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Evaluation of Municipal Water District of Orange County's Comprehensive Landscape Water Use Efficiency Program (CLWUE)

Prepared by:

MUNICIPAL WATER DISTRICT OF ORANGE COUNTY

The Family of Orange County Water Agencies

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- Metropolitan Water District of Southern California
- Municipal Water District of Orange County
- The Family of Orange County Water Agencies

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Executive Summary

The Comprehensive Landscape Water Use Efficiency (CLWUE) Program was developed by the Municipal Water District of Orange County (MWDOC) as a holistic landscape improvement program to provide monetary incentive, in the form of a rebate, for customers to implement water savings measures. The Program targeted the upgrade of antiquated irrigation equipment to smart irrigation timers, referred to as weather based irrigation controllers (WBICs), high efficiency rotating nozzles, and drip irrigation (through the Spray-to-Drip or S2D Program), the conversion of turfgrass to a CA Friendly landscape (through the Turf Removal Program), and the conversion of dedicated irrigation meters to a sustainable source.

A Program Evaluation was conducted to explore what successes and challenges came with the implementation of the Program and the Program results in terms of actual water savings. The Evaluation consisted of two parts, a Process Evaluation where customers were contacted about their experience with the Program, and an Impact Evaluation that included a statistical analysis to evaluate actual changes in residential customer water consumption. The goal of the Process Evaluation was to survey the participants of the Program regarding their observations and satisfaction since completing the Program in order to evaluate its effectiveness. The purpose of the Impact evaluation was to quantify the actual water savings resulting from the CLWUE Program and to explore how savings may be effected by the implementation of one versus two water savings measures.

The Process Evaluation survey revealed an overall positive customer response to the Program. Over 60% of participants reported that since completing their project they have noticed water savings, and 80% reported that their landscape was maintained or improved with the installation of their water savings measure. The majority of respondents indicated they would not have purchased or installed the device if not for the rebate program, and that based on their experience, they were likely to participate in another water savings program. Results suggest that an increase in program marketing and resources is something to consider moving forward.

The Impact Analysis showed there were statistically significant reductions in water consumption once installing/completing a WBIC, rotating nozzles, turf conversion, or drip irrigation. On average, WBIC customers reduced consumption by 50 gallons per day (gpd), 11% overall, and 50 gpd/clock; Rotating Nozzle sites saved 56 gpd, 11% overall, and 1.55 gpd/nozzle; Turf Removal sites saved 86 gpd, 25% overall, and 0.121 gpd/sqft; and S2D sites saved 85 gpd, 22% overall, and 0.118 gpd/sqft. Statistically significant water savings also occurred for sites implementing two measures. Sites installing a WBIC and Rotating Nozzles reduced consumption by 41 gpd or 8% overall and 1.28 gpd/timer/nozzle; WBIC and Turf Removal sites saved 87 gpd or 27% overall and 0.125 gpd/sqft/timer; Turf Removal and S2D sites saved 86 gpd or 26% overall and 0.124 gpd/sqft. Sites that installed a WBIC and participated in Turf Removal saw a statistically significant increase in water savings from sites that only installed a WBIC. There was not a significant increase in savings for other sites installing two measures.

Through the Program, more than 13 acres of turf grass has been converted to CA Friendly landscapes, 3,031 timers have been upgraded to WBICs, 51,806 inefficient spray heads have been upgraded to high efficiency rotating nozzles, 10,423 sqft of landscape previously irrigated by spray heads has been upgraded to drip irrigation, and 50 dedicated irrigation meters have been converted to utilize recycled water. These measures are saving Orange County more than 1,160 acre feet per year (AFY) of potable water and will save 14,211 acre feet (AF) over the life of the projects, exceeding the Program goals.

Introduction

The Municipal Water District of Orange County (MWDOC) offered the Comprehensive Landscape Water Use Efficiency Program (CLWUE Program or Program) from October 2015 to September 2018. The CLWUE Program emphasized MWDOC's suite of existing rebate programs to incentivize holistic landscape conversion such as irrigation device improvements, management approaches, and turf replacement in Orange County, California. Through this Program, turfgrass was transformed to California Friendly landscapes, emphasizing plantings with water needs similar to our natural average precipitation of 12 inches per year, antiquated irrigation controllers and spray nozzles were converted to smart devices and high-efficiency, low precipitation equipment, and dedicated irrigation meters were converted from potable water to an alternative, sustainable source. These best management practices (BMPs) resulted in reduced water consumption (water savings) and reductions in dry weather and stormwater runoff and its associated non-point source pollution. Urban runoff is identified as one of the top threats to ocean and surface water quality in Orange County, directly affecting beach health and its public accessibility.

The CLWUE Program utilized a rebate platform to incentivize the implementation of the aforementioned landscape BMPs. These measures increased the uniformity, efficiency, and management of irrigation systems, resulting in efficiency in water management and promoting activities that support water supply sustainability and drought resiliency.

Best Management Practices

To encompass a holistic approach to landscape improvements, the CLWUE Program focused on the following efficient landscape water use BMPs to achieve the water savings goal of 1,160 AFY.

Weather Based Irrigation Controllers

The WBIC Program advances the use of smart water application technologies to replace antiquated irrigation timers. WBICs are irrigation controller devices that regulate irrigation water use automatically by adjusting to site conditions via real time weather data or soil moisture conditions. WBICs determine how much irrigation to apply based on factors such as temperature and humidity, with weather data supplied as either signal-based or sensor-based. Soil moisture irrigation controllers offer the opportunity to optimize irrigation based on measured plant demand in the irrigation system. The sensor system can result in the bypass of scheduled irrigation events based on soil moisture content. These devices are an effective tool to automate efficient irrigation scheduling management. For the purposes of this study, weather based and soil moisture based controllers will collectively be referred to as WBICs. The goal of the WBIC Program was to install 980 smart irrigation timers, saving 362 AFY.

High Efficiency Rotating Nozzles and Drip Irrigation

The High Efficiency Rotating Nozzles Program, referred to as the Rotating Nozzles Program, promotes the implementation of high efficiency, low precipitating nozzles to replace stationary or fixed spray irrigation nozzles, the most common irrigation heads installed for ornamental beds and small turfgrass areas. These traditional spray heads apply more water than any other typical domestic irrigation nozzle head, with an average precipitation rate of 1.5 inches per hour or 60 to 180 gallons per hour (GPH), and also apply water at a rate faster than the infiltration rate of local soils, causing runoff. In addition to the high application rate, stationary spray heads have poor uniformity rates, with an average distribution uniformity of 0.41. As a result, irrigation with these types of heads is often over-designed (i.e., too many heads are installed per area) and/or over-scheduled (i.e., the irrigation system is set to run too long, beyond the plant water needs), resulting in excessive irrigation water use and runoff.

Low-precipitation rate irrigation, such as multi-trajectory and multi-stream (rotating) nozzles can yield an increase in distribution uniformity, leading to an increase in water use efficiency and a reduction in runoff. Rotating nozzles have shown a 45% increase in distribution uniformity compared to stationary spray heads. Furthermore, the precipitation rate of rotating nozzles ranges from 0.4 to 0.6 in/hr.

The Spray-to-Drip (S2D) Program provides another route for customers to replace their inefficient spray irrigation with an efficient alternative. Drip irrigation in bedded areas results in more efficient water application because it targets the root zone of the plants and irrigates 50% or less of the area, yet still results in significant increase in system efficiency. Typically drip irrigation does not wet the entire root zone; therefore, the application rate concept does not apply. These emitters have various emission rates ranging from 0.3 to 2 GPH, but most commonly flow at 1 GPH or less. Previous analysis has found sites converting to drip irrigation can cut outdoor irrigation use in half, and in most cases, completely eliminates dry weather runoff.

The goals of the Rotating Nozzles and S2D Programs were to convert 86,000 spray nozzles to high efficiency rotating nozzles, saving 344 AFY, and convert 41,000 spray nozzles irrigating 490,000 sqft of landscape to drip irrigation saving 69 AFY. Combined, this will convert 127,000 high-volume overhead spray irrigation nozzles to low-volume rotating nozzles or drip irrigation saving 413 AFY.

Turfgrass Removal

The Turf Removal Program provides incentives for participants to remove non-functional, irrigated turfgrass which, on average, requires more than four feet of supplementary irrigation water each year, will be replaced by low-water-using California Friendly plantings or living groundcovers, which require less than half the water needed by turf grass. Participants must also convert their irrigation system to low-precipitation rate equipment, adequately apply mulch to retain soil moisture, and only install materials that are permeable to air and water. The goal of the Turf Removal Program was to convert approximately 9.8 acres of non-functional turf grass to a CA Friendly landscape, saving 60 AFY.

Sustainable Water Source Conversion

The focus of this component is recycled water meter conversions. This Program provided incentives for commercial sites to convert dedicated irrigation meters to be sourced by recycled water. This results in 100%, long-term, potable water savings, and also expands the purple pipe grid to increase feasibility of future projects. The goal of the Sustainable Water Source Conversion Program was to convert 50 meters to a sustainable source, resulting in 325 AFY of potable water savings.

Evaluation Need

The purpose of this Program Evaluation is to analyze Program impact, participation, and trends. In additional to fulfilling a grant agreement requirement, MWDOC is looking to determine what successes and challenges came with implementation of the CLWUE Program, the results of the Program in terms of actual water savings, and to continue to evaluate our Programs to contribute to available data and research in this field. This Program Analysis assesses two central aspects of the CLWUE Program: Program process and Program Impact. As part of the Program Process Evaluation, an anonymous survey was distributed to Program participants to determine Program participation trends and customer responses to the Program. The Impact Analysis includes a statistical evaluation performed to determine the impact of Program participation on customer water use. This is used to determine effectiveness in terms of water saved, but will also contribute new research and analysis to the individual programs included in the broad CLWUE program, such as how the implementation of multiple devices may influence water savings.

Evaluation Objectives

One of the primary goals of this analysis is to quantify water savings at sites which incorporate one and two BMPs, and to gain insight on how to best improve MWDOC's programs moving forward.

The goal of the Program Evaluation is to determine:

1. Impact on water consumption
2. Impact of installing or participating in multiple programs
3. Participation motivations and trends
4. Customer response to the Program

This Evaluation will look to answer the following questions:

1. Did participants in the rebate programs save water?
2. Did participants who installed/participated in two programs save more water than those who installed or participated in one program?
3. Were the implemented programs successful?
4. How can programs be improved?

