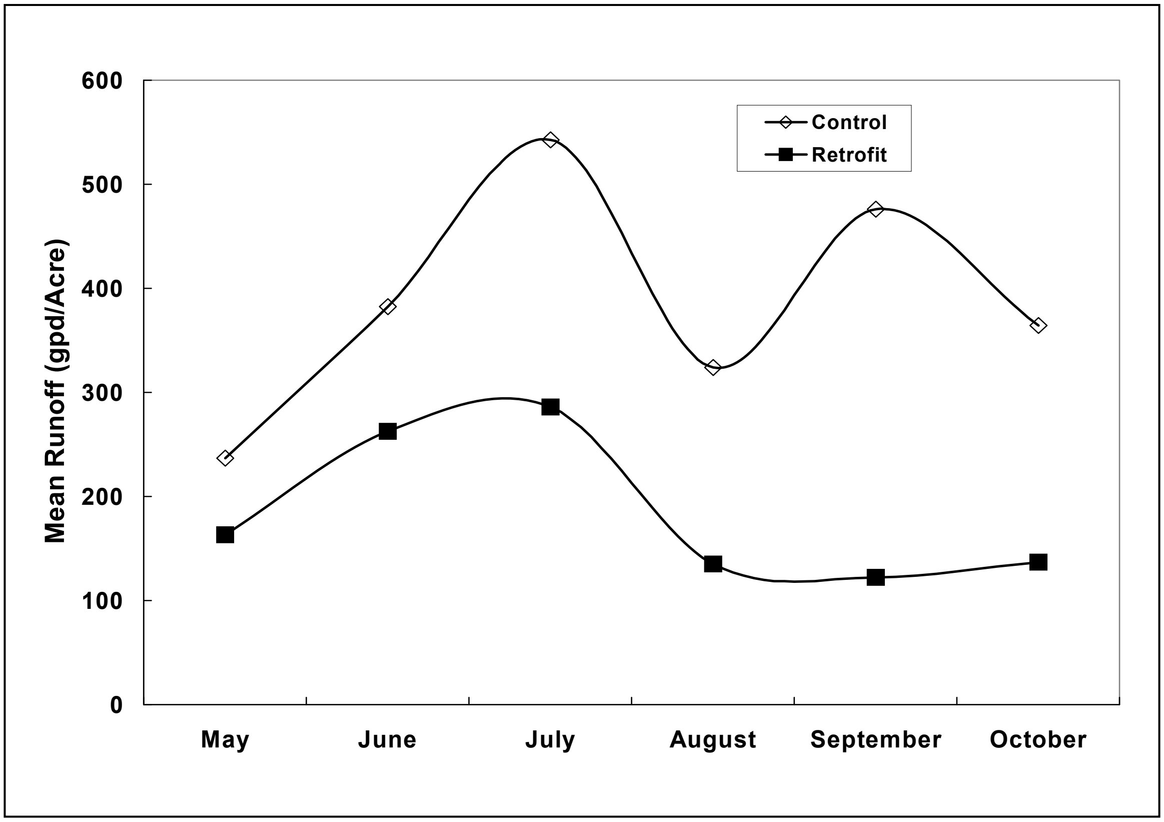


Figure 17: The Area Weighed Runoff in Buck Gully Control and Retrofitted Area in 2006

Figure 19 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 20 and Table 19 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 20) 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.

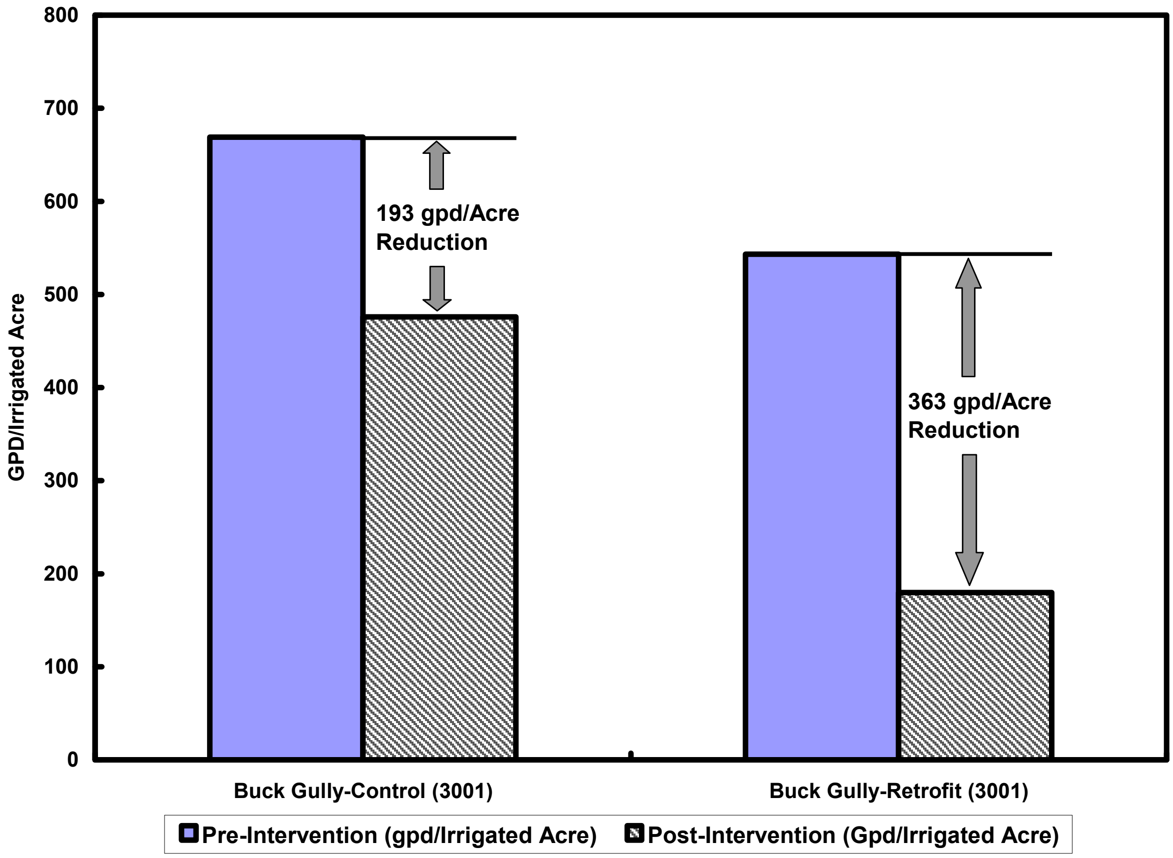


Figure 18: Runoff Reduction in Buck Gully Control and Retrofit Areas Between Pre- and Post-Intervention Periods

Table 19: 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 20: Summary of Paired T-test Result for Relative Runoff Reduction in Pre- and Post- Intervention Periods for Buck Gully Control and Retrofit Areas

	Runoff reduction between 2003 and 2006 (gpd/Acre)						
Station/ Flow Type	Control Station (3001)	Retrofit Station (3011)	Sample Size (N)	T – stat	t-critical (2-tail)	Is Runoff Reduction in Retrofit area significant?	Relative Runoff Reduction in Retrofit Area (gpd/Acre)
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 21 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).

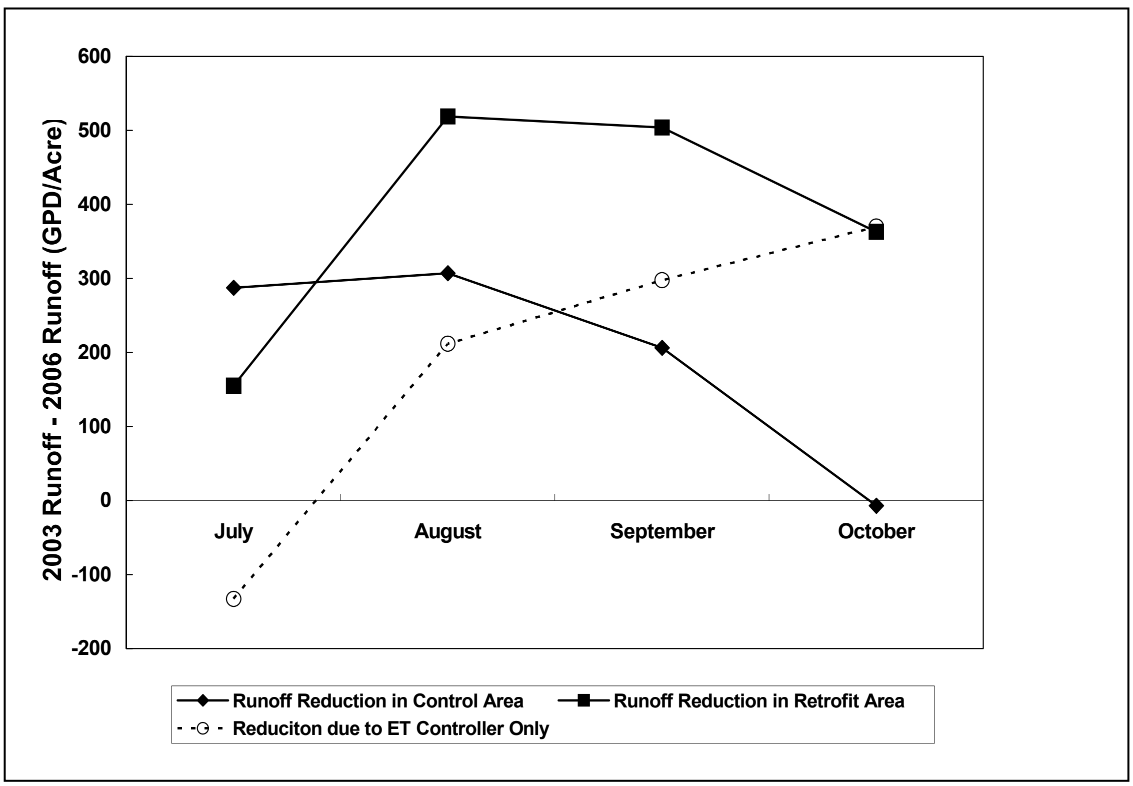


Figure 19: Runoff Reduction Between Pre- and Post-Intervention Months in Buck Gully

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 21 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 21: 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 22 and 23 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.

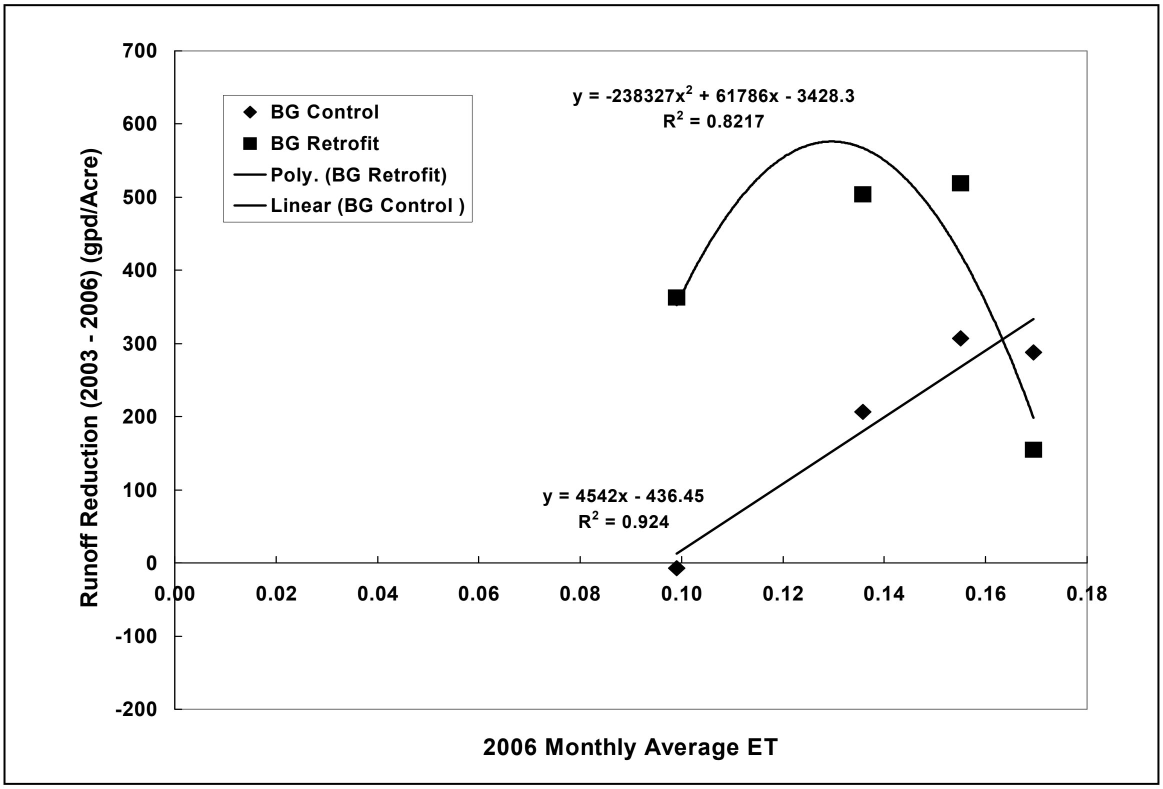


Figure 20: Regression Analyses for Buck Gully Control and Retrofit Area Runoff

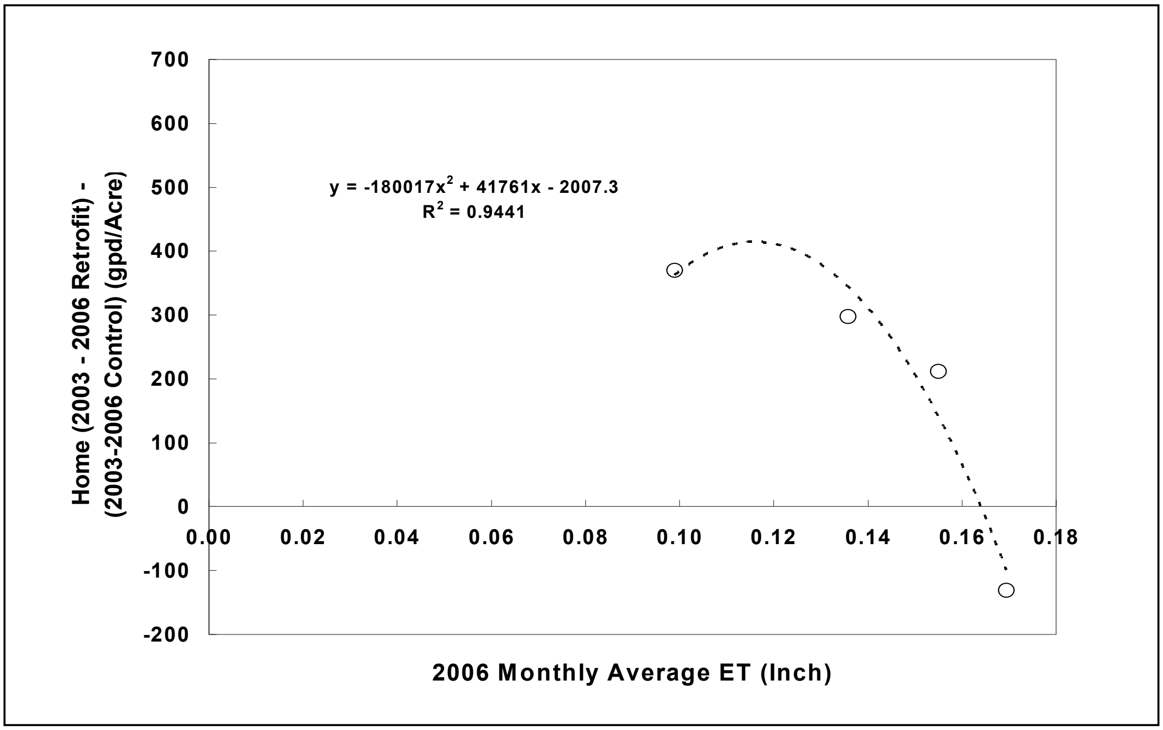


Figure 21: Regression Analyses for Selective Runoff Reduction Due to Smart Timer Installation in Retrofit Area

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

Table 22 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 24 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 23). This may be due to water use patterns in the common irrigated areas of Portola Hills.

