Chapter 2: Study Methodology

2.1 Overview

Historically, water agencies have utilized educational programs and in some cases allocation-based rate structures to achieve improved irrigation efficiency in urban landscapes. With the introduction of "smart" weather-based irrigation controller technology, which in early studies generated quantifiable and reliable irrigation water savings over time, water agencies may now have a new and effective management tool to introduce to residential and other customers. The R3 Study compared, in a controlled setting, water savings and watershed management benefits of a remote, weather-based "ET" automated irrigation controller technology. This chapter of the report presents information on the methodology used in the following areas:

- Study design, including study area development, flow monitoring and water quality sampling procedures, and determination of a viable ET irrigation controller operation and selection process.
- Evaluation of water conservation savings.
- Quantification of dry season runoff reduction savings.
- Assessment of water quality impacts.
- Approach to public acceptance/public education.

More information on study design is presented in Appendix B. Evaluation-specific information on study design, data collection/analysis, and results is presented in Chapters 3 through 6 for water conservation, dry season runoff reduction, water quality, and public education, respectively. Additional details are provided in Appendices C through F.

2.2 Study Design

Study design included developing a viable study area, which provided for accurate data collection and comparison. Identifying appropriate flow monitoring equipment and determining an effective ET irrigation controller operation and selection were also important.

The goal of this study is to compare the effectiveness of technological BMPs versus public education for reducing the volume, concentrations, and mass emissions of potential pollutants in dry weather runoff from irrigated landscapes. The technological BMP consisted of ET controllers that communicate with irrigation systems of individual households and selected large landscapes, such as street medians, parks, etc. This technology is designed to optimize watering times for landscaped areas, hence reducing over-watering and resultant runoff. (See Section 2.2.3.) The public education campaign focused both on appropriate watering times and on the correct application of pesticides, herbicides, and fertilizers. (See Section 2.3.4.) These two types of BMPs were tested in residential neighborhoods, typically the most common land use in urban watersheds (Wong et al.1997). The goal was to determine if technology or education provides more pollutant reduction so that urban runoff managers can select optimal runoff pollutant minimization strategies.

2.2.1 Development of the Study Area

When developing the R3 Study area, the study partners focused on identifying watersheds with similar characteristics that would enable them to confirm water savings identified in the previous "Westpark" study, a water conservation evaluation (IRWD, MWDOC and MWD, 200l). Because a parallel purpose was to expand upon the findings of the Westpark study by measuring changes in dry weather volume (dry season runoff evaluation) and pollutant content of residential runoff (water quality evaluation) associated with improved irrigation management practices, both single-family residences and medium-size landscapes were considered. The R3 Study area is located within IRWD's service area as shown on Figure 2-1.

The R3 Study involved data collection and evaluation not previously attempted at such a large scale. In order to ensure reliable and accurate results, the study team sought to minimize the effects of outside variables that might produce "skewed" results. The team designated a study area that included five similar neighborhoods in Irvine, California. The study area was configured so that meaningful data could be provided for the water conservation, dry weather runoff reduction, and water quality evaluations. Runoff from each of the neighborhoods could be isolated and sampled at a single point from within the municipal sewer system, enabling each neighborhood to be treated individually. At these points of drainage, the runoff volume was monitored, and water quality samples were taken. The five neighborhoods are summarized in Table 2-1 and depicted graphically on Figure 2-2.

Table 2-1
Summary of Neighborhoods

Name	Description/Purpose	Comments
Site 1001 Retrofit Group	The homes in this group were retrofitted with an ET controller and also received education information.	The Retrofit Group area consisted of: • 112 residential landscapes • 12 City of Irvine streets • 2 condominium associations • 1 homeowners association
Sites 1002 – 1004 Control Groups	The homes in this group were monitored as experimental control groups and received no ET controller and no public education materials.	The Control Group area had evaluation-specific variations in size and configuration. In addition, some evaluations assessed "matched" and "unmatched" controls from within and outside of the study area.
Site 1005 Education Group	The homes in this group received information materials only (the same education information as supplied to the Retrofit Group).	The Education Group consisted of 225 homes identified by visual selection. This area also included one large school site.