Program Effectiveness

Since the launch of the CLWUE Program in October 2015 to the reporting period ending September 30, 2018, the water savings goal of saving 1,160 AFY, and 12,783 over the life of the projects, has been surpassed, see Table 1. While two Programs came in under the specific goal for that device, Rotating Nozzles and Drip Irrigation, the others came in above their specific program goals and ultimately exceeded the overall CLWUE Program water savings goal.

Table 1. CLWUE Program Activity

	Quantity Implemented	Measure	Implemented Savings (AFY)	Lifetime Savings (AF)	Quantity Goal	Savings Goal (AFY)	Savings Goal Life (AF)
Turf Removal	571,479	sqft	77.5	775	425,000	60	595
WBIC	3,031	timers	611.6	6,116	980	362	3,625
Rotating Nozzles	51,806	nozzles	139.3	697	86,000	344	1,720
Drip Irrigation	10,423	sqft	1.4	7	491,450	69	334
Sustainable Meter Conversion	50	meters	330.8	6,616	50	325	6,500
Water Savings Totals			**1,160.6**	**14,211**		**1,160**	**12,783**

Process Analysis

The Process analysis aimed to gain customer perspective on the WBIC and Rotating Nozzles rebate programs included in the CLWUE Program. Previous MWDOC surveys have focused on S2D and Turf Removal, allowing this effort to focus on WBIC and Rotating Nozzle participants. A survey was issued to Program participants to help understand customer response to the Program, including Program satisfaction, perceived outcomes, best marketing techniques, and what participants may wish to see in the future.

Customer Survey

The Program results and satisfaction survey was distributed via email using the SurveyGizmo platform. An email containing a link to the survey was sent to customers who received a rebate for a WBIC and/or high efficiency rotating nozzles. The survey included up to 11 questions, depending on how questions were answered. Customers who indicated that their WBIC and/or nozzles were not installed and functioning properly were not directed to answer questions regarding their perceptions on how these devices have influenced water consumption or landscape health.

The Survey email reached 5,143 program participants and received 462 completed responses, a 9% response rate. Thirty people did not complete the entire survey, and partial responses were not included in the analysis.

Survey Participant Makeup

Customers were asked which rebate program or programs they participated in, with the choices of WBIC, Rotating Nozzles and Turf. While the survey was sent to participants of the WBIC and Nozzle programs, respondents were given the ability to also select Turf Removal to allow MWDOC to better catalogue how many respondents participated in two or three programs. Overall, the population of customers who participated in a combination of WBIC and S2D or Rotating Nozzles and S2D was less than 1%, so these combinations were not offered in the survey.

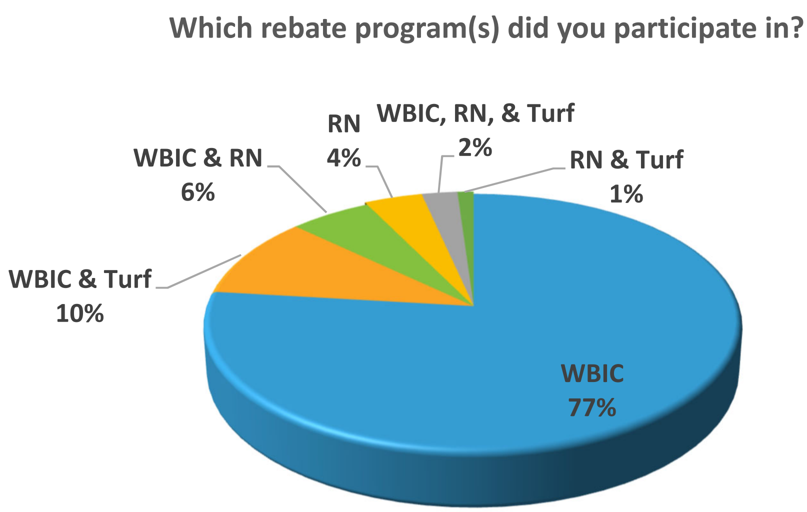

Figure 1. Device group participation by survey response.

The large majority of survey respondents participated in the Smart Timer Program only. Ten percent and 6% participated in WBIC and Turf, and WBIC and Rotating Nozzles, respectively. Figure 1 shows the complete breakdown of what programs the survey respondents participated in. These results are relatively consistent with actual participation rates, where WBIC participation is much higher than that of Rotating Nozzles. This outcome is also representative of the low levels of participation in Turf and Nozzles together.

Survey respondents were asked if their device or devices were installed and functioning correctly. Despite the survey being distributed to only those who received a rebate, 2% of WBIC only participants reported that their WBIC was not installed or functioning as it should, see Figure 2. All Rotating Nozzles and WBIC and Rotating Nozzles customers reported their device(s) were working as intended. Many WBIC applications are inspected before being approved; however, it is a logistical and financial burden to inspect 100%. This result shows that despite not all sites being inspected, nearly all WBICs and nozzles are installed properly.

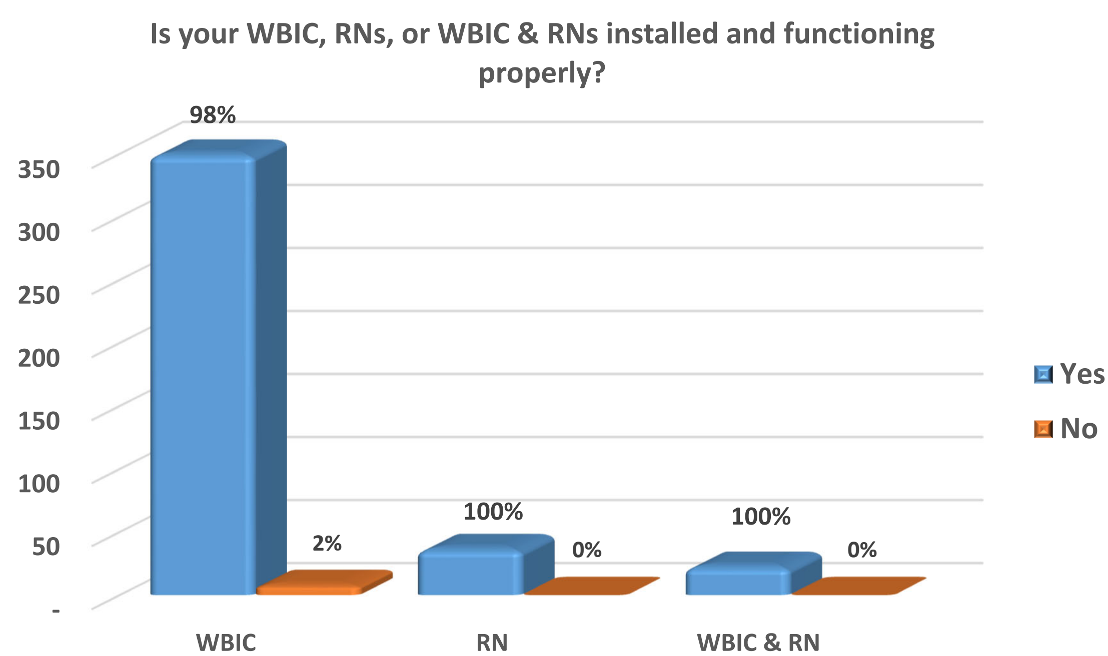

Figure 2. Vast majority of respondents reported that their device(s) are installed and functioning.

Survey respondents were asked if their device or devices were installed and functioning correctly. Despite the survey being distributed to only those who received a rebate, 2% of WBIC only participants reported that their WBIC was not installed or functioning as it should, see Figure 2. All Rotating Nozzles and WBIC and Rotating Nozzle customers reported their device(s) were working as intended.

Respondents who reported that their WBIC was not installed or functioning were asked what prevented them from doing so. The most common issue reported was that the WBIC was installed, but just not functioning properly, due to either user or manufacturer error, see Figure 3. Other reasons cited were difficulty installing, meaning technical installation regarding wiring and related installation steps, and difficulty programming, which represents issues when creating and entering irrigation programs on the controller after it has been installed and wired properly. Providing additional resources and support to customers to assist them after the controller has been installed may help with this issue. Generally, WBIC controllers must be connected to the internet, so this may also be in a factor in setup issues. Other multiple choice options for this question not shown in Figure 3 include 'just changed my mind' and 'I am planning to install at a later date', none of which were selected as a response.

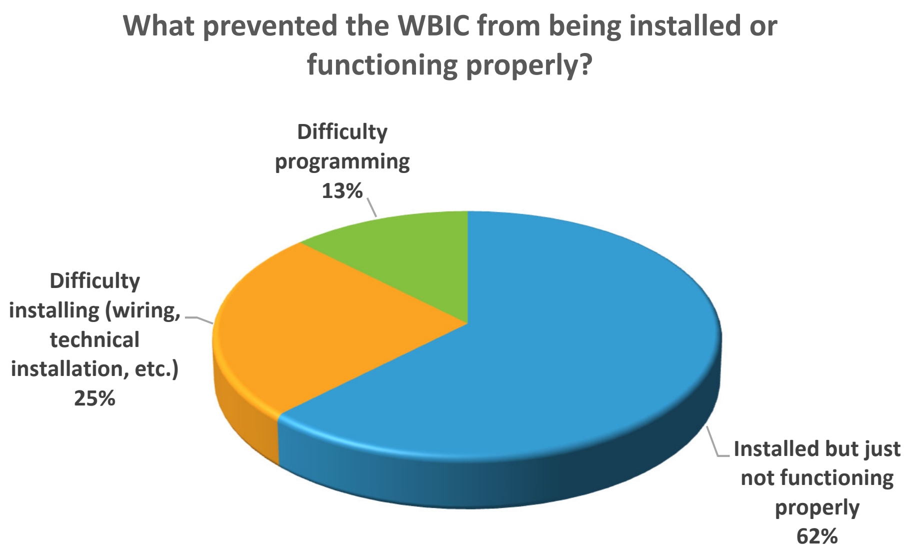

Figure 3. Why participants do not have their WBIC installed and functioning properly.