Table 22: 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

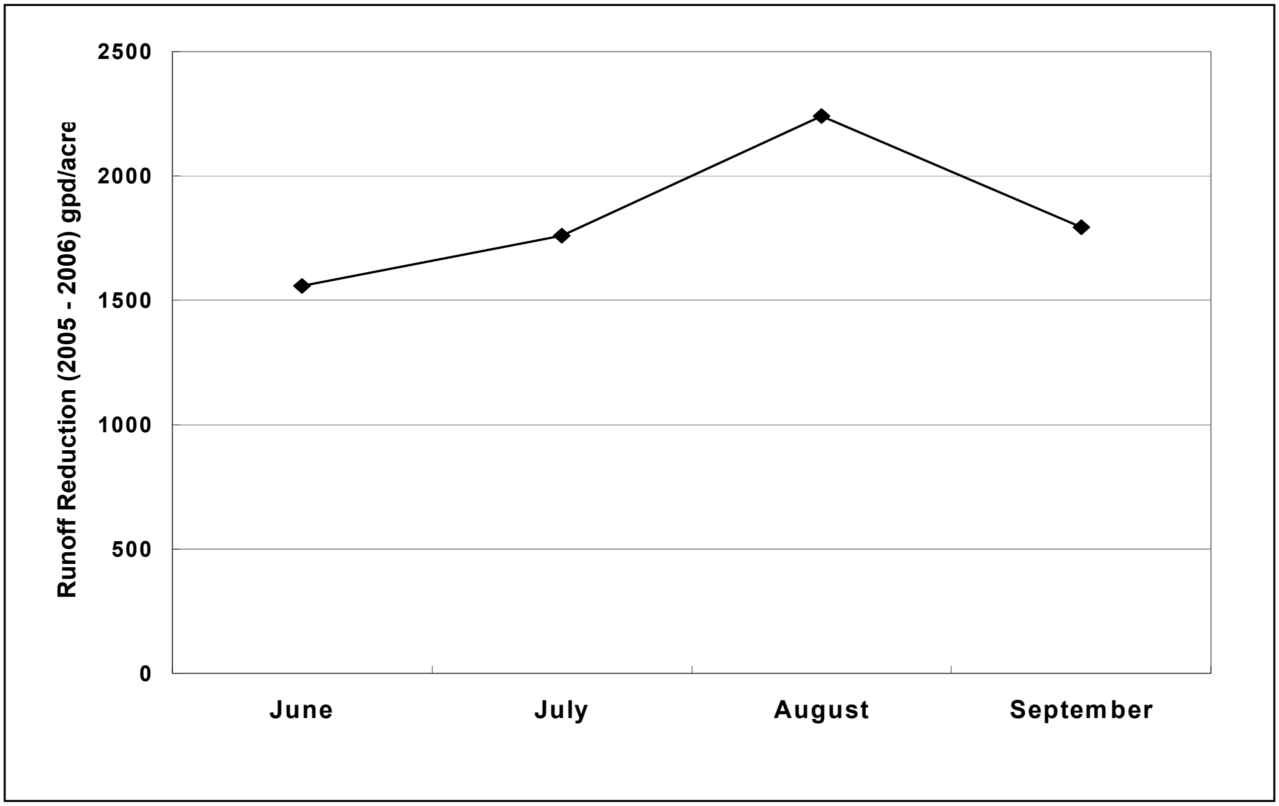


Figure 22: Runoff Reduction Between Pre- and Post-Intervention Periods in Portola Hills

Table 23: 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	2nd Degree Polynomial
Average Monthly ET (Inch)	0.229	2nd 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 24 and 25 describe the water quality parameters, sampling period and sampling frequency for the Buck Gully and Portola Hills areas.

Table 24: 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 25: 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 26 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 26: 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 27 and 28 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 29 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 30). Evaluation of flux trends indicated that only the EC flux decreased significantly between 2005 and 2006 (Table 31). The trend analyses also did not yield any systematic change over time.

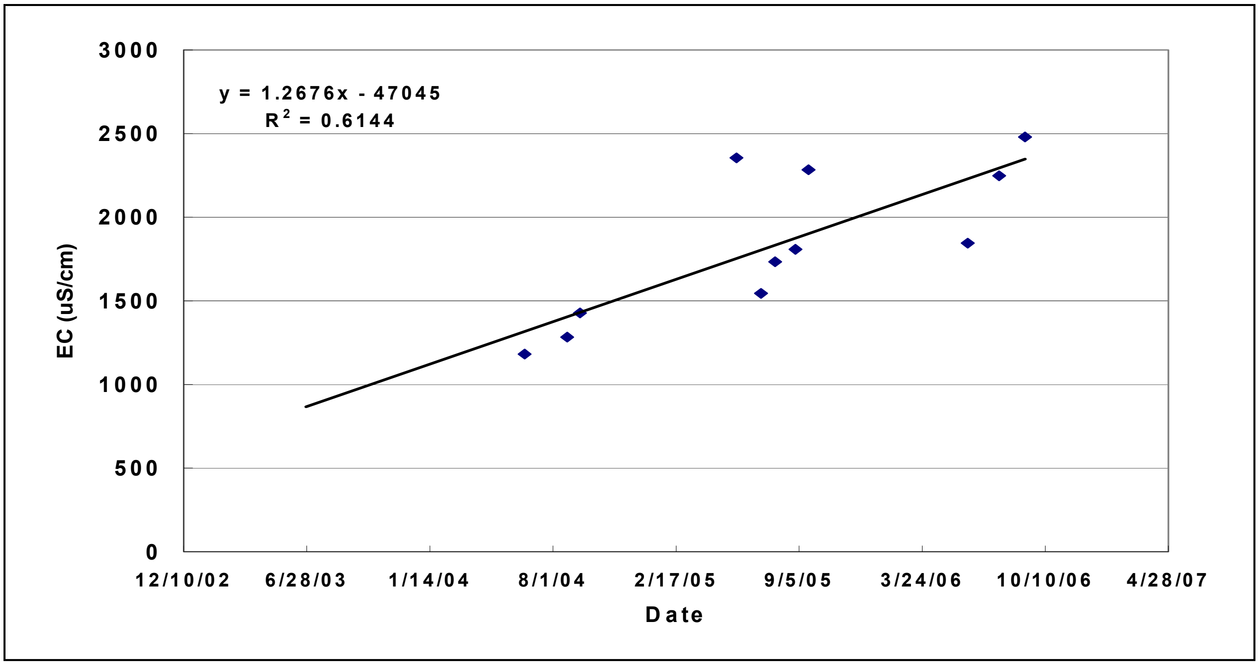


Figure 23: Time series plot and trend line for EC levels in the Portola Hills Area Runoff

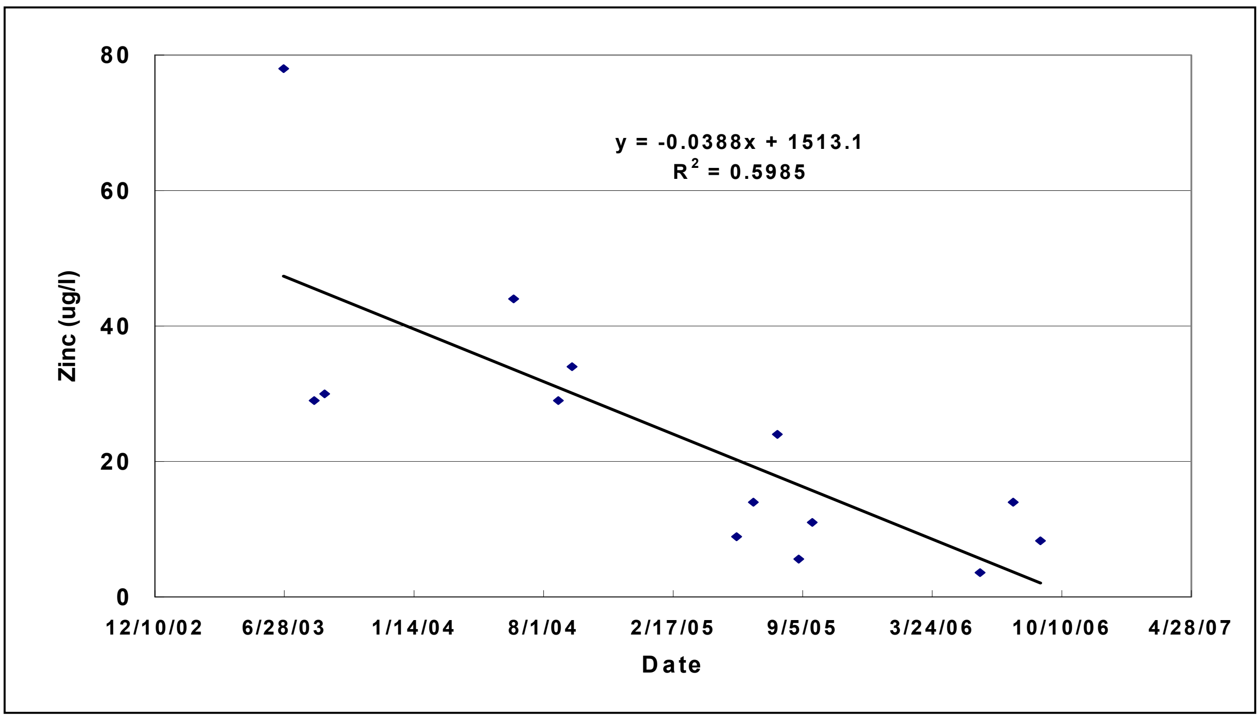


Figure 24: Time series plot and trend line for zinc levels in the Portola Hills Area Runoff

Table 27: 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 28: 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 29: Comparison of Pre- and Post Intervention Period Runoff Water Quality in Buck Gully Control and Retrofit Area

Station/ Flow Type	Mean Concentration		Sample Size (N)	T – stat	t-critical (2-tail)	Is Runoff quality significantly different?	Estimated change
	2004	2006					
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 30: 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 31: 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

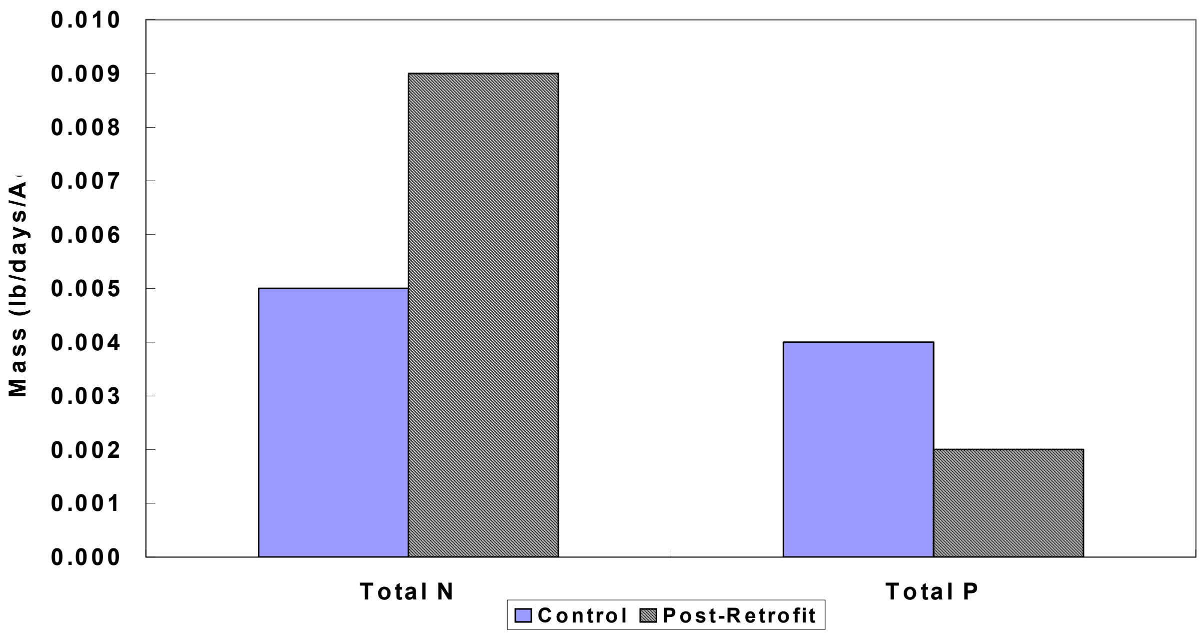
Limited water quality data (~ 3 to 4 data per year) were available for several parameters for Portola Hills. Most of the data were collected June to September of each year. Results from time series plots did not yield a consistent pattern for any group of contaminants. Reasonable correlation were obtained 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 25 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 25: 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 methods 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 units. For example, the average monthly water use in SFR units varied from 0.3 to 109 HCF, and those in commercial units 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 one, 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 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 paired t-test were often low for key parameters. 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 must 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 16 gpd/timer (not significant at 95 percent confidence level) in SFR units and about 175 gpd/timer in commercial installations (significant at the 95 percent confidence level).

- Approximately 50 percent of the timers of all the brands had a statistically different water usage. Saving from these timers resulted in 32 gpd per Smart Timer using a 12 month pre and post water consumption comparison. 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 showing no statistical difference between pre and post installation of a Smart Timer.

- Approximately 18 percent of the timers used statistically more water. Over the long run this may be responsible for saving valuable landscaping.

- 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 the water use in Coastal area, where as it resulted in water savings in Central and Foothill areas (at 80 to 90 percent confidence level). These effects may be due to impact of non-Smart Timers in water savings or other anomalies occurred.

- Water savings by Smart Timer installations for low ET (<0.20 inches per month) conditions are problematic.

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 by 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 Smart timer brand analysis by ET

The ET analysis indicated that there was more variability when the monthly average was below 0.2 inches/day. One potential scenario is that a particular brand may have had more installations in the Coastal ET zone which had a lower ET in 2006. This is one potential explanation of different performances between brands and type of installer.

6.4.1.3 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 in the 2008-2009 time frame.

6.4.2.1 Inclusion of other water saving database information

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 and high flush toilets with low flush toilets. A study to determine the savings of these devices as well as the Smart Timer could be done.

6.4.2.2 Forensic Smart Timer study

Approximately 50 percent of the Smart Timers did not have significantly different water savings and approximately 15 percent of the Smart Timers used significantly more water. This study would focus on developing the technical explanations for these observations. 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 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.

6.4.2.4 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.

6.4.2.5 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. Paired t-test for Monthly Water Savings

II. Repeated Measures ANOVA for evaluating the performance of Brands and ET Impacts

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. Paired 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. Use of a within-subjects design (sometimes called a *repeated measures* design) requires analysis with the paired samples t-test (also known as the *correlated* samples t-test). In the correlated samples design, there are two sets of scores on the dependent variable, but the scores are not independent. For example, repeated measures are obtained on one group of participants, such as in measuring water use in households before the smart timers are installed and again after the installation. Thus, each customer serves as his/her own control, and because the two sets of water use to be compared are obtained from the same people, the two groups of scores are not independent. This intercorrelation must be accounted for statistically when comparing the two groups, and that is what the paired-samples t-test does.