Figure 2-1
Location of R3 Study Area Within Southern California

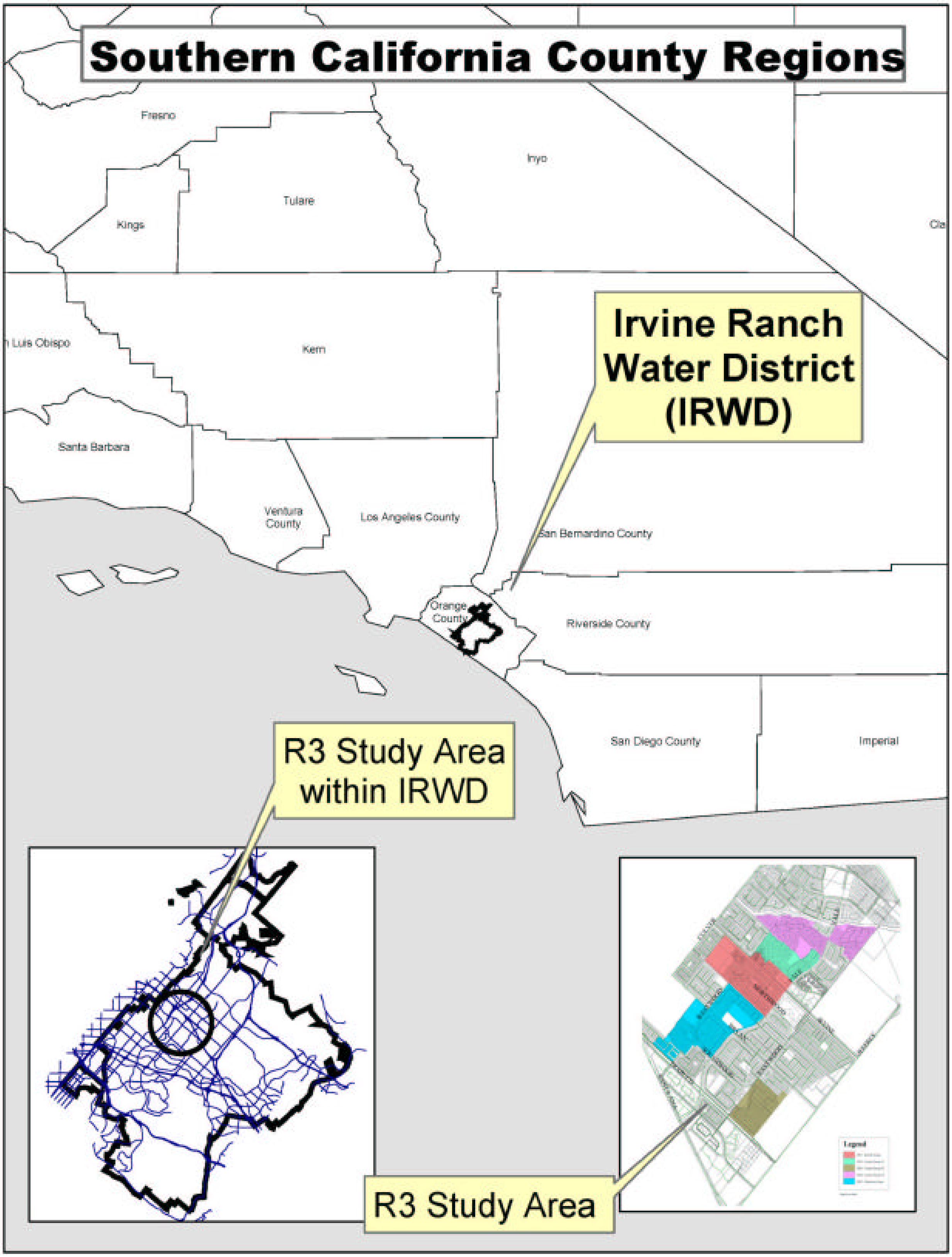
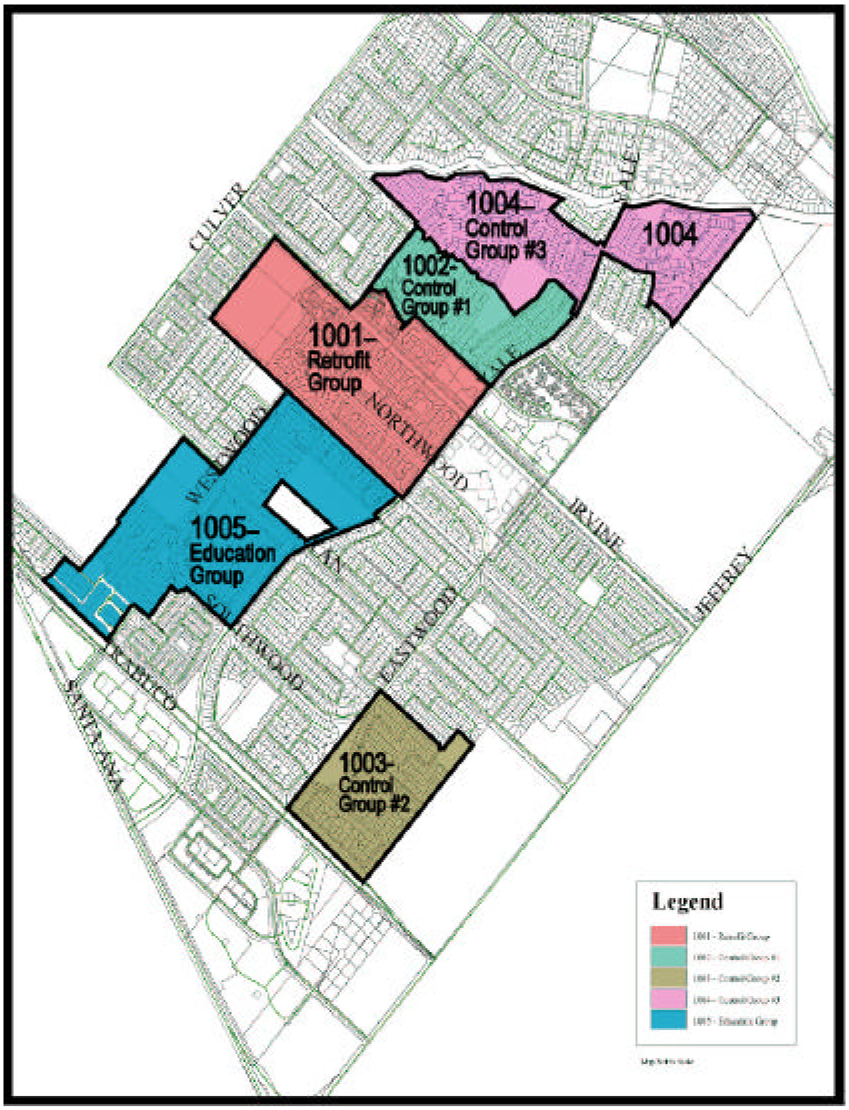