Customer Observations and Perceptions

Customers were asked to share their observations of their landscapes after installing their WBIC and/or Rotating Nozzles with regard to water use and irrigated landscape health. On average, 60% of survey participants responded that they felt like they were using less water to irrigate their landscape, the most popular response across the device groups, see Figure 4. All respondents who participated in Nozzles and Turf Removal noted that they felt like they were using less water, which is higher than the Rotating Nozzles Only group where 44% selected that response. This may be influenced by the presence of Turf Removal projects, which according to other MWDOC surveys, 90% of participants noted they noticed they were saving water. The percentage of participants noticing water savings is much higher than other responses with the exception of the Rotating Nozzles Only group, where 50% reported no change or that they were unsure of a change. Rotating nozzles have low precipitation rates, meaning some customers may have needed to increase irrigation run times to meet the water needs of their landscape. This may have led some participants to not realize a change in water savings or to think water consumption was being increased. Customers who installed a WBIC and Rotating Nozzles noted the highest instance of perceived increased water consumption. This may possibly be related to the Rotating Nozzle issue previously described, or to a similar issue occurring with WBIC installation. Because WBICs are based on actual weather, customers who may have been over irrigating in winter and under irrigating in summer (a common occurrence) are now, through the controller, applying more water during summer months to properly irrigate their landscape and saving more water during winter when many people may not necessarily expect to see savings.

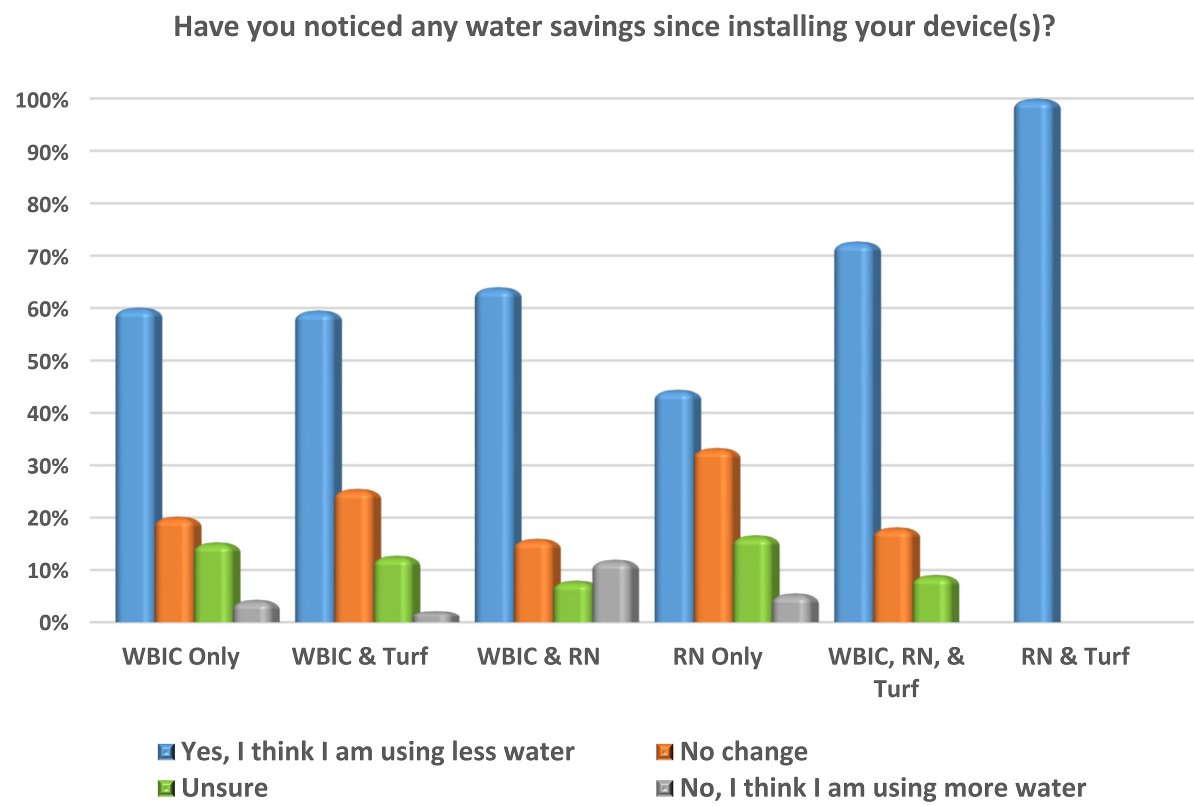

Figure 4. Customer observation of post device installation water consumption.

When asked about any changes to the health of their landscape, customers generally noted that a positive change had occurred. Forty-five percent of customers reported a positive change to their landscape, 34% reported no change, 8% were unsure of a change, and 13% reported a negative change. Figure 5 shows response per device group. Participants who implemented Rotating Nozzles and Turf Removal had the highest rate of reporting a positive change to their landscape, while the Rotating Nozzles Only group experienced the lowest and is the only device group where a positive change was not the most common response. This implies that Turf Removal may be more responsible for the response, which is reasonable considering Turf Removal is the only option that includes plant material changes. Similarly, WBIC and Turf was the second highest device group for positive landscape changes. WBIC and Rotating Nozzle participants reported the highest number of negative change responses, 20%; however, 40% of respondents did report a positive change to their landscape. Seventy-three percent of respondents noted either no change or a positive change, both of which signify that the participant has been able to improve their landscape or maintain its health by participating in a water savings program.

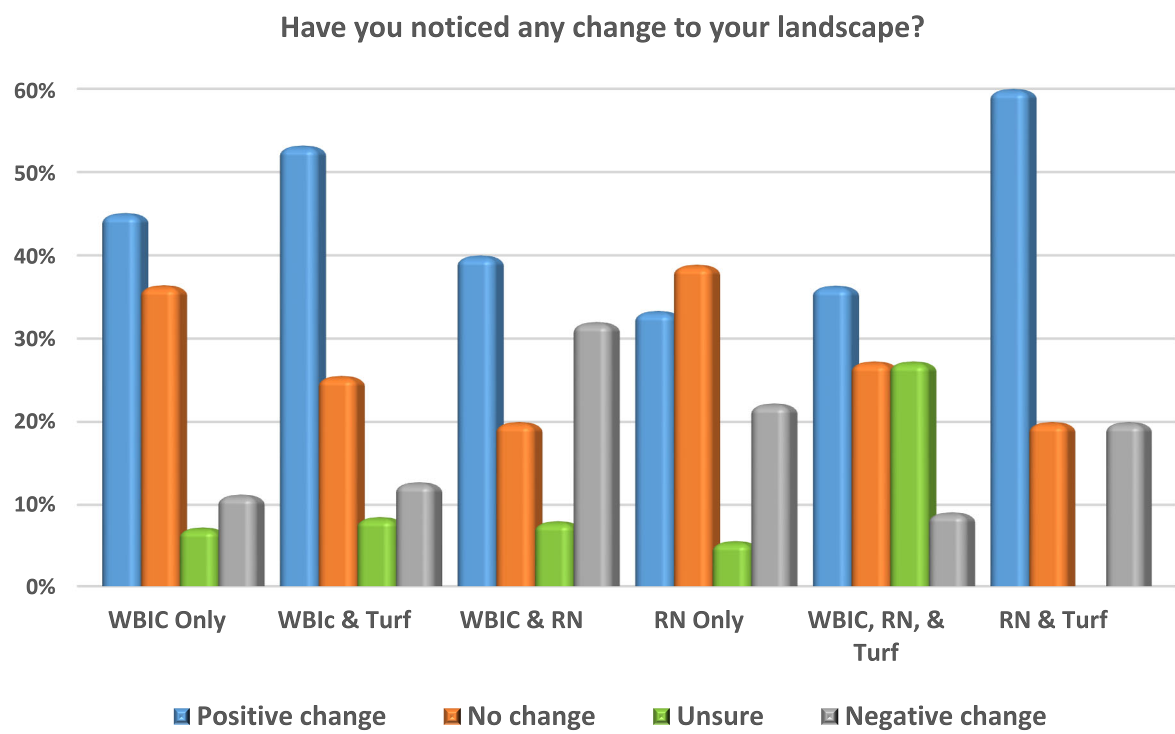

Figure 5. Customer observation of post device installation irrigated landscape health.

To see the relationship to perceived water savings and landscape health, each respondents' pair of answers was analyzed together. Figure 7 shows a matrix representing how survey participants responded to both questions as a pair. The percentage noted for each combination signifies the percent of the overall survey response population that selected that combination of response. The most positive response combination, a positive change to landscape and a reduction in water consumption, was also the most popular response, with 29% of respondents selecting both of those responses. The second most popular combination – using less water with no change to landscape health – was also an extremely positive combination, signifying water consumption has declined, but landscape health has been maintained. Together, these two pairs dominated the responses, with about 50% of respondents choosing those two responses. All other combinations represent 10% or less of the population.

Those who chose one of the two aforementioned dominant combinations represent the various device groups in the following way: 80% of Rotating Nozzles and Turf; 57% of the WBIC Only; 55% of the WBIC, Rotating Nozzles and Turf; 55% of the WBIC and Rotating Nozzles; 49% of WBIC and Turf, and 39% of the Rotating Nozzles Only populations. The WBIC and Rotating Nozzles group made up the majority of the most negative combination of more water use and a less healthy landscape. This dissatisfaction with the device combination may be due to not installing them correctly as a pair, meaning properly adjusting the nozzles and properly programming the controller to maximize the pair's effectiveness.