Data Summary

Table A1. Data Summary for SFR Installations using Average Monthly Use

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	731	Log Normal	12.71	13.24	2.83	0.005
February	834	Log Normal	11.37	12.79	7.774	0.000
March	862	Log Normal	13.87	13.17	-3.368	0.001
April	862	Log Normal	18.02	13.87	-18.036	0.000
May	862	Log Normal	20.83	18.54	-8.892	0.000
June	870	Log Normal	21.58	21.46	-0.441	0.660
July	865	Log Normal	24.85	25.34	1.63	0.104
August	866	Log Normal	25.00	23.93	-3.682	0.000
September	867	Log Normal	22.81	20.44	-9.276	0.000
October	874	Log Normal	18.86	17.62	-5.648	0.000
November	868	Log Normal	14.98	14.97	-0.057	0.954
December	873	Log Normal	13.97	13.72	-1.328	0.185

1. After transformation for distribution.

Table A2. Data Summary for Commercial Installations using Average Monthly Use

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	255	Log Normal	52.44	64.47	4.858	0.000
February	302	Log Normal	46.04	50.86	2.285	0.023
March	298	Log Normal	71.77	46.81	-9.085	0.000
April	300	Log Normal	98.48	67.11	-10.165	0.000
May	307	Log Normal	135.99	114.81	-6.140	0.000
June	311	Log Normal	146.04	133.50	-3.742	0.000
July	312	Log Normal	165.90	156.04	-2.072	0.039
August	313	Log Normal	168.58	147.13	-4.328	0.000
September	312	Log Normal	139.88	120.89	-5.019	0.000
October	311	Log Normal	106.69	104.06	-0.867	0.387
November	313	Log Normal	76.26	80.99	1.652	0.100
December	310	Log Normal	62.81	69.92	2.921	0.004

1. After transformation for distribution.

Table A3. Data Summary using 2005 (Pre-Intervention) and 2006 (Post-Intervention) Water Use for SFR Installations

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	512	Log Normal	9.98	13.03	12.756	0.000
February	799	Log Normal	9.06	12.84	17.583	0.000
March	834	Log Normal	12.84	12.19	-2.880	0.004
April	824	Log Normal	17.88	13.64	-17.098	0.000
May	808	Log Normal	20.38	18.38	-7.282	0.000
June	799	Log Normal	21.48	21.32	-0.562	0.574
July	792	Log Normal	24.90	25.24	1.027	0.305
August	769	Log Normal	24.63	24.04	1.901	0.058
September	750	Log Normal	21.89	20.26	-5.934	0.000
October	742	Log Normal	18.64	17.58	-4.184	0.000
November	650	Log Normal	15.76	14.85	-3.857	0.000
December	446	Log Normal	15.88	13.70	-7.448	0.000

1. After transformation for distribution.

Table A4. Data Summary using 2005 (Pre-Intervention) and 2006 (Post-Intervention) Water Use for SFR Installations

Month	Sample Size (N)	Distribution	Post-Installation Use (HCF)[1]	Pre-Installation Use (HCF)[1]	t-statistics	Sig. (2-tailed)
January	143	Log Normal	28.88	78.74	10.992	0.000
February	211	Log Normal	20.89	48.17	10.436	0.000
March	210	Log Normal	50.70	40.08	-3.455	0.001
April	235	Log Normal	79.22	59.41	-6.515	0.000
May	241	Log Normal	116.57	111.62	-1.188	0.236
June	240	Log Normal	138.35	135.78	-0.539	0.591
July	227	Log Normal	160.16	168.04	1.681	0.094
August	214	Log Normal	145.37	149.31	0.892	0.373
September	166	Log Normal	107.75	108.78	0.227	0.821
October	158	Log Normal	84.54	99.61	3.867	0.000
November	149	Log Normal	66.52	73.49	1.423	0.157
December	115	Log Normal	65.06	75.48	2.281	0.024

1. After transformation for distribution.

Table A5. Data Summary for individual SFR Smart Timer performance analyses

Smart Timers	Total No. of Timers	No Significant Change	Water Use Increased	Water Use Decreased	% Timers Water Use Decreased
All Timers	899	439	166	294	32.70%
Brand A	249	129	25	95	38.15%
Brand B	297	146	38	113	38.05%
Brand C	19	9	2	8	42.11%
Brand D	7	4	2	1	14.29%
Brand E	183	95	57	31	16.94%
Brand G	144	56	42	46	31.94%

Table A6. Data Summary for individual SFR Smart Timers that have paired data for all 12 months

Smart Timers	Total No. of Timers	No Significant Change	Water Use Increased	Water Use Decreased	% Timers Water Use Decreased
All Timers	707	357	128	222	31.40%
Brand A	178	96	17	65	36.52%
Brand B	260	130	33	97	37.31%
Brand C	13	6	0	7	53.85%
Brand D	5	3	1	1	20.00%
Brand E	162	86	51	25	15.43%
Brand G	89	36	26	27	30.34%

II. Repeated Measures ANOVA for evaluating the performance of Brands and ET Impacts

Method Description

Repeated Measures Analysis of Variance (Zar, J.H., 1999), a part of the General Linear Model (GLM) is a statistical technique used where the dependent variable is of the interval type and multiple measures are made on the same subject (where there is lack of independence). Independent variables are nominal, however the model can include interval type covariates. Among the possible effects to be derived are time and group effects, as well as interactions between independent variables. Usually the multiple measures are made over some unit of time, thus the time effect. A paired t-test is a simplistic form of repeated measures ANOVA where one group is measured twice.

In this study, it was of interest to investigate the monthly mean water usage when going from the “dumb” meters to the “smart” timers in the same area (the repeated measure). A repeated measures ANOVA was used to simultaneously compare this mean (of before and After use) for several different types of smart meters while adjusting for multiple comparisons.

Data Summary

Table A7. Data Summary for Evaluation of Performance of Smart Controller Brands in SFR Installations[1]

Month	Brands that used significantly (p = 0.05) different amount of water from each other
January	
February	B & G
March	A & G, B & G, E & G
April	A & G, B & G, E & G
May	B & G
June	B & G
July	No difference among brands
August	E & G
September	No difference among brands
October	No difference among brands
November	No difference among brands
December	No difference among brands

Table A8. Data Summary for Evaluation of Performance of Smart Controllers brands in commercial installations

Month	Brands that used significantly (p = 0.05) different amount of water from each other
January	B & C, B & E, B & G, C & H, E & H, E & G
February	B & E, B & G, H & G
March	B & G, H & G
April	C & H, H & E, H & G
May	C & H, H & G
June	C & H, H & G
July	C & H, H & G
August	C & H, H & G
September	C & H, H & G
October	C & H, H & G
November	B& G, H & G
December	B& G, H & G

Table A9. Data Summary of Evaluation of ET Impact on SFR Meter Performance

Month	ET Zones that performed significantly (p = 0.05) different from each other
January	No difference among ET Zones
February	No difference among ET Zones
March	No difference among ET Zones
April	No difference among ET Zones
May	No difference among ET Zones
June	No difference among ET Zones
July	No difference among ET Zones
August	No difference among ET Zones
September	No difference among ET Zones
October	No difference among ET Zones
November	No difference among ET Zones
December	No difference among ET Zones

III. 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 A10. Data Summary for Evaluating Performance of Smart Controller Brands in SFR Installations. Chi-square value for comparison of Smart Timer Brands[1]

Brand	Brand A	Brand B	Brand C	Brand D	Brand E	Brand G
Brand A	-					
Brand B	0.01	-				
Brand C	0.01	0.01	-			
Brand D	2.83	1.67	3.19	-		
Brand E	24.01	25.04	8.71	0.11	-	
Brand G	*1.81*	*1.84*	*1.31*	*0.34*	*9.26*	-

1. The chi-statistics for comparison at 95% confidence level is 3.841.

Table A11. Data Summary for Evaluating Performance of Smart Timer Brands Commercial Installations. Chi-square value for comparison of Smart Timer Brands[11]

Brand	Brand B	Brand G	Brand H
Brand B	-		
Brand G	18.00	-	
Brand H	11.59	0.01	-

1. The chi-statistics for comparison at 95% confidence level is 3.841.

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 meters and year of installation, etc.

IV. One way ANOVA Test in Conjunction with Post Hoc Scheffe Test to Compare Performance of Smart Timer Brands

Oneway ANOVA is a statistical test which is most often used to compare several means. It is the equivalent of the independent samples t-test where more than two means are being compared. Assumptions are that the samples are normally distributed and independent from each other. Because several individual comparisons are being made, there needs to be some correction for multiple testing. There are a host of post-hoc tests incorporated in most ANOVA software. Scheffe is a common one, and the one we used.

Results for SFR Installations

Descriptives

rrsum

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	229	-7.8849	18.85072	1.24569	-10.3394	-5.4303	-49.33	53.51
2	293	-6.6097	21.83636	1.27569	-9.1204	-4.0989	-66.47	74.40
3	19	-5.0422	29.35296	6.73403	-19.1899	9.1055	-52.86	68.90
4	7	11.0572	40.96851	15.48464	-26.8324	48.9467	-40.65	90.42
5	177	8.8311	28.58637	2.14868	4.5906	13.0716	-80.91	92.67
6	17	-12.3806	18.42693	4.46919	-21.8549	-2.9064	-62.90	11.31
7	135	-.8904	27.62963	2.37798	-5.5936	3.8128	-83.70	85.10
Total	877	-2.8828	24.71271	.83449	-4.5207	-1.2450	-83.70	92.67

Note: Brands 1 through 7 in the ANOVA output indicate Brands A through G in the report.

ANOVA

rrsum

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	37604.725	6	6267.454	10.963	.000
Within Groups	497384.080	870	571.706		
Total	534988.804	876			

The post hoc p values are provided in the Table below.

Multiple Comparisons

Dependent Variable: rrsum
Scheffe

(I) Manufacturer Type	(J) Manufacturer Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
1	2	-1.27523	2.10897	.999	-8.7773	6.2269
	3	-2.84266	5.70844	1.000	-23.1489	17.4636
	4	-18.94206	9.17436	.641	-51.5774	13.6933
	5	-16.71596*	2.39301	.000	-25.2285	-8.2035
	6	4.49573	6.01051	.997	-16.8851	25.8765
	7	-6.99447	2.59449	.298	-16.2237	2.2347
2	1	1.27523	2.10897	.999	-6.2269	8.7773
	3	-1.56743	5.66048	1.000	-21.7031	18.5682
	4	-17.66683	9.14459	.713	-50.1963	14.8626
	5	-15.44073*	2.27622	.000	-23.5378	-7.3437
	6	5.77096	5.96498	.988	-15.4479	26.9898
	7	-5.71924	2.48718	.508	-14.5667	3.1282
3	1	2.84266	5.70844	1.000	-17.4636	23.1489
	2	1.56743	5.66048	1.000	-18.5682	21.7031
	4	-16.09940	10.57176	.888	-53.7056	21.5068
	5	-13.87330	5.77233	.449	-34.4068	6.6602
	6	7.33839	7.98245	.991	-21.0570	35.7338
	7	-4.15180	5.85872	.998	-24.9926	16.6890
4	1	18.94206	9.17436	.641	-13.6933	51.5774
	2	17.66683	9.14459	.713	-14.8626	50.1963
	3	16.09940	10.57176	.888	-21.5068	53.7056
	5	2.22610	9.21424	1.000	-30.5511	35.0033
	6	23.43779	10.73788	.575	-14.7593	61.6349
	7	11.94759	9.26861	.948	-21.0230	44.9182
5	1	16.71596*	2.39301	.000	8.2035	25.2285
	2	15.44073*	2.27622	.000	7.3437	23.5378
	3	13.87330	5.77233	.449	-6.6602	34.4068
	4	-2.22610	9.21424	1.000	-35.0033	30.5511
	6	21.21169	6.07122	.059	-.3851	42.8084
	7	9.72150*	2.73218	.050	.0025	19.4405
6	1	-4.49573	6.01051	.997	-25.8765	16.8851
	2	-5.77096	5.96498	.988	-26.9898	15.4479
	3	-7.33839	7.98245	.991	-35.7338	21.0570
	4	-23.43779	10.73788	.575	-61.6349	14.7593
	5	-21.21169	6.07122	.059	-42.8084	.3851
	7	-11.49020	6.15342	.746	-33.3794	10.3990
7	1	6.99447	2.59449	.298	-2.2347	16.2237
	2	5.71924	2.48718	.508	-3.1282	14.5667
	3	4.15180	5.85872	.998	-16.6890	24.9926
	4	-11.94759	9.26861	.948	-44.9182	21.0230
	5	-9.72150*	2.73218	.050	-19.4405	-.0025
	6	11.49020	6.15342	.746	-10.3990	33.3794

*. The mean difference is significant at the .05 level.

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

Method Description

A method described by Zar et al., (1974) (Section 17.1 Comparing Simple Linear Regression Equations – Comparing Two Slopes) was used to compare the slopes of regression analyses performed to relate impact of ET on water use during pre-installation and post-installation periods. The hypothesis tested was, the slope of regression analyses for the post-installation period was different than the slope of pre-installation period. This method uses Student's t in a way similar to comparing two population means. For this study, the smart timers were grouped into three ET Zones based on their Zip Codes. The ET Vs Water Use Regression Analyses were performed separately for each group.

Data Summary

Table A13. Data Summary for Evaluating Linear Regression for ET Vs Water Use Relationship in SFRs. Comparison of slopes for pre- and post-installation regression.

ET Zone	DF	t-value	t-critical (α = 0.05)
Coastal	20	-1.35	2.086
Central	20	1.81	2.086
Foothill	20	0.65	2.086

Table A14. Data Summary for Evaluating Linear Regression for ET and Water Use Relationship in SFRs. Comparison of slopes for measured and ET-adjusted pre-installation water use

ET Zone	DF	t-value	t-critical (α = 0.05)
Coastal	20	-1.09	2.086
Central	20	1.48	2.086
Foothill	20	0.64	2.086

Table A15. Data Summary for Evaluating Linear Regression for ET and Water Use Relationship in Commercial Installations. Comparison of slopes for pre- and post-installation regression analyses.

ET Zone	DF	t-value	t-critical (α = 0.05)
Coastal	20	-0.18	2.086
Central	20	1.77	2.086
Foothill	20	1.27	2.086

Table A16. Data Summary for Evaluating Linear Regression for ET and Water Use Relationship in Commercial Installations. Comparison of slopes for measured and ET-adjusted pre-installation water use

ET Zone	DF	t-value	t-critical (α = 0.05)
Coastal	20	-0.30	2.086
Central	20	**2.25***	2.086
Foothill	20	1.37	2.086

* - Statistically significant

V. REFERENCES

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Appendix B: Zip Codes and ET Zone Assignments

Appendix B: Zip Codes and ET Zone Assignments

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	
	92709	
	92710	
	92780	
	92802	
	92804	
	92810	
	92840	
	92841	
	92843	
	92844	
	92845	
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Appendix C: Buck Gully Runoff Water Quality Analysis-Supplemental Report

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Buck Gully Runoff Water Quality Analysis-Supplemental Report

28 November 2007

Prepared for

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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 theflow 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: Pre-Intervention	Data Collection Period: Post-Intervention	Types of Analyses
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.