Figure 2-2
R3 Study Neighborhood Areas



In the first of the neighborhoods (Site 1001 or retrofit group), participating homes received a site evaluation and installation of an ET controller to automatically adjust irrigation schedules. Additionally, the residents at these homes received information regarding environmentally-sensitive landscape maintenance practices. The controllers were installed in 112 residential homes, 12 city street landscapes in the City of Irvine, two condominium associations' landscapes, and one homeowners association (HOA) landscape. The HOA landscape had three distinctive sites: 1) pool/park/tennis courts, 2) park, and 3) streetscapes.

The second neighborhood (Site 1005, or education group) received the same environmentally-sensitive landscape maintenance information as the first group, as well as a suggested irrigation schedule.

The three remaining neighborhoods (Sites 1002 – 1004, or control group) did not receive ET controllers and were not provided educational materials. Residents in the control groups had no knowledge of the study and were used only for comparison purposes. The make-up of the control group varied depending upon the evaluation. In the water conservation evaluation, "matched controls" were used in addition to the control group sites. In the water conservation and the dry weather runoff evaluations, only data from Site 1004 was used, as discussed in Sections 2.3.1 and 2.3.2. Data from all three sites was used in the water quality evaluation.

The five neighborhoods were selected based on the following criteria: 1) isolation from other neighborhood watersheds, 2) climate, 3) land use, 4) development age, and 5) irrigation water management techniques. These parameters are described in greater detail in Appendix B.

2.2.2 Flow Monitoring / Water Quality Sampling

This section summarizes the approach to flow monitoring and water quality sampling.

2.2.2.1 Flow Monitoring

Two main criteria were established for the study's flow monitoring equipment. First, the monitor could not alter the pipe or channel. Second, the monitoring had to be sufficiently accurate to distinguish seasonal flow changes and any flow change that resulted from the two study treatments (retrofit and education). Because the storm drain systems used for flow monitoring are designed to convey peak storm flows, and the focus of the R3 study was on changes in dry season (low flow) runoff associated with the treatments, the flow monitors had to be able to detect relatively small differences in low volume flows in large diameter storm drains. This situation was exacerbated by the fact that only a portion of each tributary neighborhood received the study treatments. Two flow monitoring technologies were determined to meet these criteria:

- Manning's equation plus a level sensor
- Velocity sensor and level monitor (area-velocity)

The area-velocity method was chosen due to lack of slope information for the storm drain system. The selected equipment was an American Sigma 950, which is battery-operated and can record data every minute. The equipment has an ultrasonic transmitter and a velocity sensor, both of which were installed in the storm drain. The ultrasonic transmitter establishes the water surface level and area, while the velocity sensor determines the velocity of the water in the pipe. Flow is calculated by the equation:

- Flow = Area x Velocity

Because four of the five monitoring locations were in a pipe, several variations on the ultrasonic transmitter / velocity sensor were tested before the combination of sonic and velocity wafer were finalized.

The accuracy of the flow monitoring equipment was tested at all study sites. This was accomplished by metering flow (at three different levels) from a fire hydrant within each tributary watershed and comparing these metered flows to flows measured at the flow monitoring locations. As expected, the accuracy of the flow monitors varied from site to site depending on the nature and condition of each storm drain. For example, some settling of the storm drain was noted near the flow monitor for Site 1002, resulting in an accumulation of sediment. This physical "anomaly" altered the hydraulic characteristics of the pipe and affected the accuracy of flow measurements. However, based on the flow test results, it was believed that these issues were manageable. The subsequent analysis of flow data as presented in Chapter 4 of this report suggests that this belief was partially correct; although flow monitoring problems required data from two of the three control sites to be discarded, the data from the other three sites (two treatments and one control) was sufficiently accurate to allow for the determination of meaningful statistical results.

2.2.2.2 Water Quality Sampling

The water quality sampling program quantified constituents found in residential runoff flows. This program consisted of two phases: 1) pre-study and 2) dry weather sampling. More information about water quality sampling and analysis is provided in Section 2.3.3, Chapter 5 and Appendices B and E.