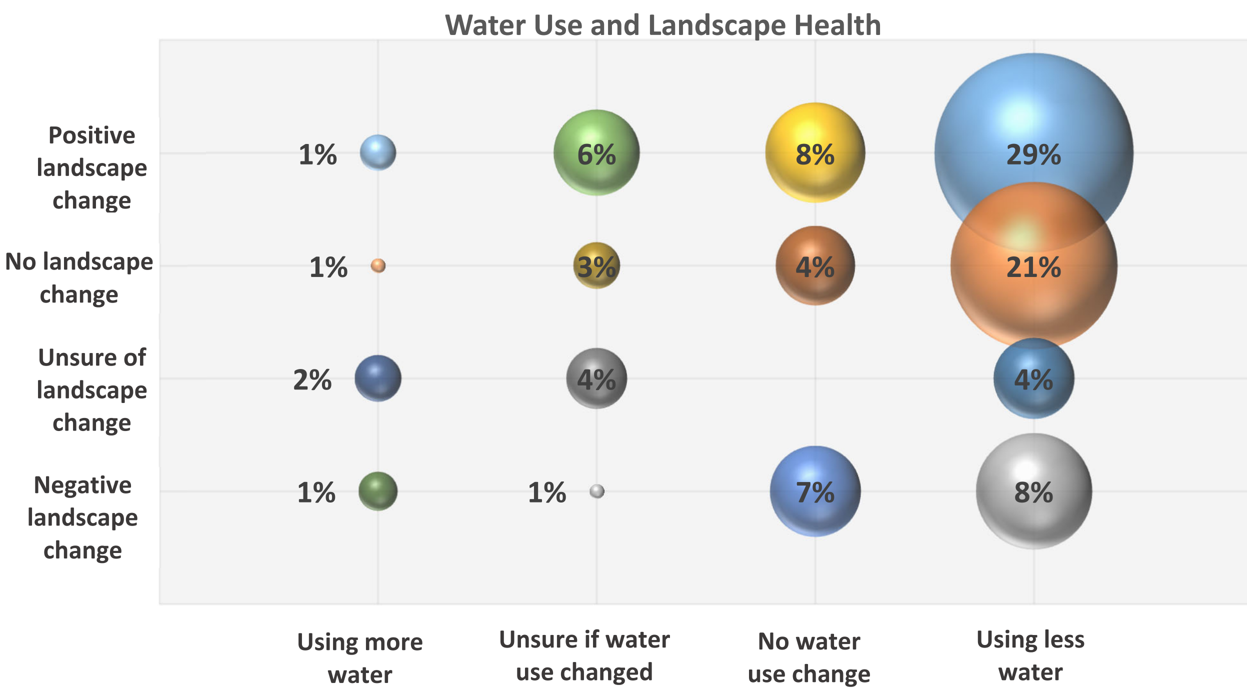

Figure 7. Responses as pairs to both water use and landscape health questions.

Participants were also asked if they would have purchased their WBIC and/or nozzles even if there was not a rebate incentive. Seventy-one percent of respondents indicated that they would not have purchased the device(s) if not for receiving a rebate or they were unsure if they would have purchased the device, see Figure 6. Only 29% of participants reported that they would have purchased the devices regardless of an incentive. This indicates that two thirds of participants were the targeted audience for the rebate, meaning they represent those who needed the incentive to be willing to make the purchase and installation, and only one third represents the population who join the program but do not actually need the incentive to be motivated order to make the purchase and/or installation. Previous MWDOC survey results have indicated that a 70%/30% split is an average rate.

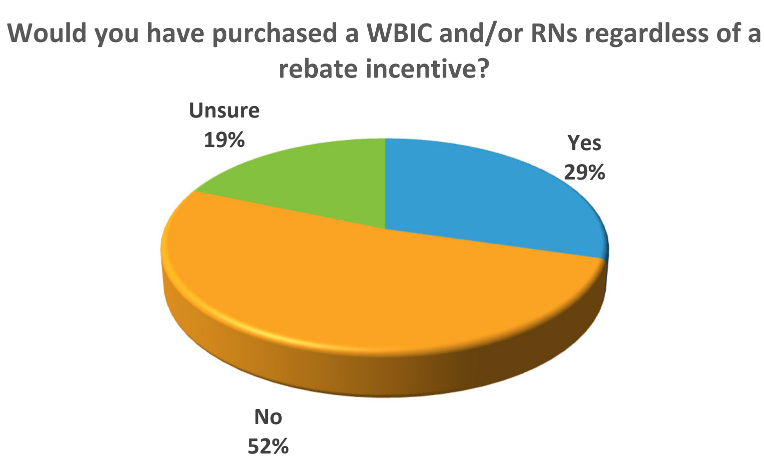

Figure 6. Willingness of customers to purchase and install water savings devices.

Program Satisfaction

Survey participants were given two Likert-scale questions regarding their satisfaction and experience with the Programs. The first asked how their overall Program satisfaction ranked based on four options ranging from very unsatisfied (represented as a score of 1) to very satisfied (represented as a score of 4). Figure 8 shows these responses by device group. The average response to the question is a 2.8, with the WBIC only group responding the highest and the Rotating Nozzle and Turf group responding the lowest. The ranking for this question seems lower than expected and may have been influenced by the setup of the question on the survey. The satisfaction ranks were displayed with 'very unsatisfied' to the left moving towards 'very satisfied' on the right. When looking at customers who chose they were very unsatisfied, their answers to other questions did not seem to match this level of dissatisfaction, meaning it is possible they meant to choose they were very satisfied, but accidently chose the first option on the left instead.

The second Likert-scale question asked participants to rate how likely they were to participate in another water savings program. These responses were quantified using a similar ranking system as the previous question, highly likely is represented as a 4, down to very unlikely as a 1. The overall average response was a 3.5, higher than the rank of program satisfaction. All device groups scored above a 3, with Rotating Nozzles and Turf Removal ranking the highest, and WBIC and Rotating Nozzles ranking the

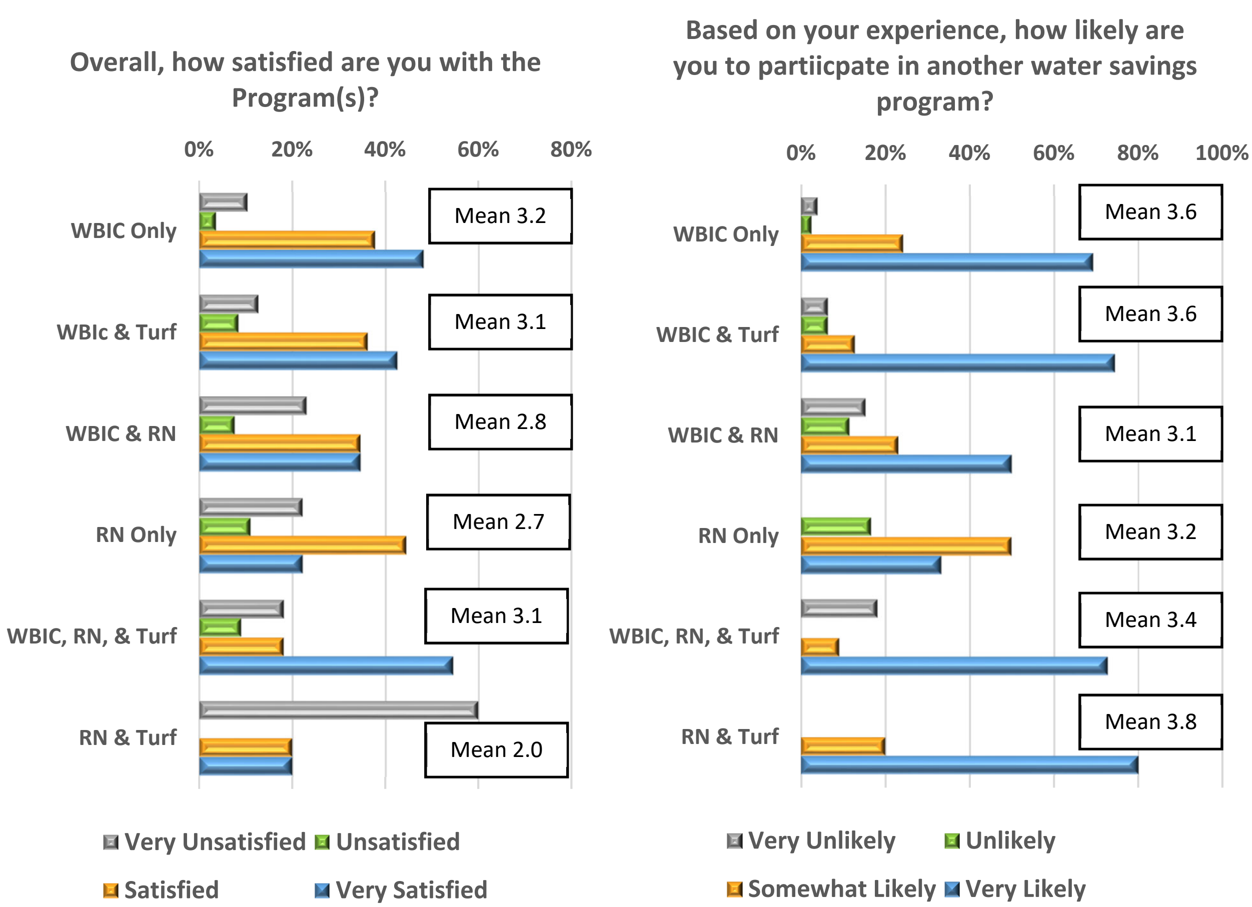

Figure 8. Likert scale representing program satisfaction responses.

lowest. The positive responses regarding likeliness to participate in the future for devices that scored low for program satisfaction further supports the idea that participants may have been thrown off with how the scale of answers was presented to them for the first Likert-scale question. It seems unlikely that a participant would select they were very unsatisfied with the Program, yet very likely to participate in another program based on their experience.

These responses show that these Program participants are willing to engage in programs in the future, and should be considered when marketing future programs.

Marketing and Future Programs

Next, survey participants were asked a few marketing questions to best understand how they found out about the program, how to best reach them in the future, and what other MWDOC programs they have been exposed to.

The majority of respondents, 72%, indicated that they found out about the Program(s) through the MWDOC website, with information provided with their water bill, or through a family or friend. Fifteen percent reported that they found out about the Programs when purchasing the device, which means some customers may have be influenced to a higher efficiency model of the device they were interested in, or they were going to purchase the device anyway and decided to apply afterwards. Only 4% indicated that they found out about the Program when participating in another rebate program, suggesting that improving cross program marketing may be a helpful improvement. See Figure 9 for complete results.