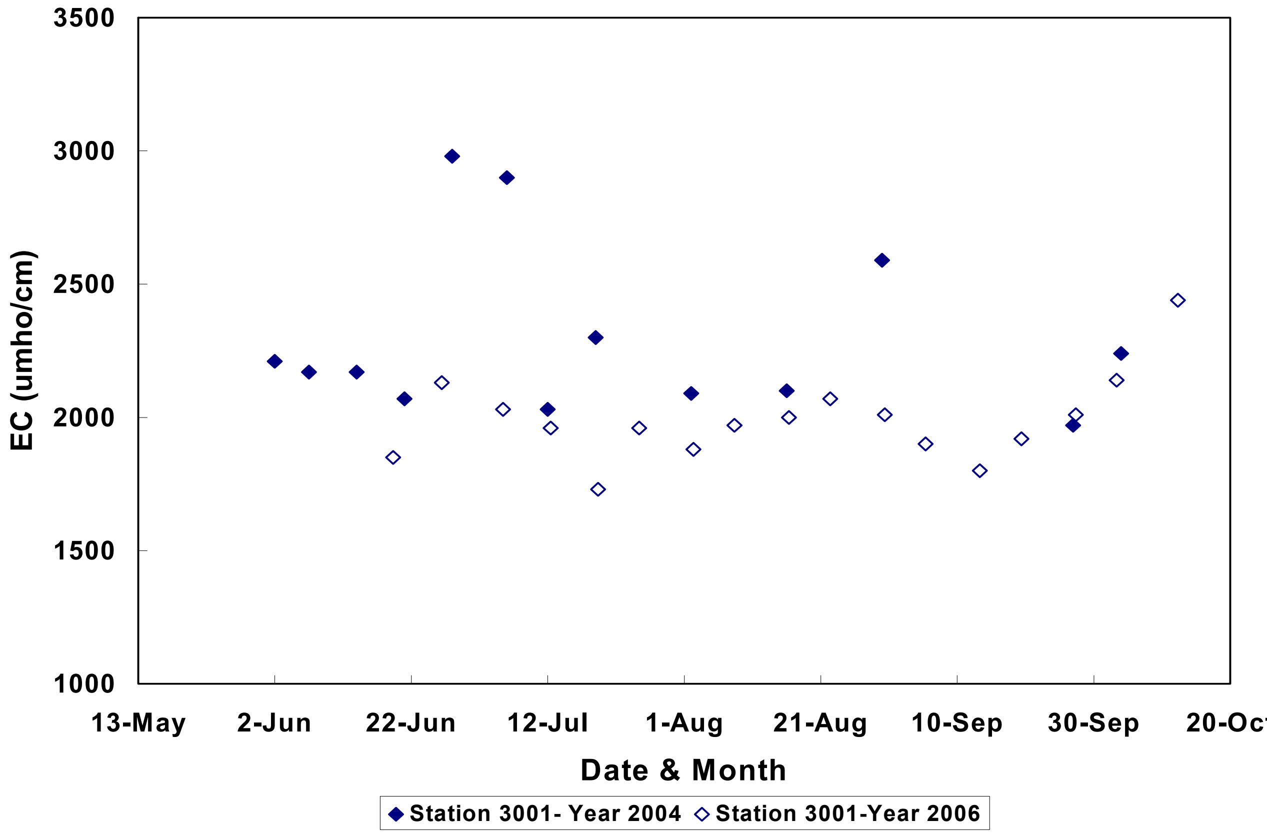

Figure 1: Time Series Plot for Electric Conductivity in Control Station (# 3001) During Pre- and Post-Intervention Periods

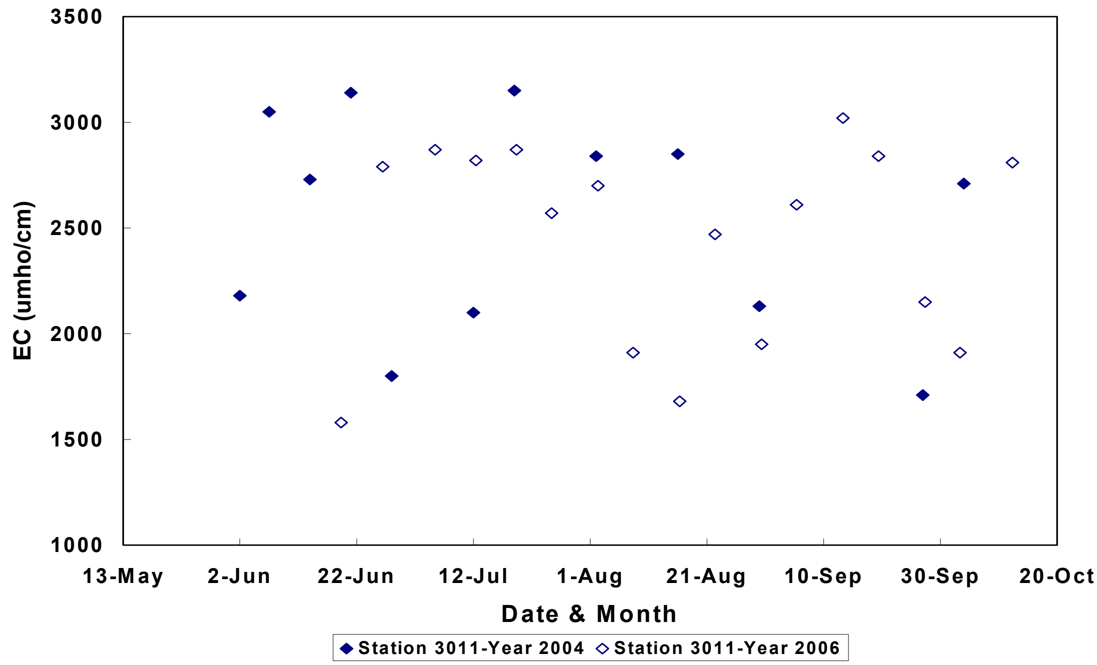

Figure 2: Time Series Plot for Electric Conductivity in Retrofit Station (# 3011) During Pre- and Post-Intervention Periods

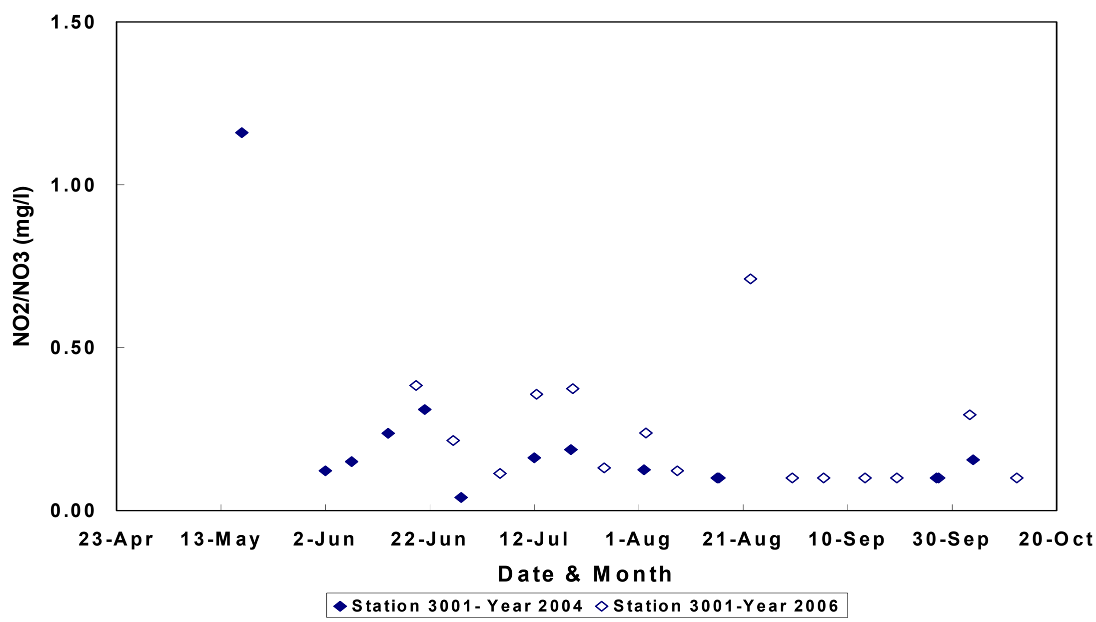

Figure 3: Time Series Plot for Nitrate/Nitrite Levels in Control Station (# 3001) During Pre- and Post-Intervention Periods

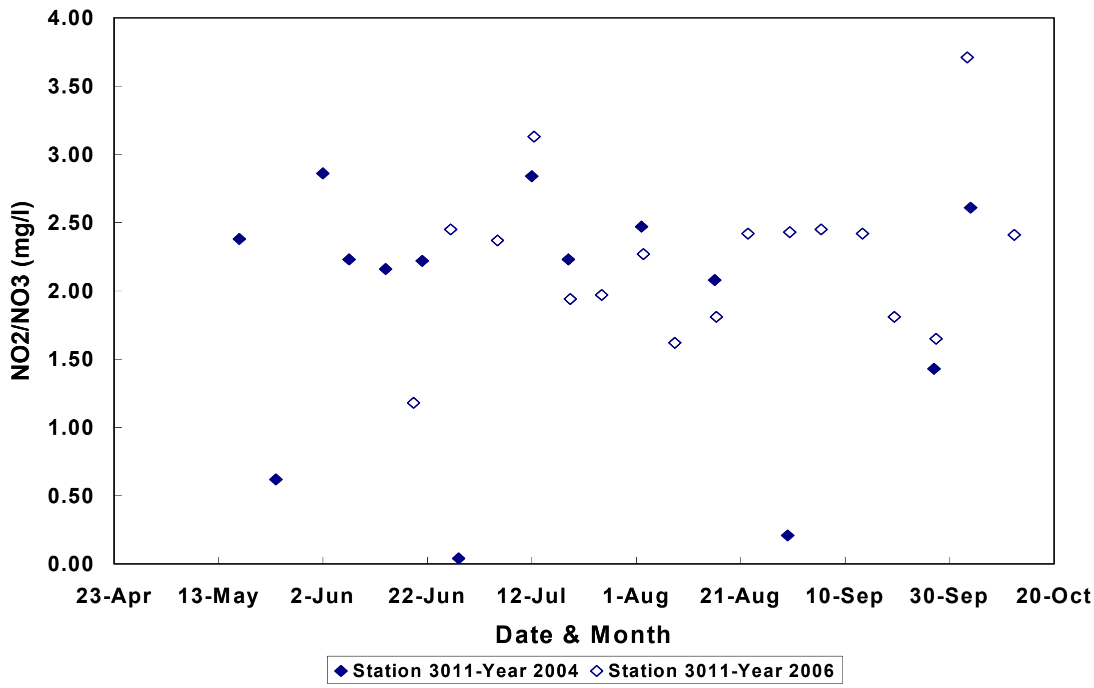

Figure 4: Time Series Plot for Nitrate/nitrite Levels in Retrofit Station (# 3011) During Pre- and Post-Intervention Periods

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).

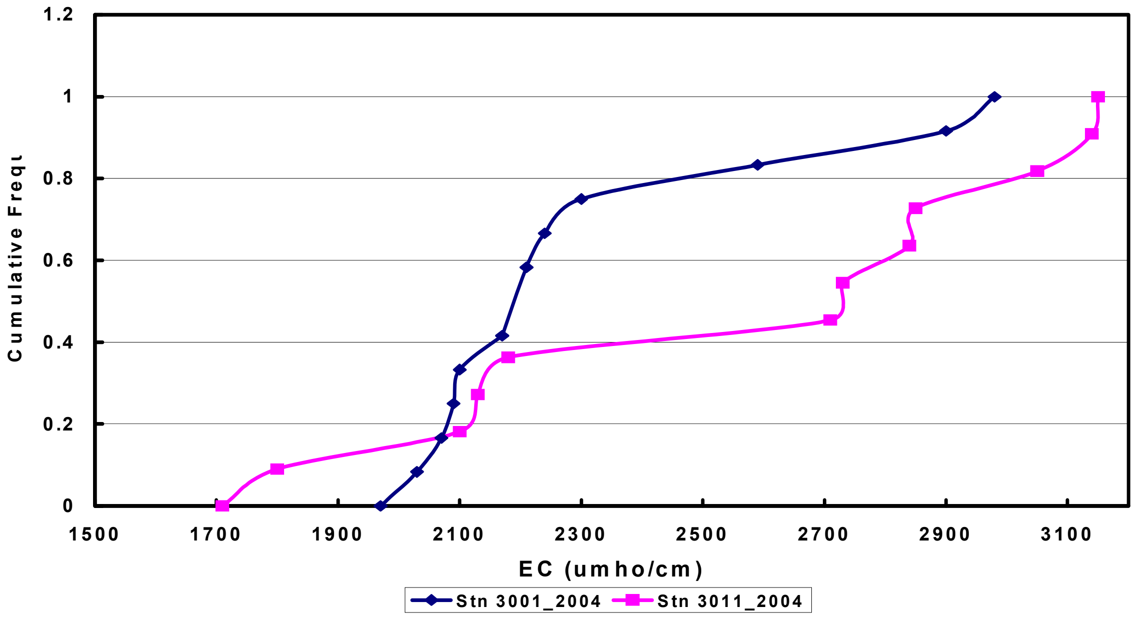

Figure 5: Cumulative frequency Plot for EC Levels in Control and Retrofit Stations Prior to Installation of Smart Timers

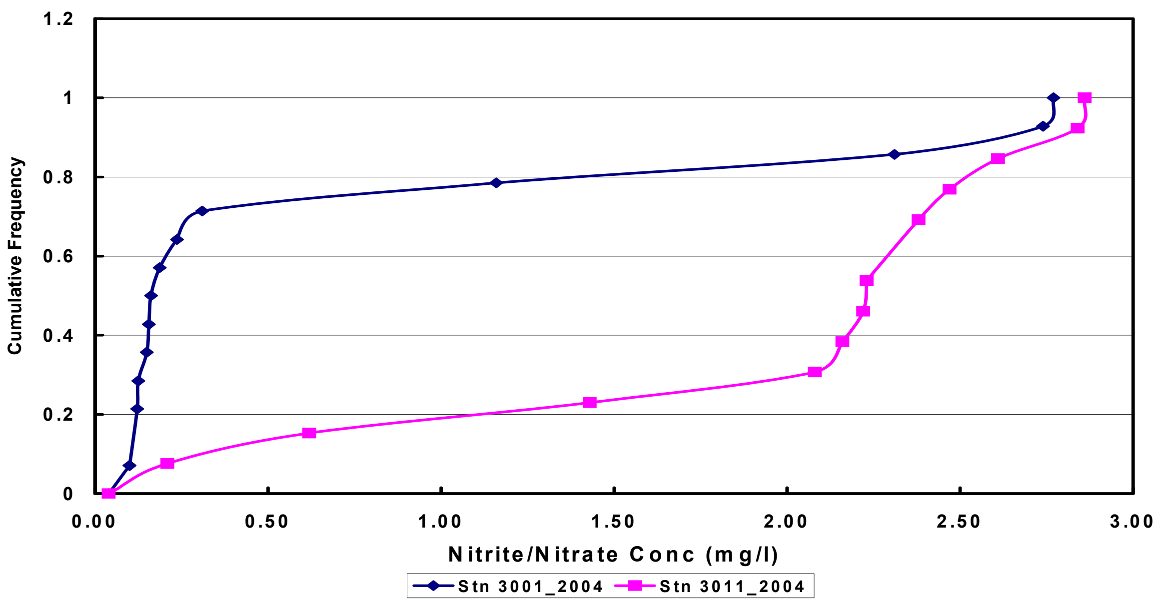

Figure 6: Cumulative frequency Plot for NO_3/NO_2 Levels in Control and Retrofit Stations Prior to Installation of Smart Timers