2.2.3 ET Irrigation Controller Operation and Selection Process

The technology-based BMP consisted of an ET controller + education. The ET controller selected was similar to most automatic sprinkler timers available at home improvement stores and nurseries, but with the capacity to receive radio signals that will alter sprinkler timing based on current weather conditions. If the weather is hot and dry, the radio signal calls for longer or more frequent irrigation. If the weather is cool and moist, such as recent precipitation, the radio signals call for shorter or less frequent irrigation. For the R3 Study, the existing sprinkler timers that are set manually by the homeowner were replaced with the radio-controlled ET controller systems. Trained technicians were used to ensure successful installation because the ET controller requires programming for each valve including area (size of yard or planter per valve), soil type (clay, sand, etc.), and landscape type (turfgrass, shrubbery, etc.). The remaining irrigation system was unchanged, including piping and sprinkler head configuration.

Since residential areas include landscapes other than the homeowners, these "common area" and streetscape landscape areas ("medium-size" landscapes) were included in the water management component of the R3 Study. As shown in Table 2-2, the medium-size landscapes accounted for an estimated 70 percent of the total landscape area treated in the retrofit group (Site 1001). The installation process for both residential and medium-size landscapes is described in Appendix B.

2.2.3.1 Controller Installation

The study evaluated the performance of the engineering of irrigation management techniques to reduce the consumption and residential runoff while maintaining the quality of the landscape. A typical irrigation controller is difficult to program and limited in the scope of the scheduling ability. Proper scheduling requires calculations based on real time ET data, landscape topography, and plant type, which are beyond the capabilities of typical controllers. The landscaper in the field is left to guess or rely on past experience as to the correct amount of water, the correct runtime to prevent runoff, and the correct number of days of the week to water.

The controllers were installed following the general principle that an ET controller is a water management tool and that professional operation should result in conservation and reduction of runoff. A picture of the controller is shown on Figure 2-3. More information is provided in Appendix B.

Figure 2-3
ET Controller

2.2.3.2 ET Controller Operation

The operation of the ET controller in this study was optimized by proper irrigation scheduling. As discussed further in Chapter 4 and Appendices B, D1 and D2, the ET controller must meet three key criteria: cost, ease of operation, and ability to conserve water and reduce runoff.

2.3 Study Evaluations

This section summarizes the water conservation evaluation, the quantification of changes in dry season runoff reduction savings, the analysis of water quality impacts, and the approach to customer acceptance / public education.

Table 2-2
Study Sites Land Use and Treatment Summary

Site 1001

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage*	No. of Controllers
SFR	565	66.8	112	6.6	112
Condo	109	10.3	2	1.9	8
HOA	4	5.9	1	0.9	3
School	2	4.6			
Landscape	10	19.4	12	11.2	15
Street	97	49.7			
Unmetered	64	11.5			
Total	**851**	**168.1**	**127**	**20.5**	**138**

***Note: All acreage except SFR were considered "medium-size" landscapes.**

Site 1002

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage	No. of Controllers
SFR	-	-	control	control	control
Condo	-	-	control	control	control
HOA	-	-	control	control	control
School	-	-	control	control	control
Landscape	-	-	control	control	control
Street	-	-	control	control	control
Unmetered	-	-	control	control	control
Total	**-**	**-**			

Table 2-2 (continued)
Study Sites Land Use and Treatment Summary

Site 1003

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage	No. of Controllers
SFR	-	-	control	control	control
Condo	-	-	control	control	control
HOA	-	-	control	control	control
School	-	-	control	control	control
Landscape	-	-	control	control	control
Street	-	-	control	control	control
Unmetered	-	-	control	control	control
Total	**-**	**-**			

Site 1004

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage	No. of Controllers
SFR	417	47.8	control	control	control
Condo	-	-	control	control	control
HOA	1	0.9	control	control	control
School	1	8.0	control	control	control
Landscape	2	0.0	control	control	control
Street	42	25.0	control	control	control
Unmetered	61	7.1	control	control	control
Total	**524**	**88.8**			