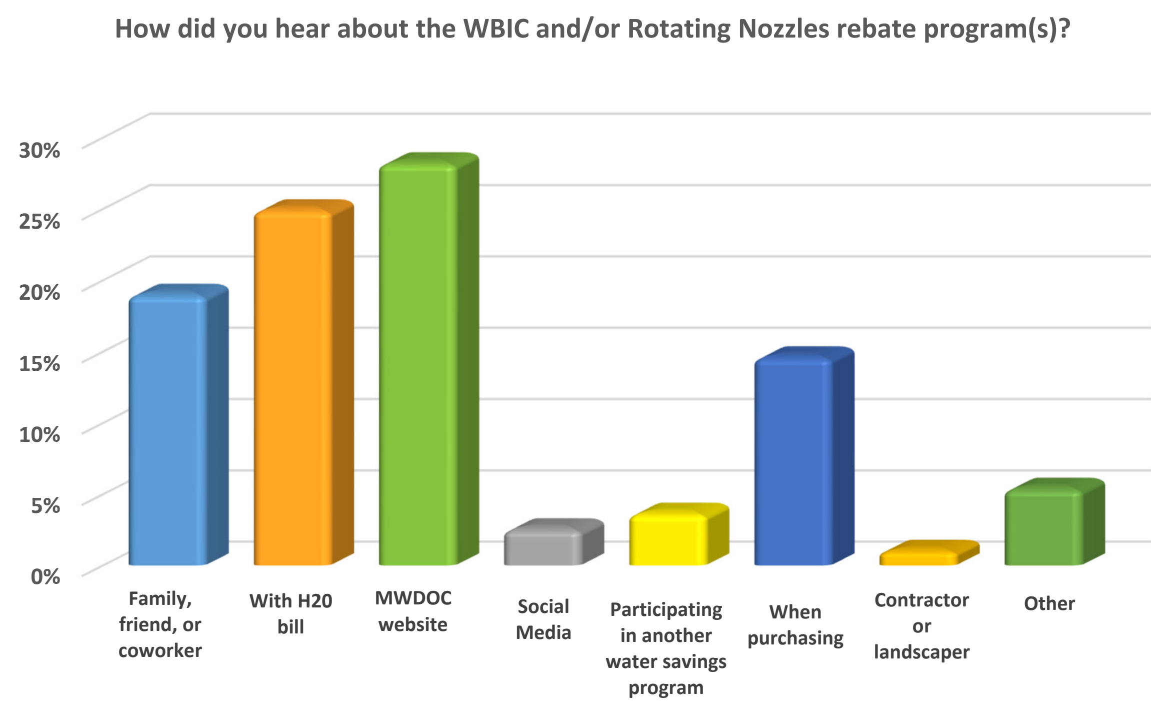

Figure 9. Survey participants patch to finding the WBIC and/or Rotating Nozzles Programs.

When asked the best method of communicating future water savings opportunities, information provided with the water bill and email were by far the most popular choices with 61% and 68% of particiapnts selecting them, respectively. Twenty-three percent did indicate they would like to see flyers at home improvement retail stores, which is a consideration for the future but, as touched on previously, this may bring in customers who already were intending on purchasing the device, and may not target those who would not purchase the device without the rebate.

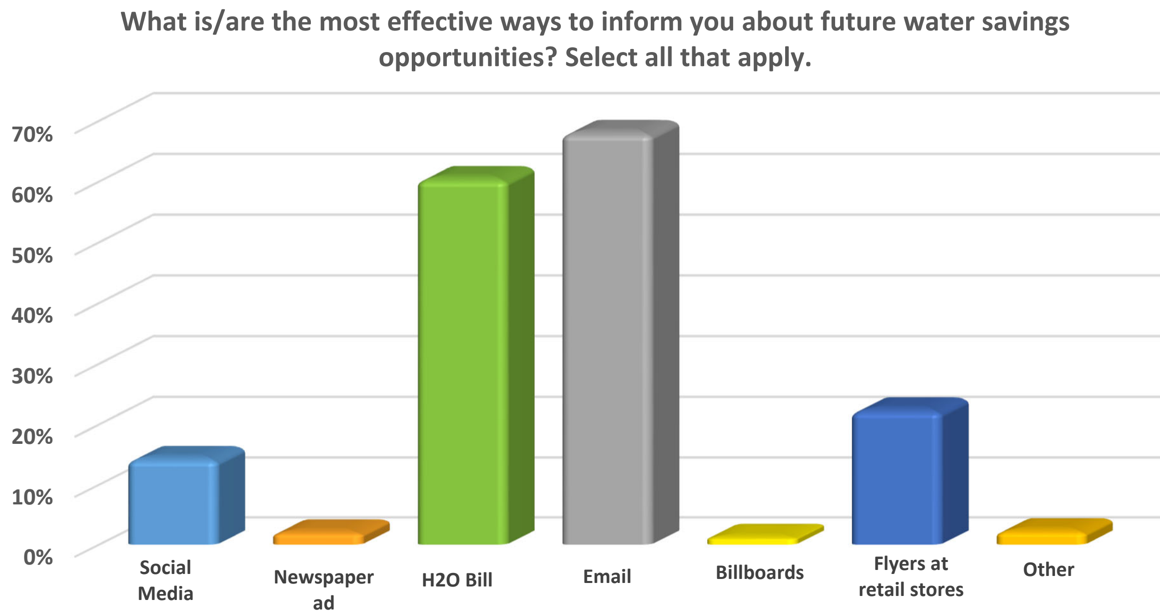

Figure 10. How to best inform the public about future water savings programs.

Lastly, participants were provided a list of MWDOC's suite of residential rebate programs and asked to identify those they had previously heard of before taking the survey. The programs the participant indicated they participated in at the start of the survey were not included in the check list, but are part of the final response tally shown in Figure 11. Unsurprisingly, the most common response was WBICs, the Program with the majority of survey respondents' participation. The second most well-known program is the Turf Removal Program. Sixty-one percent reported knowing about this Program even though only 14% of respondents participated in it. The least known program is the S2D program – only 21% reported that they had heard of this program. Additionally, 17% indicated they had not heard of ant other programs offered by MWDOC besides the one(s) they participated. The responses to the questions in this section really point to the Programs that need a marketing boost, and will help determine how to direct future marking efforts to best promote the programs.

Participants were asked to provide suggestions on ways the Program could be improved through an open text answer. The most constructive feedback included improving marketing to make the public more aware of the offered programs and to provide more resources and information regarding the device and applicable maintenance, tips, and suggestions.

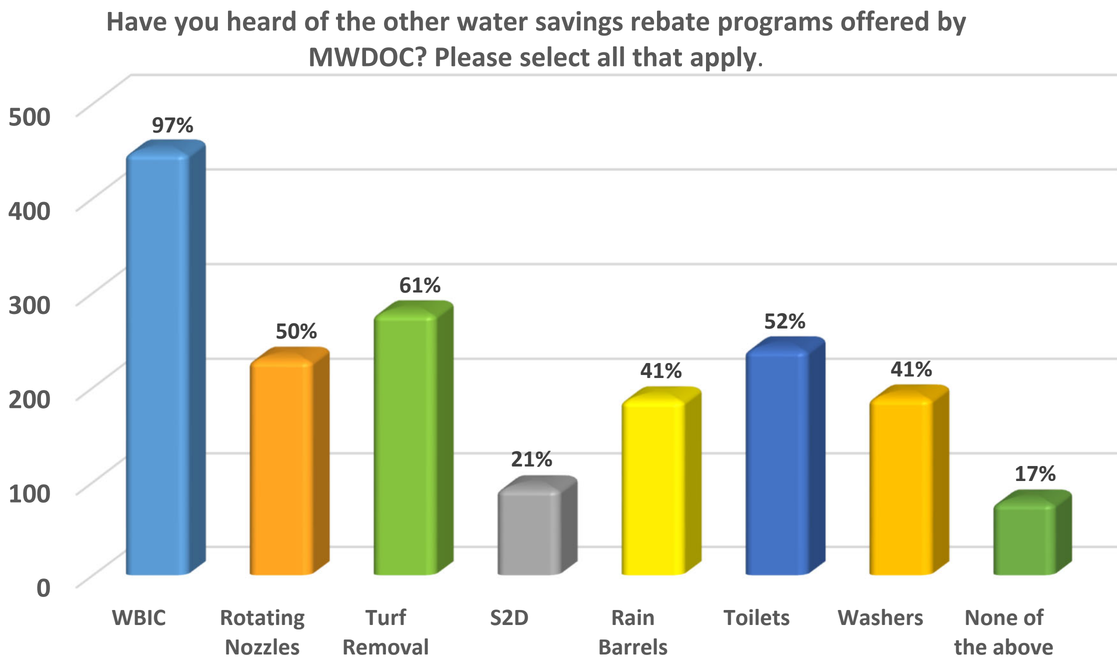

Figure 11. Programs that survey participants had been aware of prior to taking the survey.

Takeaways and Steps Moving Forward

The response to the WBIC and Rotating Nozzle Programs was positive and fell relatively in line with results from similar surveys directed to Spray-to-Drip and Turf Removal participants. Ninety-eight percent of participants reported the device was installed and functioning properly, meaning the inspection measures taken to ensure quality control are working well. The Programs received generally positive feedback in terms of customer perceived water savings and landscape health, with the majority of participants indicating they noticed they were saving water and have maintained or improved their landscape. Additionally, about two thirds of respondents indicated they might not have purchased and installed the device(s) without being offered the rebate Programs, meaning the program is achieving its goal of incentivizing those who would otherwise not implement the water savings measure. Also, based on their experience, most customers said they were likely or highly likely to participate in another program in the future.

Based on the relatively low responses when asked if they had heard of other MWDOC water savings programs, it appears that increasing marketing efforts should be a priority moving forward. Information provided with water bills, otherwise known as bill inserts, has consistently been reported as the top way that participants have found out about the program and is also a top response when asked the best way to be contacted in the future. Another top choice is email; however, as a wholesaler, MWDOC only has emails of those who have already participated in a program. Pursuing bill insert and email advertising will most likely hinge on coordination and support with MWDOC’s retail agencies and will be explored to maximize future program participation. Additionally, adding resources to assist customers installing their device, learning more about it, and maintaining it in the future is an additional step. Ways to improve marketing and resources are being discussed and considered by MWDOC staff.

Impact Analysis

A statistical analysis was performed to evaluate the impact of the CLWUE Program on customer water consumption, quantify the volume of water that has been saved as a result of this Program, and to analyze savings at project sites implementing multiple water efficient landscape measures. This analysis specifically targets residential sites that participated in WBICs, Rotating Nozzles, Turf Removal, and S2D.