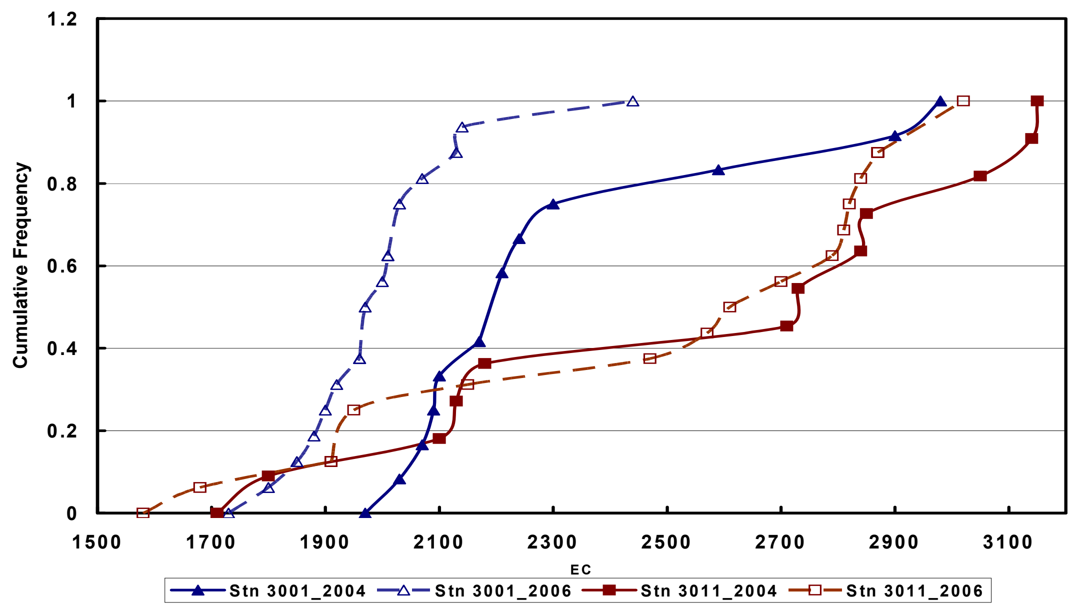

Figure 7: Cumulative frequency Plot for EC Levels in Control and Retrofit Stations Prior to and After Installation of Smart Timers

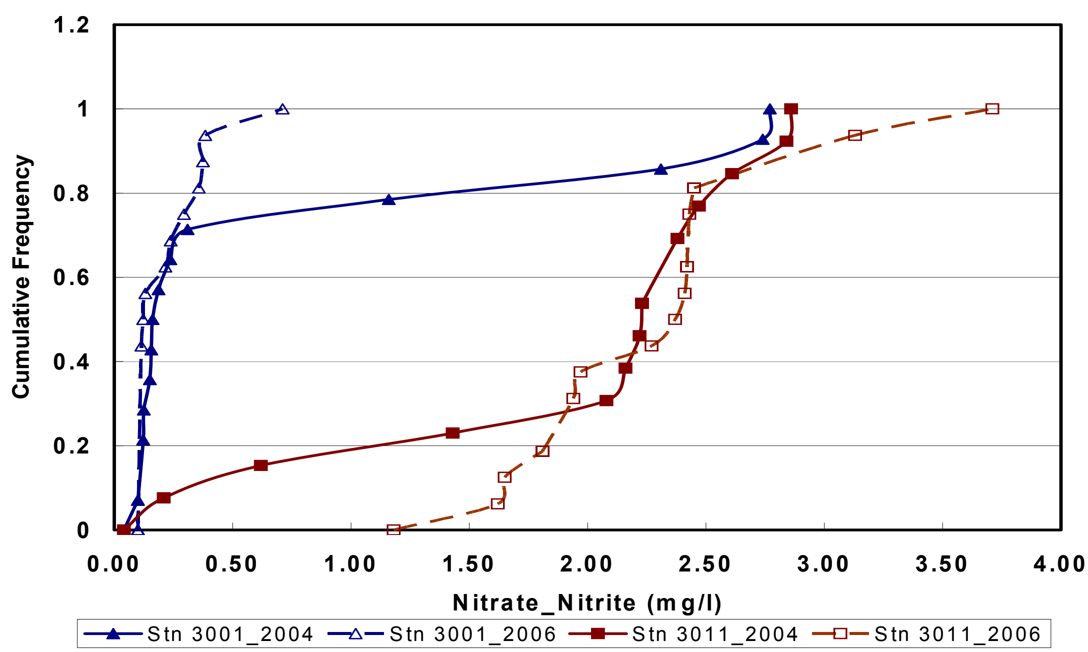

Figure 8: Cumulative frequency Plot for NO_3/NO_2 Levels in Control and Retrofit Stations Prior to and After Installation of Smart Timers

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.

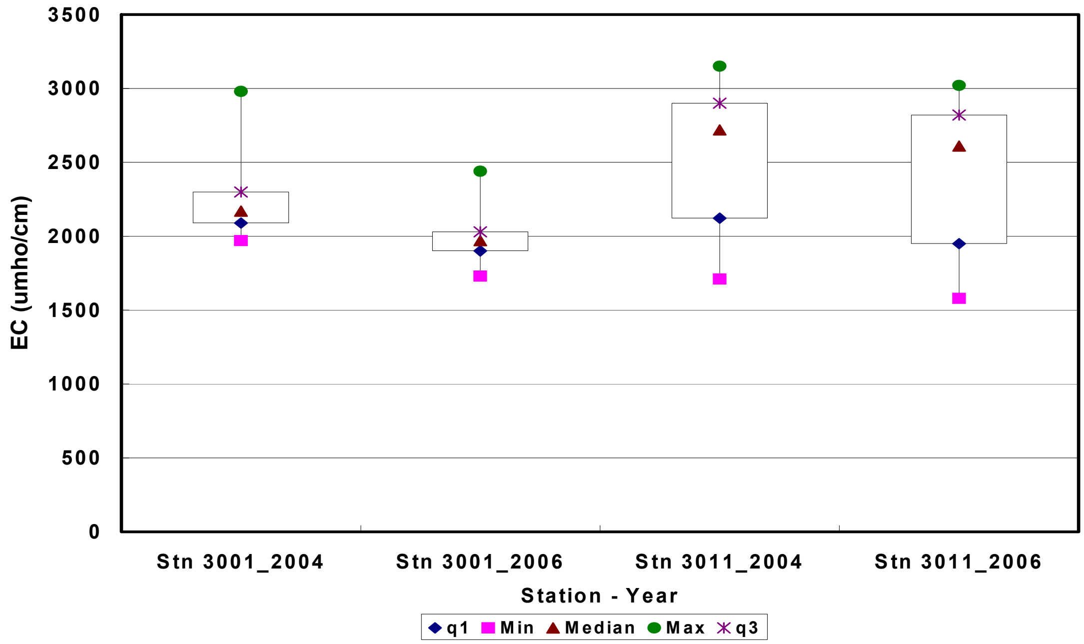

Figure 9: Box Plot for EC Levels in Control and Retrofit Stations Prior to Installation of Smart Timers

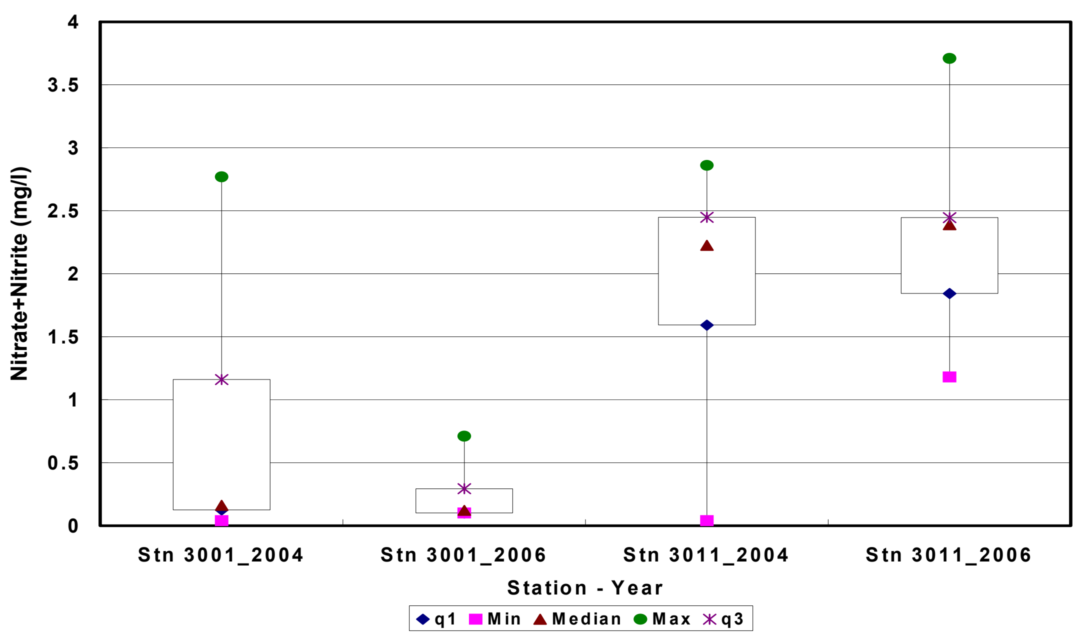

Figure 10: Box Plot for Nitrate/nitrite Levels in Control and Retrofit Stations Prior to Installation of Smart Timers

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).

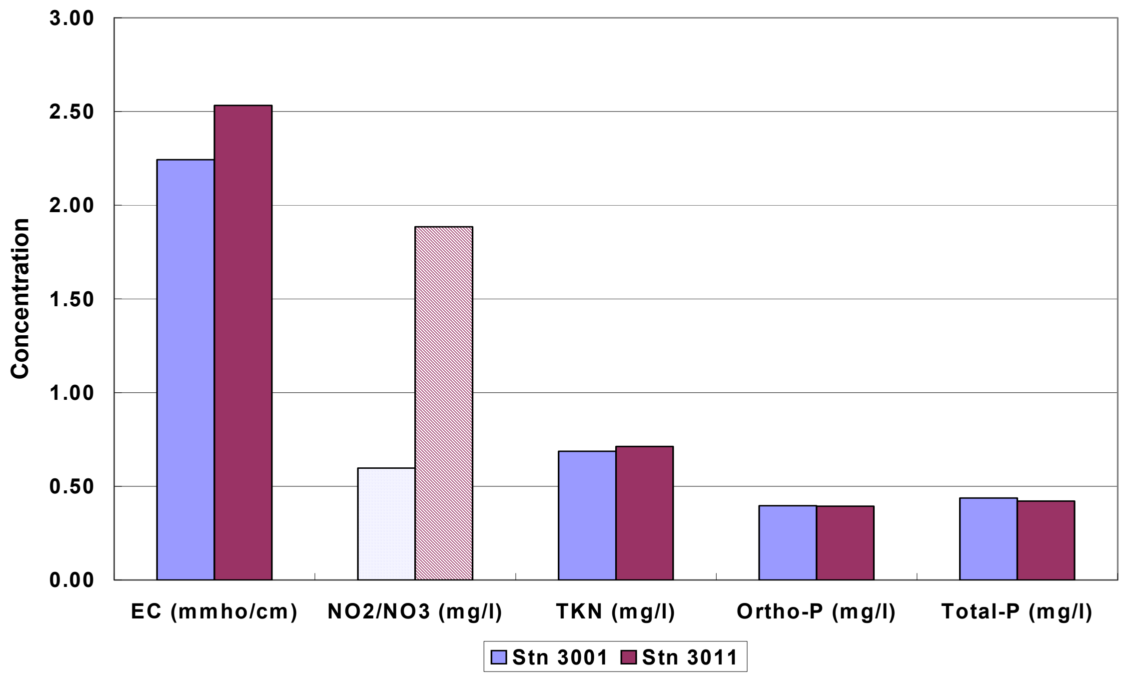

Figure 11: Mean Concentration of Various Water Quality Parameters for Control (# 3001) and Retrofit Stations (# 3011) During Pre-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

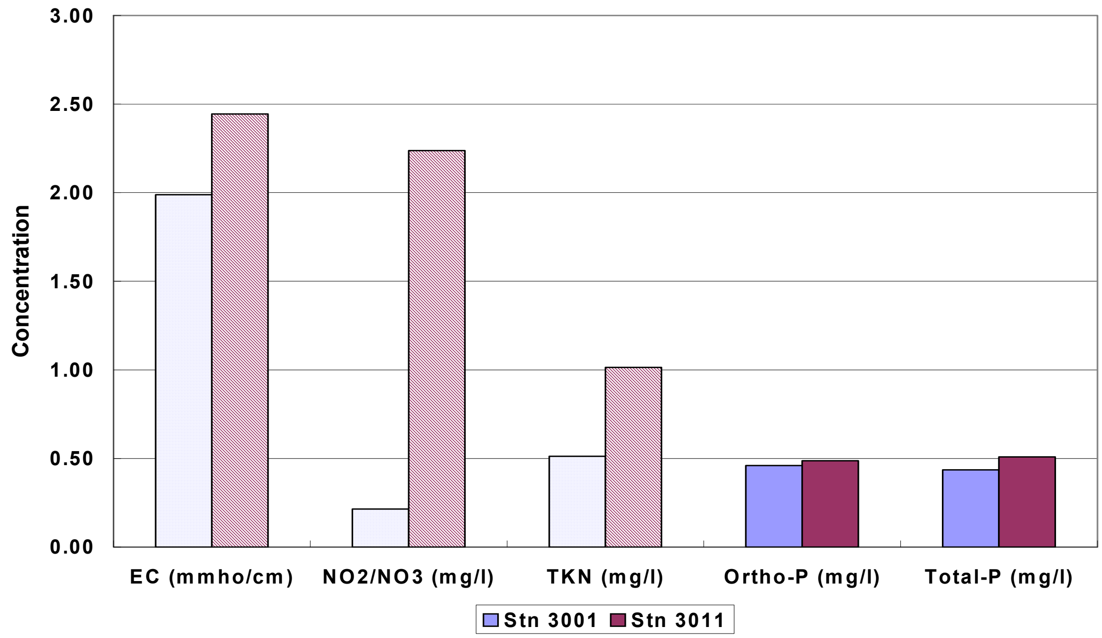

Figure 12: Mean Concentration of Various Water Quality Parameters for Control (# 3001) and Retrofit Stations (# 3011) During Post-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

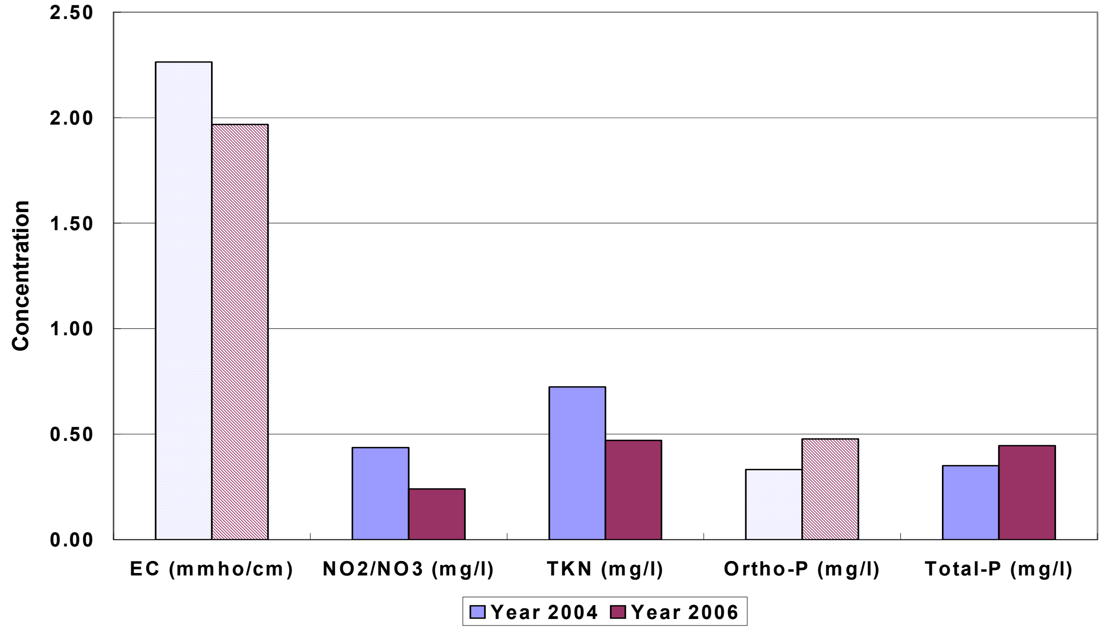

Figure 13: Mean Concentration of Various Water Quality Parameters for Control Station (# 3001) During Pre- and Post-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