Site 1005

Land Use	No. of Lots	Acres	Treatment Sites	Treatment Acreage	No. of Controllers
SFR	559	67.9	225	13.0	n/a
Condo	-	-	-	-	n/a
HOA	1	1.5	-	-	n/a
School	2	12.1	-	-	n/a
Landscape	2	0.0	-	-	n/a
Street	45	0.0	-	-	n/a
Unmetered	8	2.7	-	-	n/a
Total	**617**	**84.2**	**225**	**13.0**	**0**

2.3.1 Water Conservation Evaluation

The water conservation evaluation was conducted by A&N Technical Services, Inc. The firm performed a statistical analysis of historical water consumption records from, roughly, July 1997 to August 2002. Two main types of water use were reviewed: single-family residences and medium-size landscapes. For the single-family residences, data was compared among the retrofit group, the education group, and the control group. For the medium-size landscape accounts, a slightly different approach was used. Accounts within the study area were compared to "matched" and "unmatched" controls in the City of Irvine, both within and outside of the study area. Matched controls were similar in sun exposure, irrigation type, soil type, etc. Unmatched controls were areas not similar enough to be used for direct comparison but areas that could be used for weather normalization. A detailed description of the methods used to evaluate water savings for the single-family residence and medium-size landscape sites is provided in Chapter 3 and Appendix C of this report.

2.3.2 Dry Season Runoff Reduction Savings Quantification

In addition to the water conservation evaluation, A&N Technical Services, Inc., performed a statistical analysis of the reduction of runoff induced by ET controller and irrigation education. With the assistance of IRWD staff, who collected runoff data, A&N developed regression models to estimate mean runoff by site.

Two of the control sites (1002 and 1003) had recurring measurements issues that produced generally unreliable data. Site 1002 was found to have a physical hydraulic jump, which caused sediments to build in such a way that flows avoided the monitor. At Site 1003, there was an occurrence of illegal dumping of cement into the storm drain. This event reshaped the monitoring area, led to continuous collection of debris, and caused the monitor to perform erratically. Thus, it was only possible to use data from Site 1004. More details are provided in Chapter 4 and Appendices D1 and D2.

2.3.3 Water Quality Impacts Assessment

As described in Section 2.2.2.2, the water quality sampling program quantified constituents found in residential runoff flows. Two independent reviews of the water quality data were performed. The initial review, conducted by SCCWRP, used parametric statistical techniques (t-test; analysis of variance [ANOVA]), which provide a good descriptive review of the study. However, these techniques are generally considered to have less power for detecting differences in data than other statistical tests. A subsequent statistical overview was performed by Geosyntec Consultants to review alternative and possibly more "robust" data analysis techniques. This work, which included the review of only a portion of the data set, focused on additional descriptive techniques (time series plots; box plots; probability distributions) and the use of non-parametric statistical techniques (rank-sum test; Kruskal-Wallis [K-W]). The SCCWRP and Geosyntec Consultants reports are presented in Appendix E-1 and E-2, respectively.

2.3.4 Public Acceptance / Public Education Approach

The public acceptance evaluation was conducted to compare the effectiveness of proposed BMPs for ET controller technology + education and education only. The participating ET technology retrofit group homes received a site evaluation and installation of an ET controller to manage the irrigation system. Additionally, the residents of these homes received information regarding environmentally-sensitive landscape practices. The education-only group received an initial informational packet containing three items: an introductory letter, an informational booklet, and a soil probe to measure the water content of landscaped soils.

In addition to the initial packet, monthly reminders were mailed to each homeowner that included tips for maintaining the irrigation system. Suggested sprinkler run times (for the non-ET controller neighborhood) and tips on fertilizer or pesticide application usage, including non-toxic alternatives, were also provided in the monthly newsletter. A telephone log was kept to monitor incoming customer calls relating to the R3 Study, and a pre- and post-program survey was developed to measure customer impact of the study. More details are provided in Chapter 6 and Appendix F.