This evaluation used historic customer water consumption data provided by MWDOC's retail agencies, per signed permissions granted by the Program participants. Sites were excluded only if consumption history did not contain at least one full year of usable of pre-project consumption data and at least one full year of usable post-project consumption data.

Linear regressions were used to quantify the change in water consumption before and after participating in one or more water savings programs, at a 95% confidence. Water use occurring before participation (pre-project) was compared to water use occurring after participation (post-project). Change in water consumption was evaluated in terms of gallons per day (gpd) use, percent change of gpd use, and gpd per measure (gpd/measure) savings. Savings were calculated for sites participating in only one or a combination of two landscape devices. These results were then compared amongst the device groups to see if and how water savings may increase when participating in two programs versus only one.

Methodology

Data Collection

MWDOC's Program database was combed for residential customers who participated in and completed a BMP water savings rebate program, including WBICs, Rotating Nozzles, Spray-to-Drip, and Turf Removal. Water consumption history was requested by MWDOC from the corresponding retail water agencies for customers who participated in only one of the following - WBIC, Rotating Nozzles, Turf Removal, Spray-to-Drip programs only, and for customers who participated in two programs - WIBC and Nozzles, WBIC and Turf Removal, and Turf and S2D. Combinations of S2D and Rotating Nozzles, S2D and WBIC, and Turf Removal and Rotating Nozzles did not have a large enough population to be analyzed in this study. Each participant represents a residential single family home, with one meter providing water both indoors and outdoors.

To select the sites whose data was requested, participants in the database were organized based on their participation in one or multiple rebate programs. For the pairs that were included (listed above), there was still a relatively small number of qualifying sites, so data for each site was requested. Because there was an extremely large number of potential sites for single rebate groups, sites were selected at random using a random number generator in Microsoft Excel in a proportionate quantity per agency based on each agency's overall representation in the Programs.

Consumption history was received from retailers and homogenized into a standard format where each water account's gallon per day water consumption was calculated per that billing cycle and was associated with the month the majority of the cycle fell into. Additional information was added, including project size and if that assigned month occurred during the peak or minimal irrigation season. All sites are residential homes and have one meter per application.

Customer data was categorized into three stages: (1) Pre-Project: Water consumption occurring before starting the project; (2) Post-Project: Consumption occurring after completing the project; and (3) Project Noise: Consumption occurring near or during project implementation, including the period from application to completion. Consumption occurring during this time is considered 'noise' that may not accurately represent typical consumption patterns due to project construction, preparation, or mediation.

The Project Noise stage was isolated for the purpose of being removed from the analysis to eliminate any interference or noise that may influence consumption patterns. For WBICs and Rotating Nozzles, the Project Noise stage is, at minimum, 60 consecutive days: 30 days before and 30 days after the installation date. For Turf Removal and S2D, the Project Noise stage is, at minimum, 90 consecutive days: 45 days before and 45 days after the mean of the project application and completion date (see Figure 16) due to project construction taking longer than a device installation. If a customer's application submitted date and/or project completion date fell outside of the project noise range, the application or completion date was used instead, meaning the noise range for that particular site would be greater than 90 days. For multi-device customers, if the installation dates for device x and device y are within a year period of each other, the Project Noise stage is expanded to cover consumption occurring between installation dates, and includes 30 or 45 days less than the earlier device installation date and 30 or 45 days more than the later device installation date.

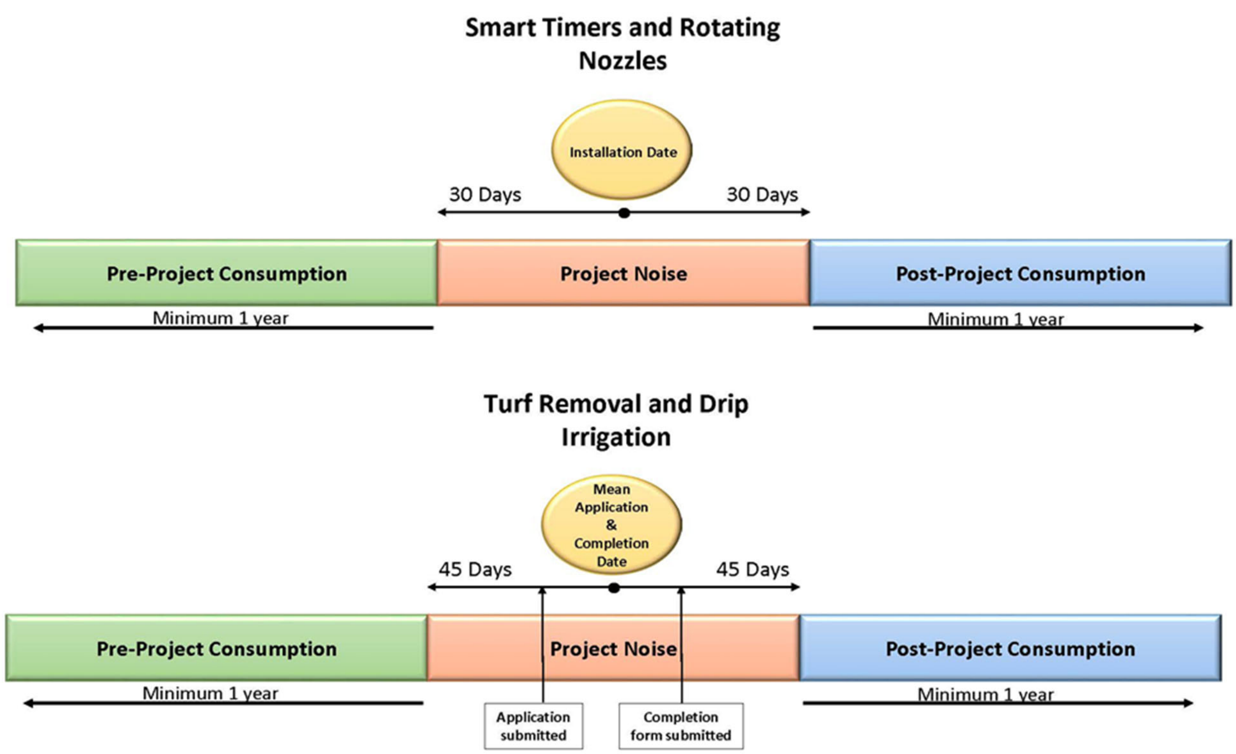

Figure 12. Consumption classification model.

Statistical Analysis

Analysis by Device

Consumption patterns were evaluated separately based on device/measure installed. The device groups are as follows:

- WBIC Only
- Rotating Nozzles Only
- WBIC and Rotating Nozzles
- Turf Removal Only
- WBIC and Turf Removal
- S2D Only
- Turf Removal and S2D

Using JMP Statistical Software to evaluate customers who installed only one measure, an Analysis of Variance (ANOVA) tested the following hypothesis:

H_0: There is no statistical difference between pre-project water consumption and post-project water consumption.

H_a: There is a statistical difference between pre-project water consumption and post-project consumption.

Least squares means (LSM) were used to establish pre-installation and post-installation consumption means to represent consumption for each device group. The pre-installation and post-installation values were used to determine the percent change from pre-installation to post-installation and the average savings per site (pre values minus post values) in gpd. Savings per device were established as gpd/device based on the gallon per day savings divided by the number of devices installed (or amount of square footage for turf and drip projects). In some cases, the removal of outliers increased the normality of the dataset; however, no more than the top 0.05% of outliers were removed leaving 97.5%.

The data was analyzed two ways per device group: (1) All Data– all pre-project (also referred to as pre-installation) consumption was measured against all post-project (also referred to as post-installation) consumption; and (2) Irrigation Season, or irrigation need - data is separated by month to determine if it occurred in the minimal irrigation season or peak irrigation season. The population per device group is shown in Table 2. Each participant represents one residential single family home meter.

Table 2. Population by Device Group

Device Group	N
WBIC Only	57
Rotating Nozzles Only	53
WBIC and Rotating Nozzles	90
Turf Removal	32
WBIC and Turf Removal	39
S2D Only	18
Turf Removal and S2D	44

Definition of Irrigation Season

For this study, the peak irrigating season for Orange County is considered April-October, and the minimal irrigating season is considered November-March. Historically, April and October can potentially be considered in either the peak or the minimal water need seasons. These months sit on the periphery of Orange County irrigation-need seasons and typically transition in and out of the dry/warm and cool/wet seasons. For this study, April and October are both considered part of the peak irrigation season, based upon the past seven years of precipitation and temperature in Orange County (2010-2018). From 2010 to 2018, October and April months have generally been warmer and drier than average. The red text in Table 3 signifies values that are warmer or drier than the 68 year average from 1950 to 2018. Data was observed at the Santa Ana weather station in Orange County.

Table 3. Weather Data for April and October in Orange County

	Precipitation		High Temp (°F)		Average Temp		Low Temp	
	April	October	April	October	April	October	April	October
Normal*	**0.84**	**0.38**	**73.1**	**79.9**	**62.4**	**68.6**	**51.7**	**57.3**
2018	0.0	0.77	75.5	80.4	65.5	71.0	55.4	62.5
2017	0.07	0.00	78.2	85.3	67.5	74.0	56.9	62.7
2016	0.14	0.71	75.5	81.4	66.4	71.1	57.1	60.7
2015	0.16	0.05	77.0	86.3	66.4	76.3	55.7	66.3
2014	0.37	0.00	76.7	84.4	65.9	73.6	55.2	62.9
2013	0.05	0.28	72.0	78.2	63.7	68.6	55.3	58.1
2012	1.54	0.35	75.4	80.6	63.9	70.9	52.4	61.1
2011	0.03	0.91	74.3	80.3	64.1	68.5	53.8	56.8
2010	1.47	2.49	72.7	76.7	62.0	68.0	51.3	59.2

*Average from 1950-2018

Irrigation season is an extremely important variable to explore because it will differentiate patterns of water consumption over two climatically distinct parts of the year and will distinguish if any water savings achieved is weighted to one season in comparison to the other.