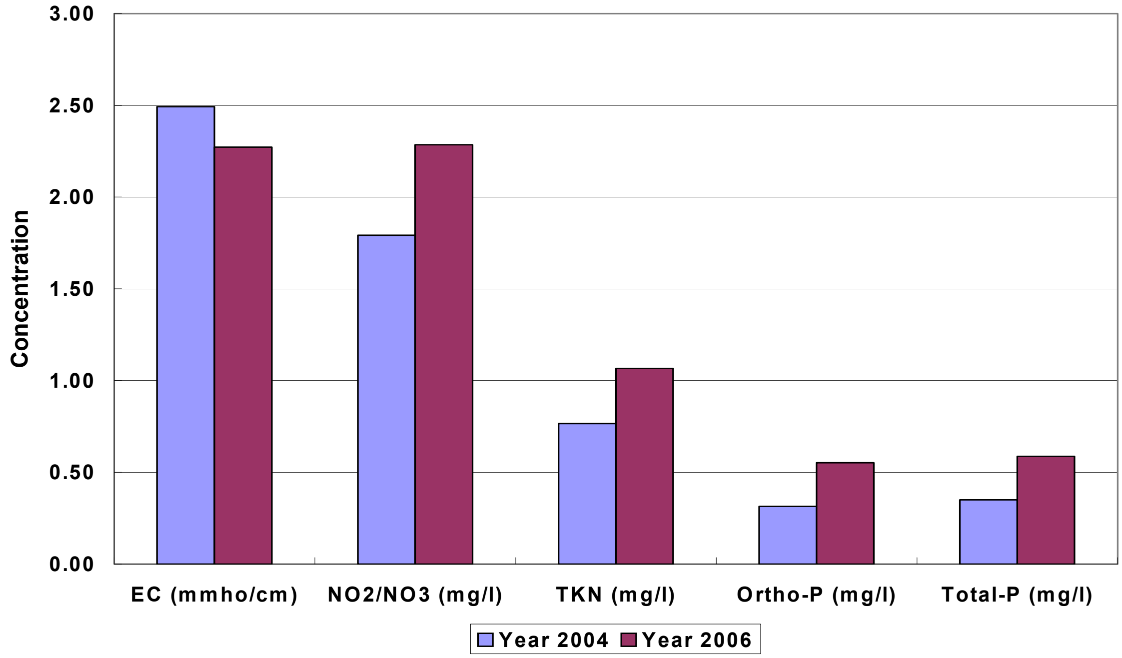

Figure 14: Mean Concentration of Various Water Quality Parameters For Retrofit Station (# 3001) During Pre- and Post-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

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.

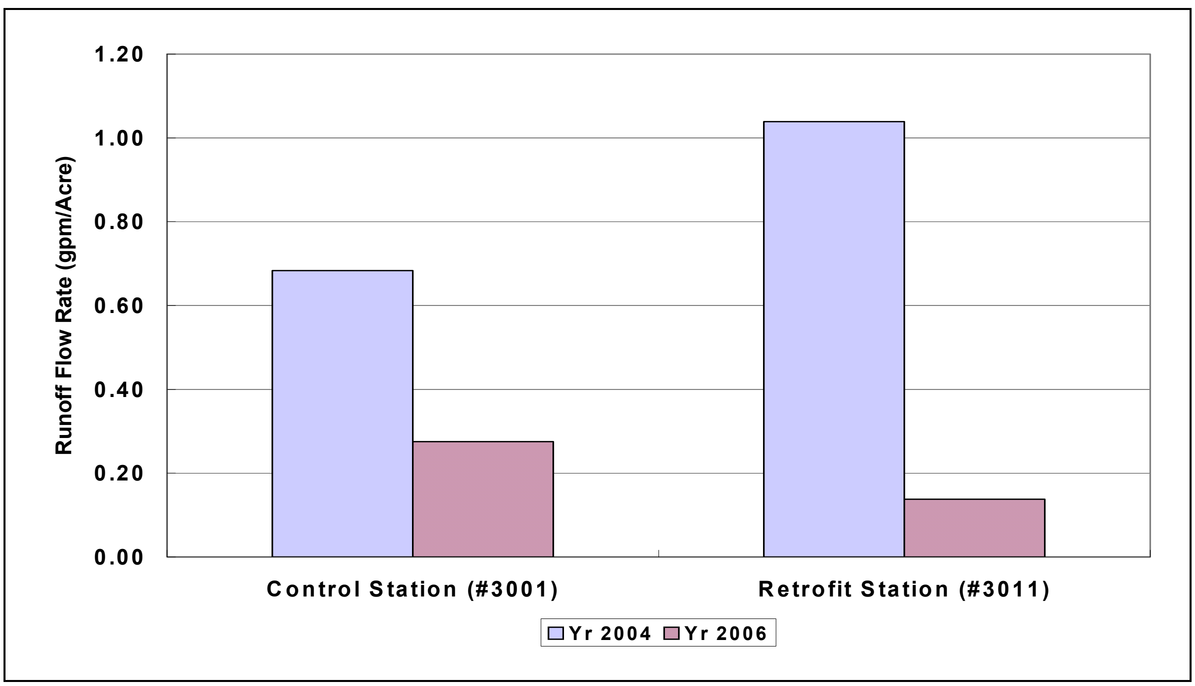

Figure 15: Runoff Flow Rates in Control and Retrofit Areas

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.

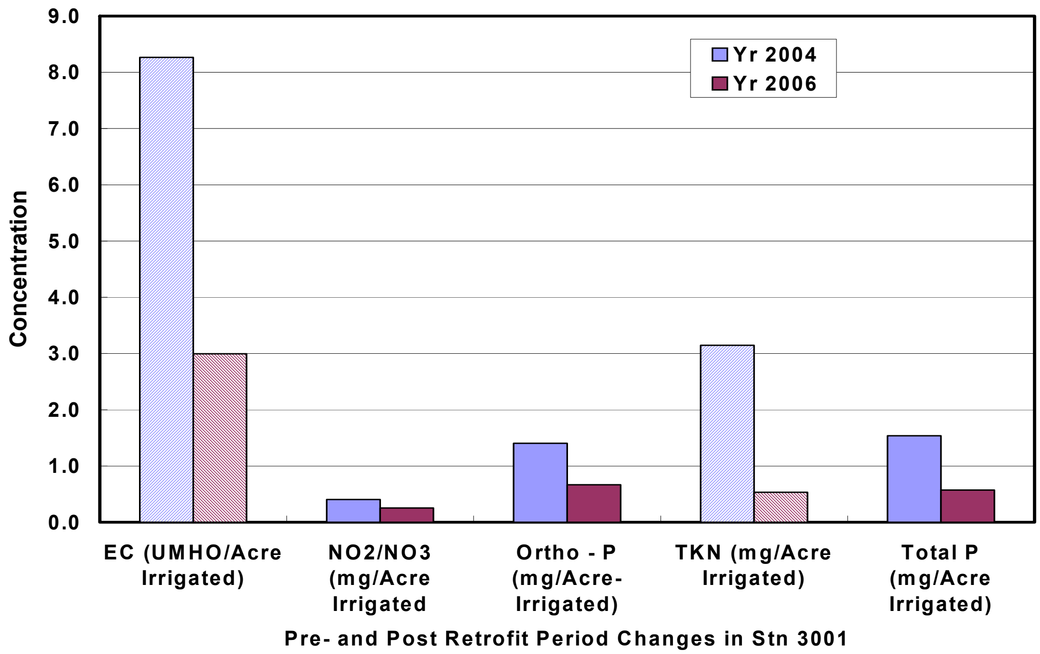

Figure 16: Mean Mass Flux of Various Water Quality Parameters for Control Station (# 3001) During Pre- and Post-Intervention Period. (The doted/stashed bars mean the mass flux are statistically different)

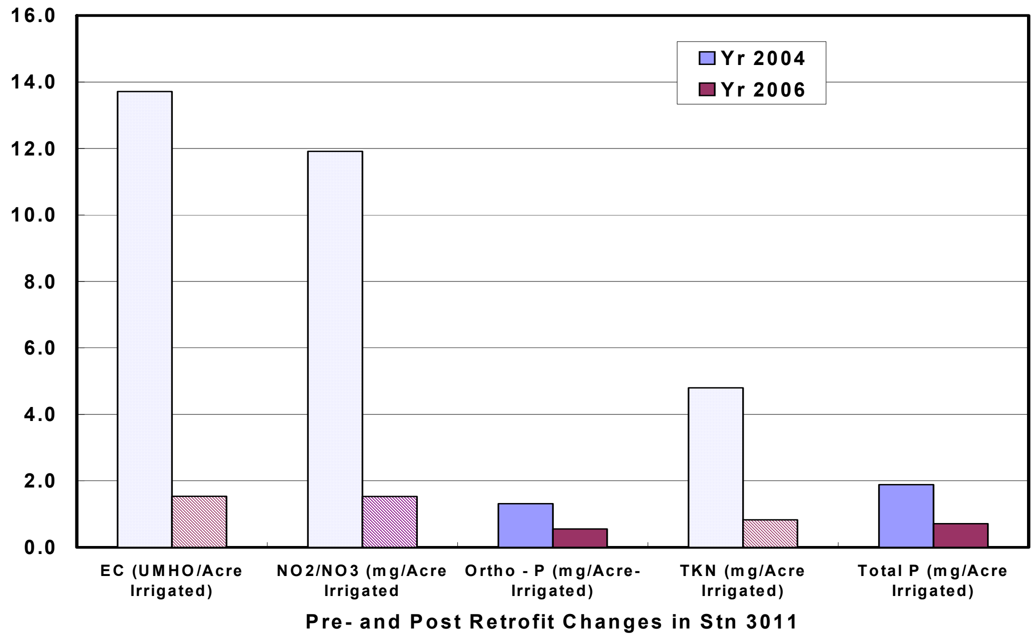

Figure 17: Mean Mass Flux of Various Water Quality Parameters for Retrofit Station (# 3011) During Pre- and Post-Intervention Period. (The doted/stashed bars mean the concentrations are statistically different)

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.

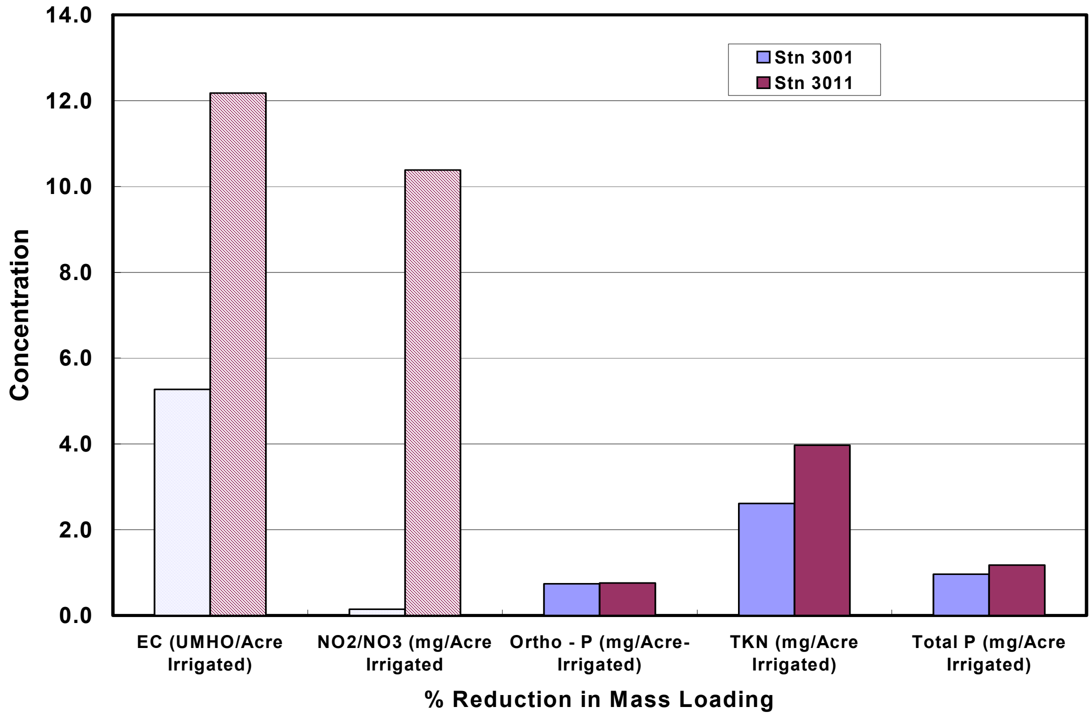

Figure 18: % Reduction in Mass Loading for Various Water Quality Parameters in Control and Retrofit Stations Between Pre- and Post-Intervention Periods. (The doted/stashed bars mean the concentrations are statistically different)

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

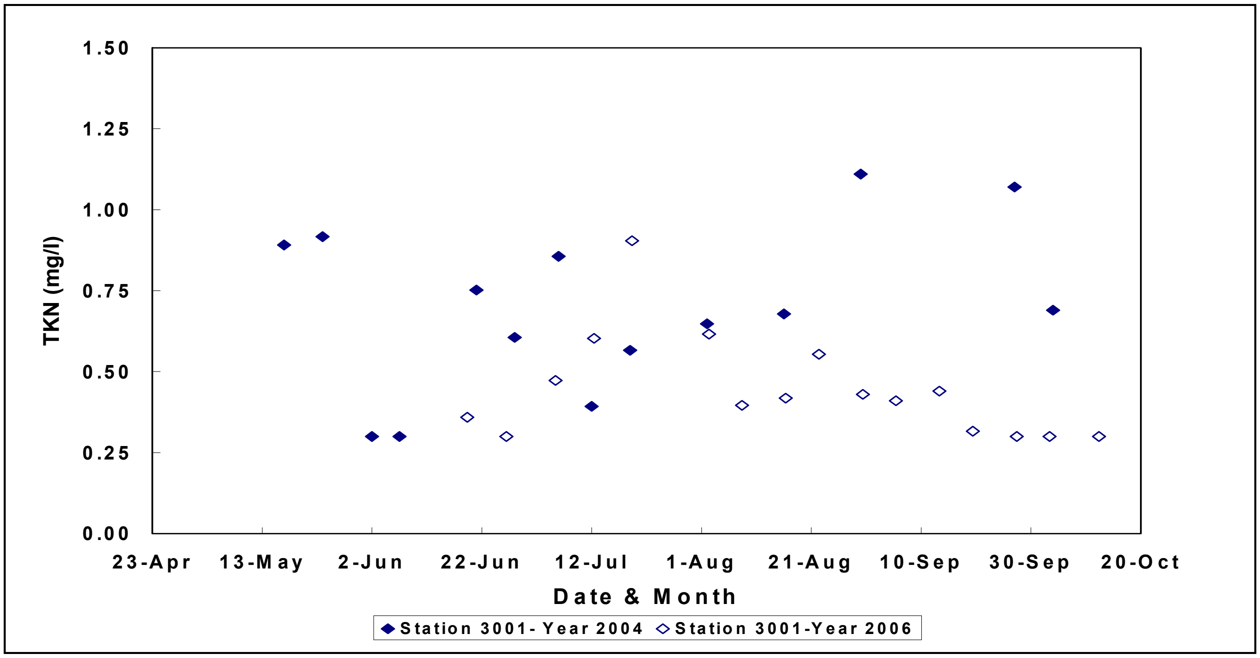

Figure A1. Time Series Plot for TKN in Control Station (#3001) during pre- and post-intervention periods