Comparison of Device Groups

To compare water savings of customers who installed one measure to those who installed two measures, gpd savings and percent reduction savings by device group were compared the following ways:

- WBIC to WBIC and Rotating Nozzles
- Rotating Nozzles to WBIC and Rotating Nozzles
- WBIC to WBIC and Turf Removal

- Turf Removal to WBIC and Turf Removal
- Turf Removal to Turf Removal and S2D
- S2D to Turf Removal and S2D

ANOVA compared the savings of these groups using the following hypothesis:

H_0: There is no statistical difference between water savings achieved through installing one measure and water savings achieved when installing an additional measure.

H_a: There is a statistical difference between water savings achieved through installing one measure and water savings achieved when installing an additional measure.

Results

Water Savings by Device Group

The following results represent the differences in water consumption, by device group, from before and after installing that BMP.

Weather Based Irrigation Controller

A statistically significant reduction in customer water consumption occurred from before the WBIC was installed to after the installation of the device was completed, see Table 4. Overall, each site, which installed 1 WBIC per meter, reduced consumption by an average of 50 gpd, an 11% reduction. The minimal irrigation season saw higher percent reduction savings and very similar savings in terms of gpd savings. This may be representative of customers overwatering during winter, when the WBIC would accurately lower water use while allowing for the appropriate use during warm, dry months. Consumption change by month is shown in Figure 13.

Table 4. WBIC Only Site Water Savings

	LSM Pre (GPD)	LSM Post (GPD	Savings per Site (GPD)	Site % Reduction	Av. Device/ site	Device Savings	P-Value
Overall Savings	449	399	50	11%	1 clock	50 gpd/timer	<0.0001*
Peak Irrigation	522	461	62	12%	1 clock	50 gpd/timer	0.0001*
Min. Irrigation	355	297	58	16%	1 clock	50 gpd/timer	<0.0001*

*Statistical Significance

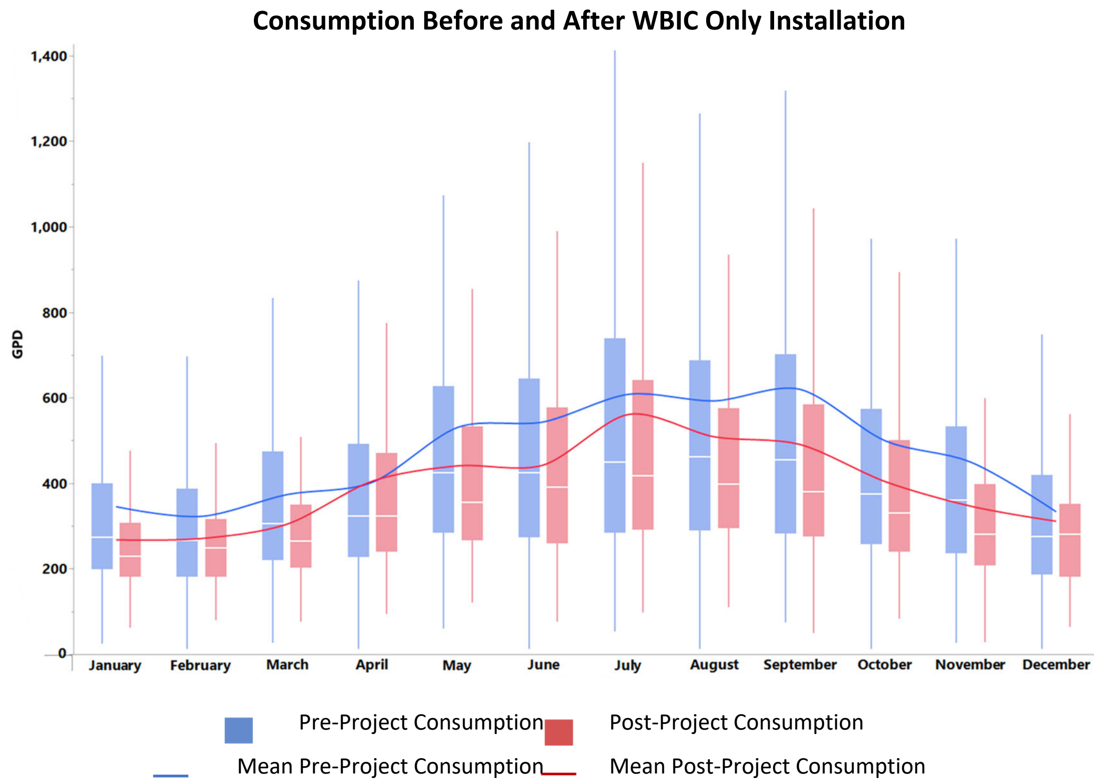

Figure 13. Monthly boxplots representing consumption before and after installing a WBIC.

Rotating Nozzles

Customers who installed high efficiency rotating nozzles overall experienced statistically significant savings from pre-installation to post-installation. Rotating nozzle customers saved 56 gpd, an 11% over reduction, see Table 5. On average, 36 nozzles were installed per home, meaning per device savings are 1.55 gpd/nozzle. Gallong per day savings and gpd/nozzle savings were higher during the peak irrigation season than the minimal irrigation season, which is to be expected as water use is typically always higher in summer months. However percent reduction savings were 50% higher in the minimal irrigation season and has a stronger statistical significance.

Table 5. Rotating Nozzles Only Water Savings

	LSM Pre (GPD)	LSM Post (GPD	Savings per Site (GPD)	Site % Reduction	Av. Device/ site	Device Savings	P-Value
Overall Savings	500	444	56	11%	36 nozzles	1.55 gpd/nozzle	<0.0001*
Peak Irrigation	596	534	62	10%	36 nozzles	1.73 gpd/nozzle	0.0007*
Min. Irrigation	370	315	54	15%	36 nozzles	1.51 gpd/nozzle	<0.0001*

*Statistical Significance

Figure 14 shows pre and post-installation consumption by month, where post-installation mean and median monthly consumption is consistently less than pre-installation consumption, with the largest reductions occurring in January, May, and September. Additionally, the top of the upper quartile range is consistently less after installing the nozzles.

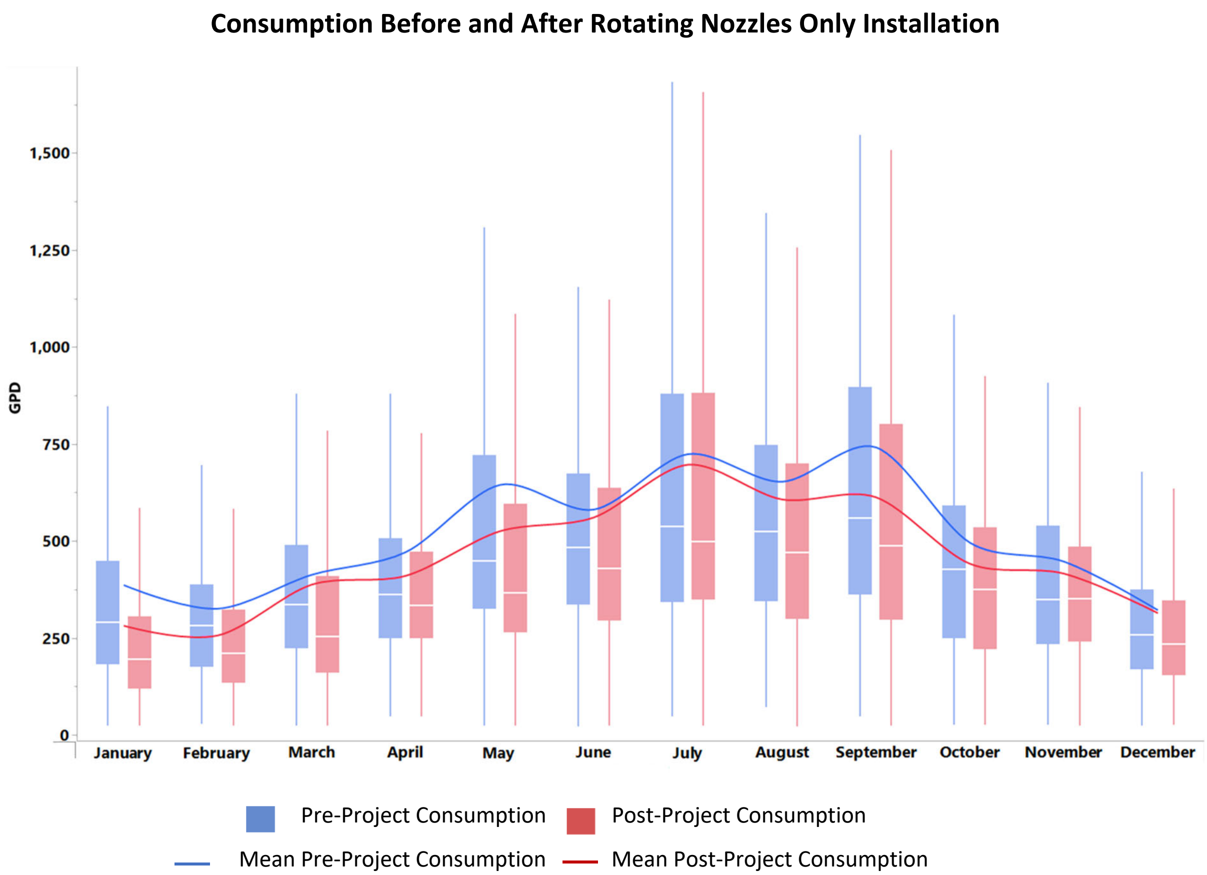

Figure 14. Rotating Nozzles participant consumption by month.

WBIC and Rotating Nozzle

Sites that installed both a WBIC and Rotating Nozzles saw statistically significant savings overall and during both the peak and minimal irrigation seasons, see Table 6. Overall, sites saved 41 gpd, an 8% reduction. These sites installed one WBIC and, on average, 32 nozzles. Considering this, on a device basis sites saved 1.37 gpd per nozzle/timer. Savings were greater during the minimal irrigation season, which saw higher savings in terms of percent reduction of overall water consumption and gpd savings, despite water consumption generally being higher in the peak irrigation season. Similar to the WBIC only group, this may be caused by participants severely overwatering in winter before installing the WBIC. The combination of a WBIC and Rotating Nozzles allows customers to apply a more appropriate amount of water based on weather (positive effect of a WBIC) and to apply it in a more efficient manner, reducing water loss due to runoff and overspray (positive effect of Rotating Nozzles).