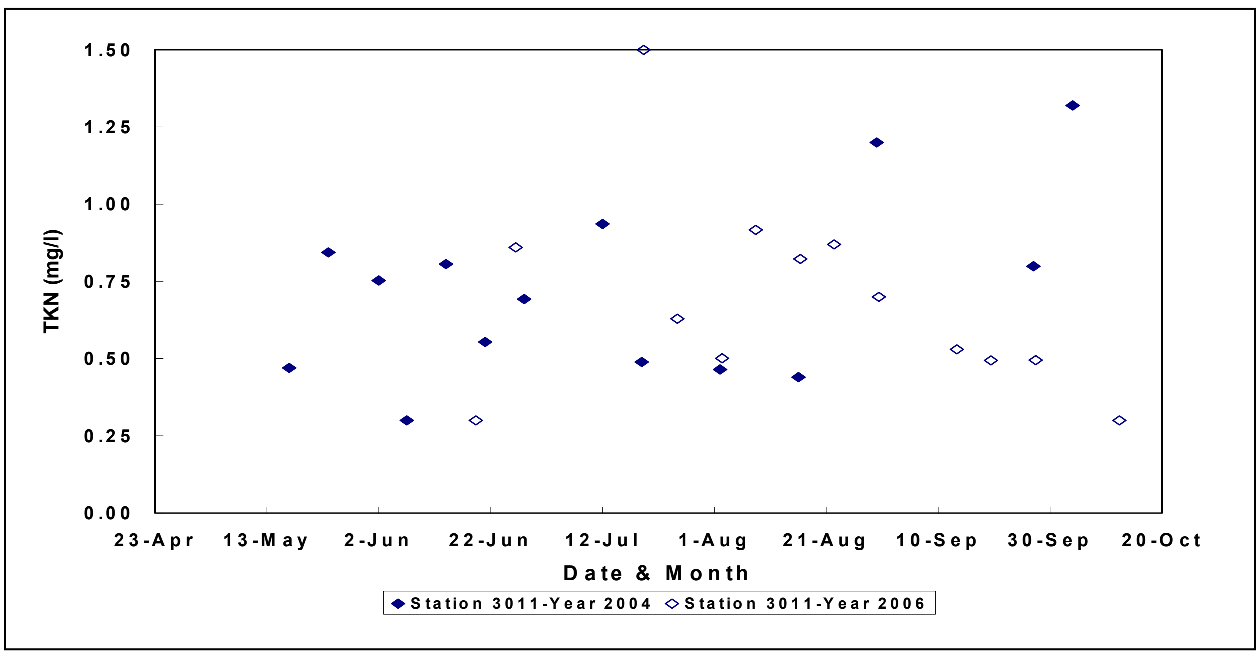

Figure A2. Time Series Plot for TKN in Retrofit Station (#3011) during pre- and post-intervention periods

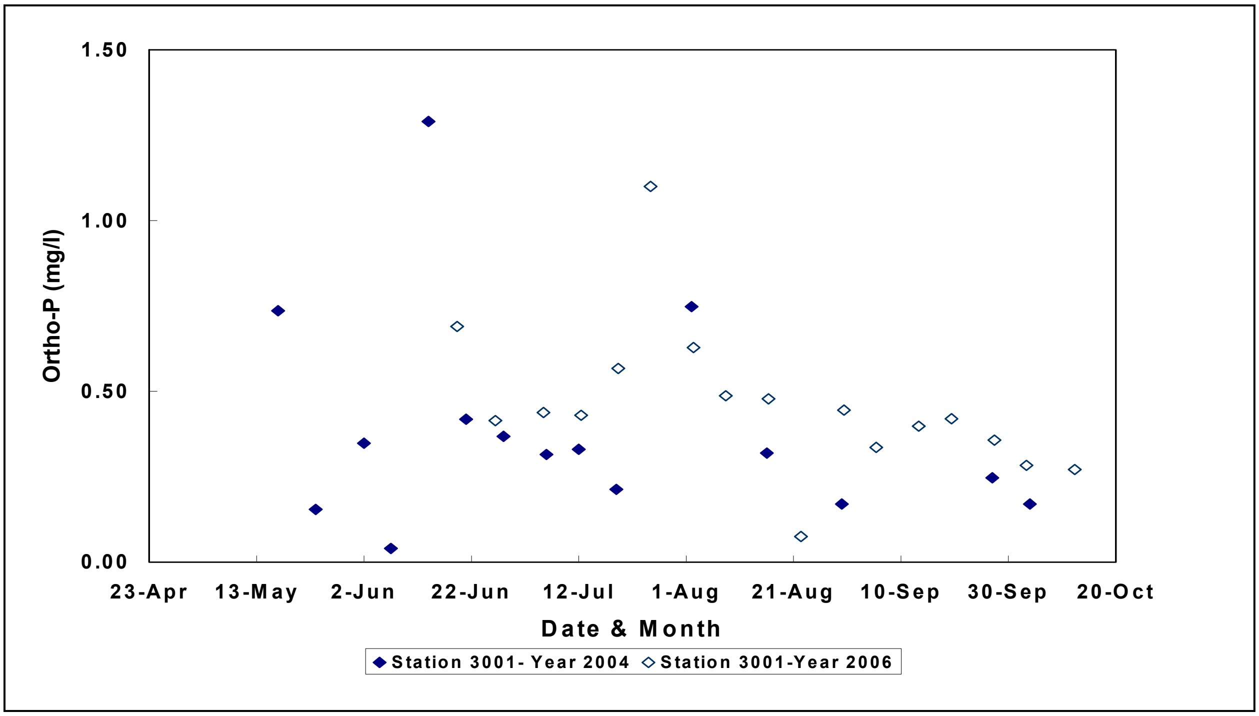

Figure A3. Time Series Plot for Ortho-P in Control Station (#3001) during pre- and post-intervention periods

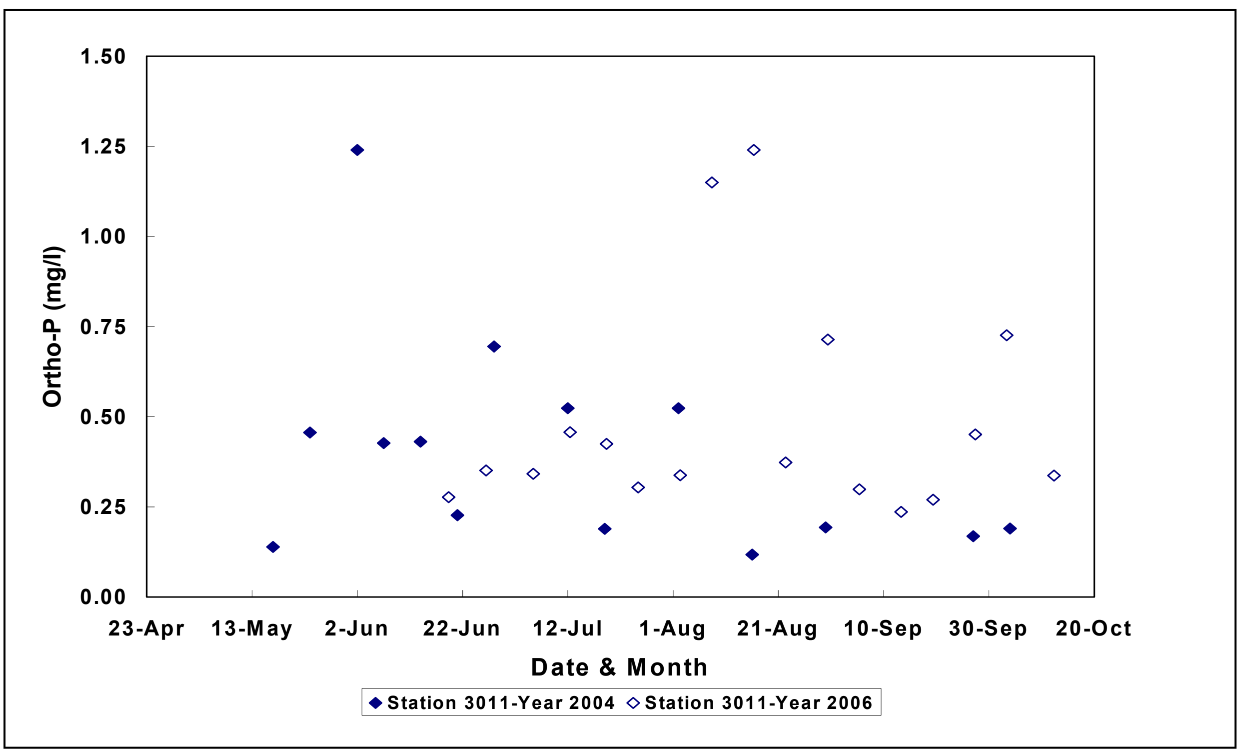

Figure A4. Time Series Plot for Ortho-P in Retrofit Station (#3011) during pre- and post-intervention periods

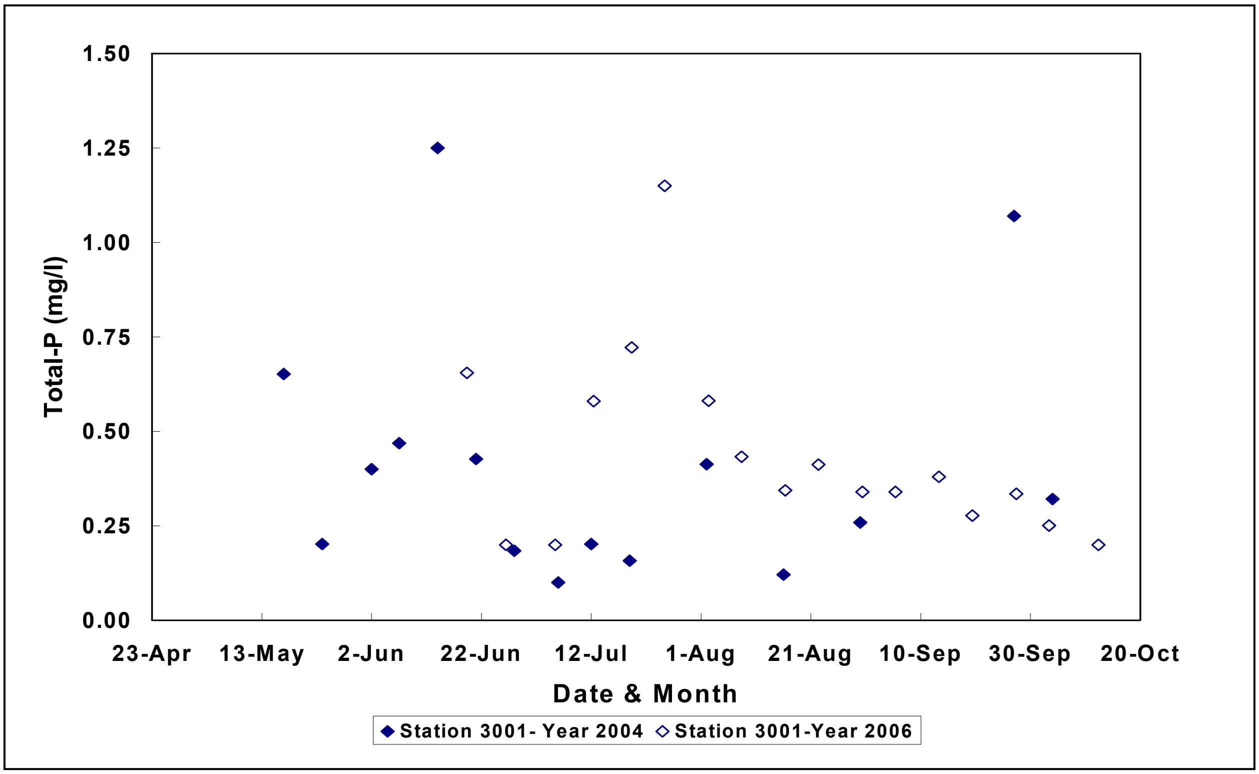

Figure A5. Time Series Plot for Total-P in Control Station (#3001) during pre- and post-intervention periods

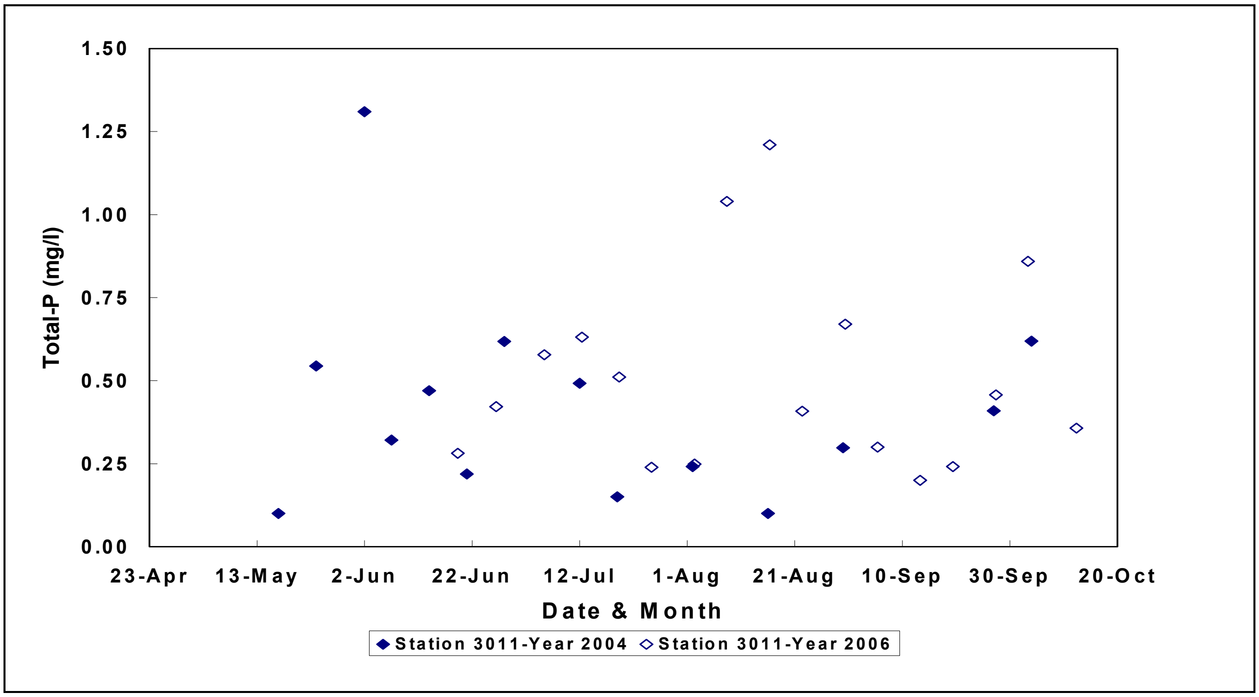

Figure A6. Time Series Plot for Total-P in Retrofit Station (#3011) during pre- and post-intervention periods

Appendix B: Cumulative Frequency and Box Plots

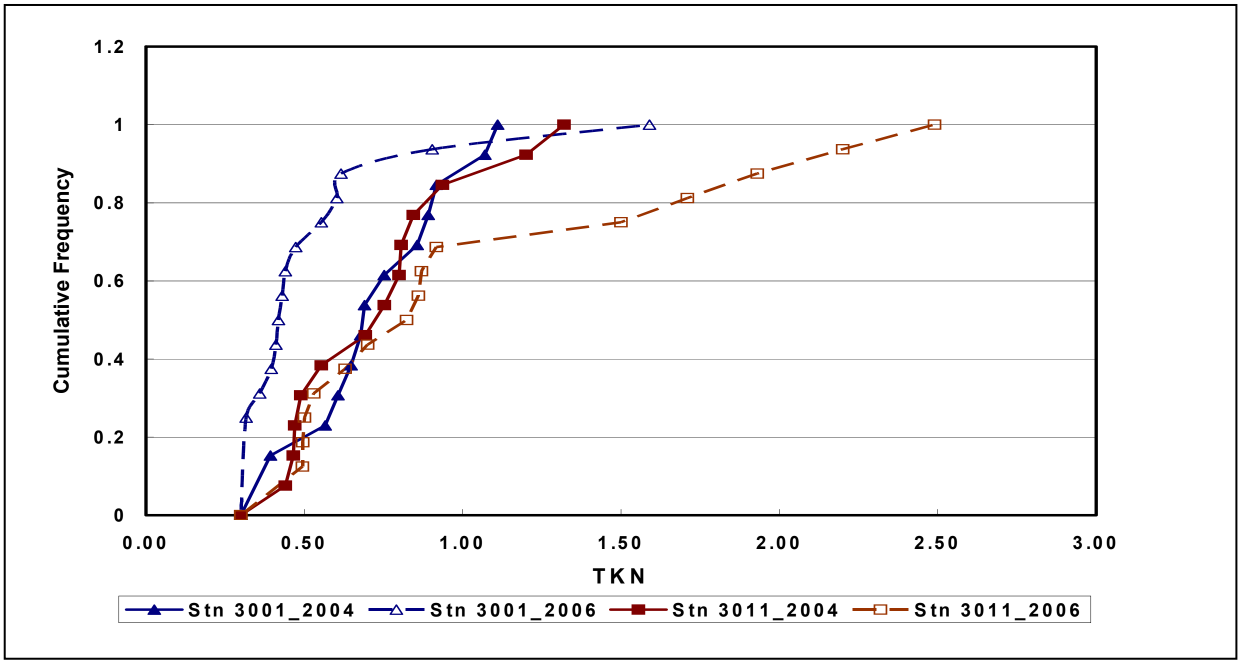

Figure B1. Cumulative Frequency Plot for TKN in Control and Retrofit Stations during pre- and post-intervention periods

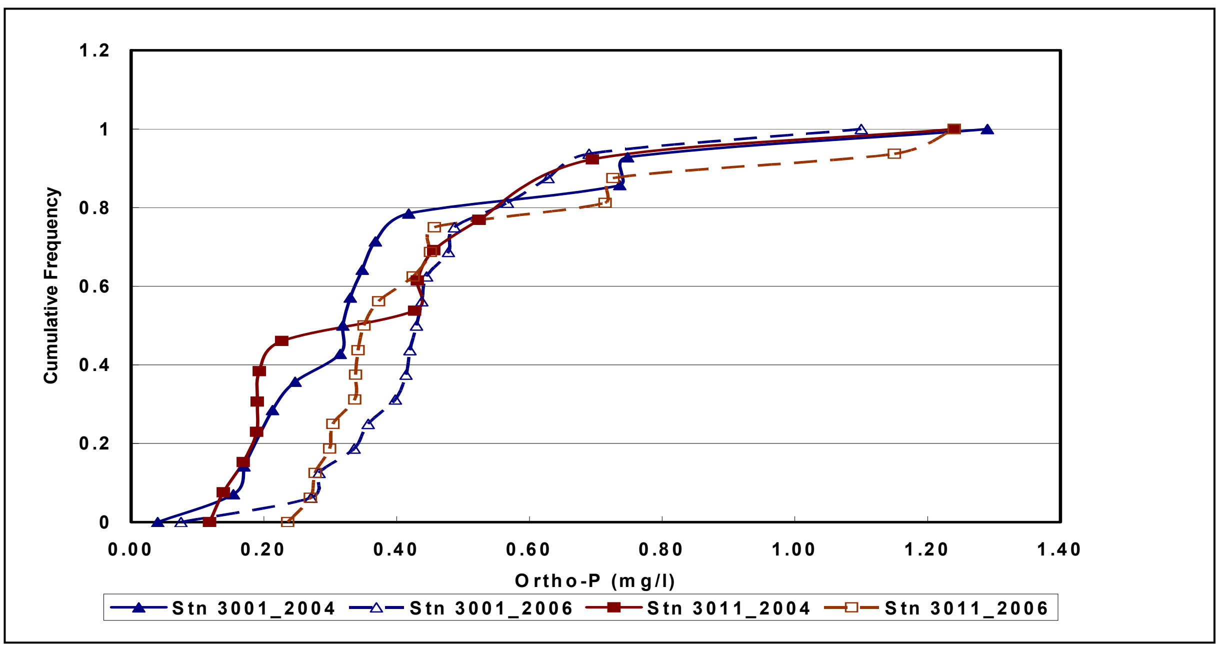

Figure B2. Cumulative Frequency Plot for Ortho-P in Control and Retrofit Stations during pre- and post-intervention periods

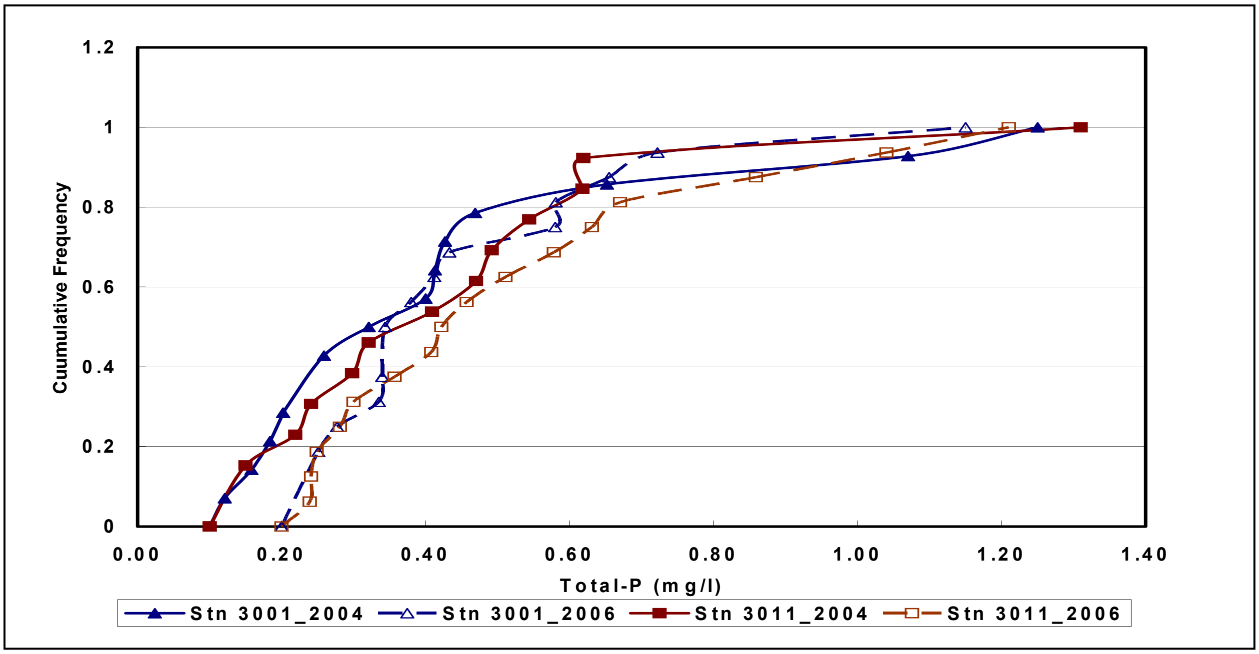

Figure B3. Cumulative Frequency Plot for Total-P in Control and Retrofit Stations during pre- and post-intervention periods

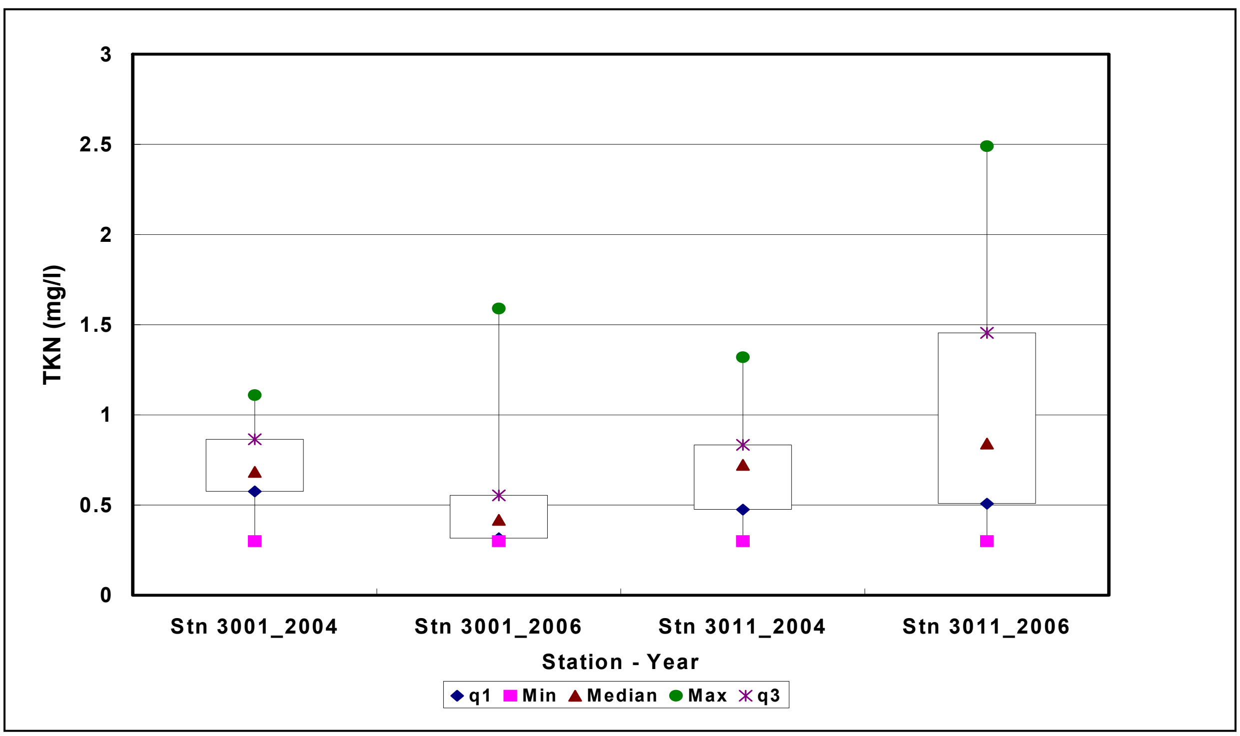

Figure B4. Box Plot for TKN in Control and Retrofit Stations during pre- and post-intervention periods

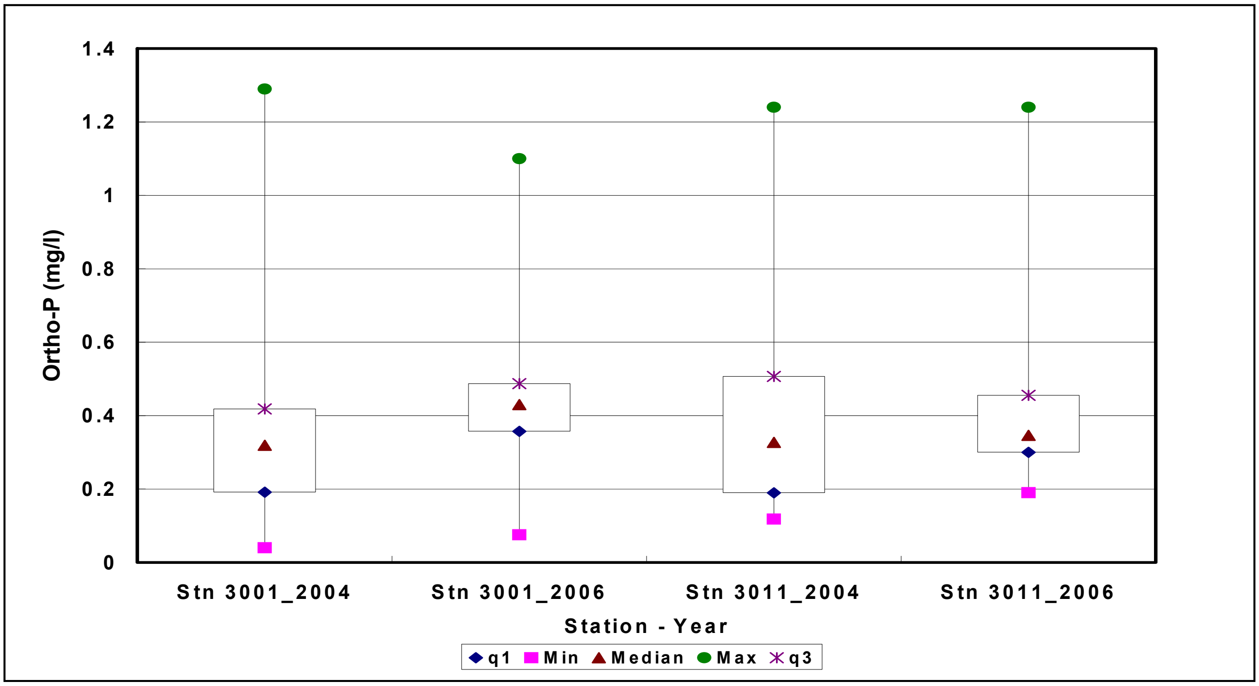

Figure B5. Box Plot for Ortho-P in Control and Retrofit Stations during pre- and post-intervention periods

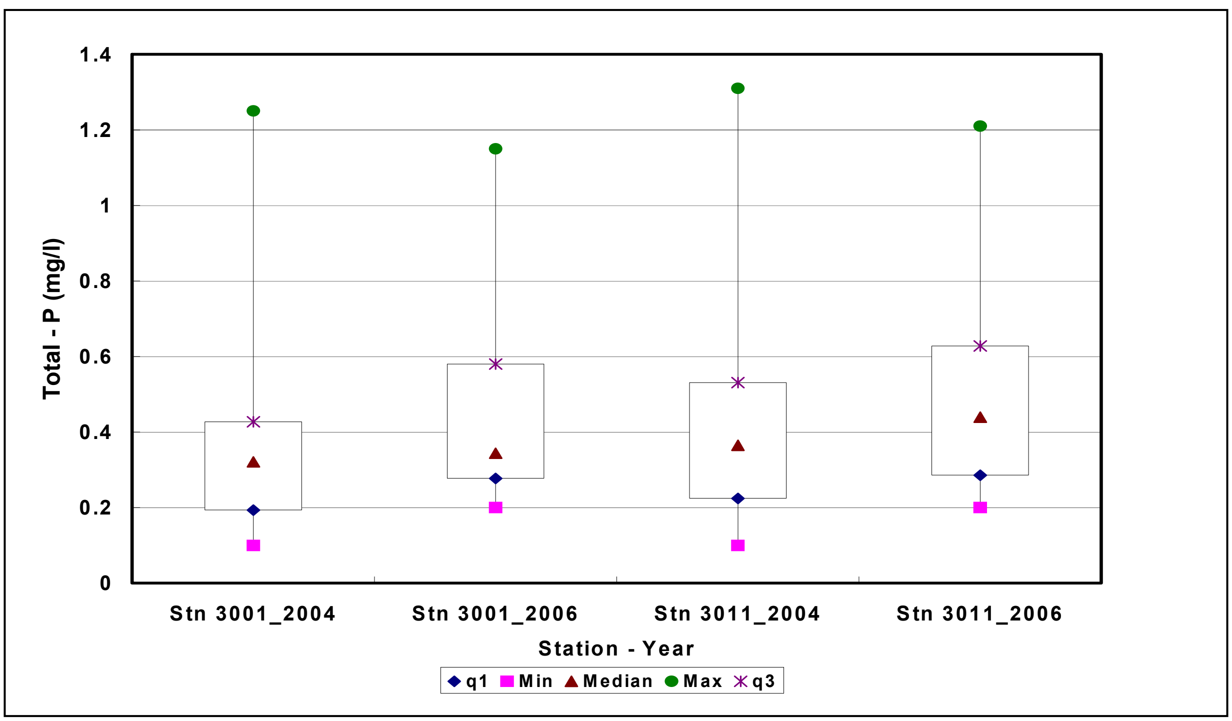

Figure B6. Box Plot for Total-P in Control and Retrofit Stations during pre- and post-intervention periods