Table 6. WBIC and Rotating Nozzles Water Savings

	LSM Pre (GPD)	LSM Post (GPD)	Savings per Site (GPD)	Site % Reduction	# of Devices per site	Device Savings	P-Value
Overall Savings	485	444	41	8%	1 timer; 30 nozzles	1.37 gpd/ timer+nozzle	<0.0001*
Peak Irrigation	573	524	48	8%	1 timer; 30 nozzles	1.60 gpd/ timer+nozzle	0.0001*
Min. Irrigation	401	349	52	13%	1 timer; 30 nozzles	2.10 gpd/ timer+nozzle	<0.0001*

*Statistical Significance

As shown in Figure 15, the upper quartile range is dramatically reduced from pre-installation consumption to post-installation consumption. This is especially apparent during the minimal irrigation need months, and visible in most of peak irrigation months such as April, May, June, August, and October. Additionally, the bottom of the lower quartile range generally increased from pre-installation to post-installation, but creates a smoother, traditional consumption arch that peaks in the middle of the year. This slight increase in the bottom range of consumption is most likely caused by the WBIC

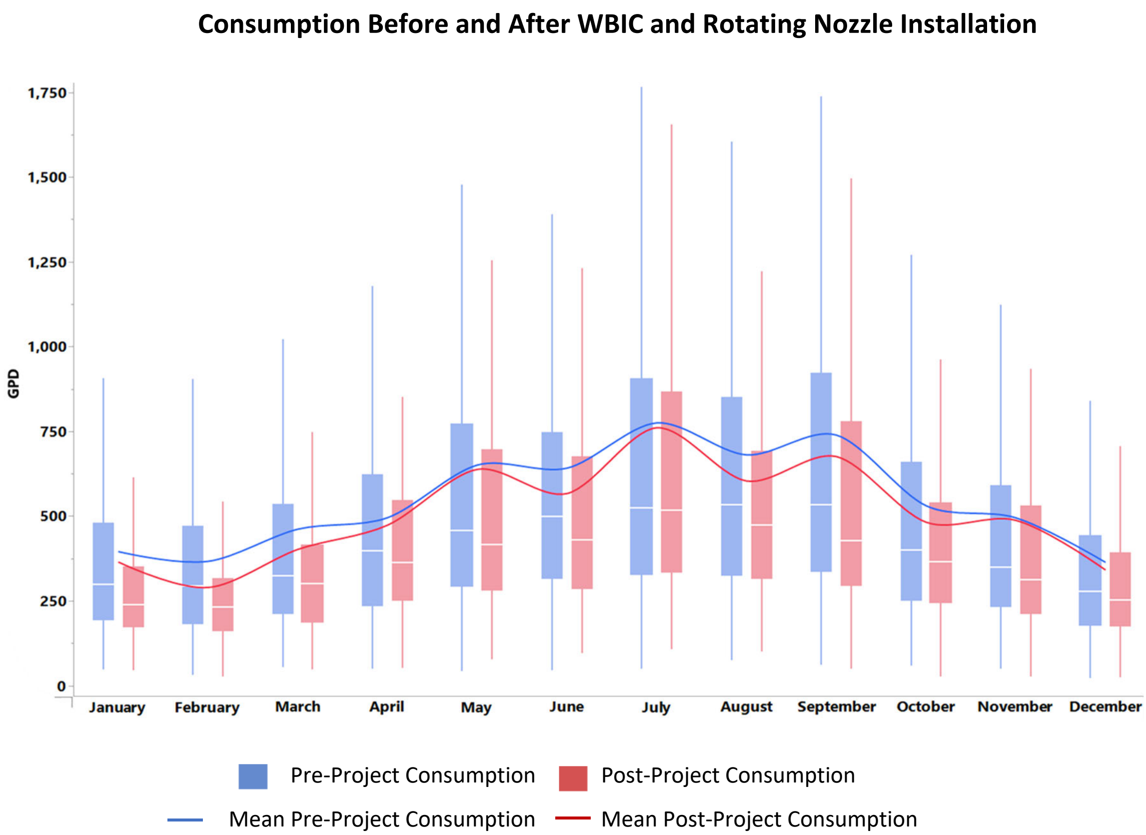

Figure 15. Monthly water use before and after WBIC and Rotating Nozzles installation.

ensuring that the irrigated area is receiving an adequate amount of water, even if that is an increase from what was being applied previously, meaning that the WBIC is helping to correct both overwatering and under watering.

Turf Removal

Sites that participated in Turf Removal Only, on average, reduced water consumption by 25%, or 86 gpd. The average project size was 709 square feet, meaning sites saved 0.122 gpd/sqft or approximately 44 gpd/year. These sites experienced statistically significant savings overall and in both the minimal and peak irrigation seasons. Savings were highest in the peak irrigation season compared to the minimal irrigation season, see Table 7. Percent reduction savings nearly doubled from minimal to peak irrigation season, and gallon per day savings increased by almost 200%. Average savings during the peak irrigation season were 0.171 gpd/sqft, which translates to nearly 63 gallons per year per square foot over the months of April through October. Additionally, overall water use reduced 31% during this time.

Table 7. Turf Removal Water Savings

	LSM Pre (GPD)	LSM Post (GPD	Savings per Site (GPD)	Site % Reduction	# of Devices per site	Device Savings	P-Value
Overall Savings	340	254	86	25%	709 sqft	0.122 gpd/ sqft	<0.0001*
Peak Irrigation	395	274	121	31%	709 sqft	0.171 gpd/ sqft	<0.0001*
Min. Irrigation	266	224	43	16%	709 sqft	0.060 gpd/ sqft	0.0011*

*Statistical Significance

As shown in Figure 16, water consumption across the calendar year decreased in terms of mean, median, and values above the upper quartile. August consumption had the greatest reduction in terms of percent reduction, gpd, and gpd/sqft savings. August is commonly a month where overwatering occurs because the length of daylight shrinks, diminishing water need. Is common to see applied irrigation remain the same as July, when days are longest. Seeing high savings in August is a positive reflection of appropriate planting and irrigation efficiency. September and June were the second and third highest savings months, respectively. Consumption during winter months decreased the least, specifically in January and February; however, as exemplified by the trend lines in Figure 16, consumption consistently reduced every month, with the largest reductions occurring during summer months. The curve of water consumption over the calendar year is flatter for post-project than pre-project, which suggests a decrease in outdoor wateruse. Indoor use, generally, is consistent throughout the year, while outdoor use increases in the warm, dry months. The smaller range of values, especially above the third quartile, suggest that smaller percent of water consumption is going towards outdoor use post- nstallation.

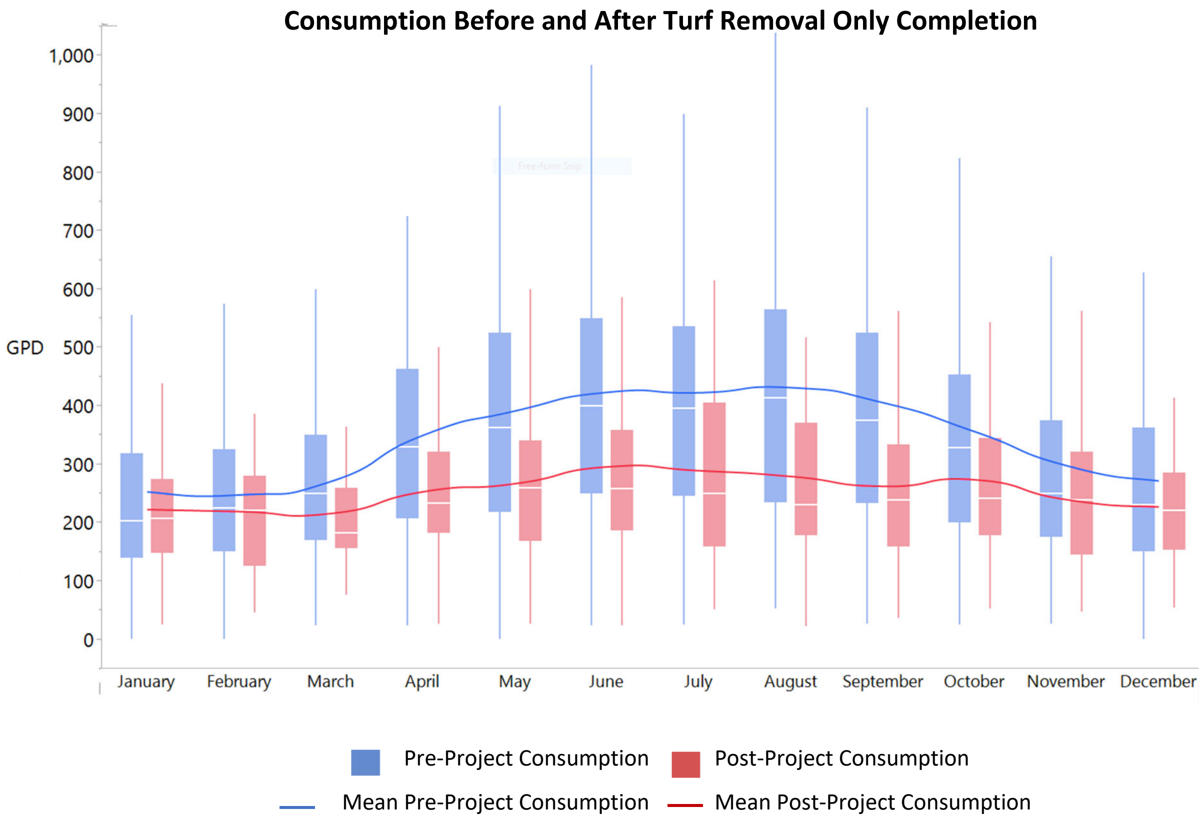

Figure 16. Water use by month pre and post Turf Removal project installation.

WBIC and Turf Removal

Sites that installed both a WBIC and completed a Turf Removal Project saved 87 gpd per site and 27% overall. The average device count per site is 693 sqft (Turf Removal) and 1 timer, meaning sites saved 0.125 gpd/sqft and timer, see Table 8. Savings were similar in both the peak and minimal irrigation season. The peak irrigation season saw higher savings in terms of gpd per site; however, percent reduction was greater during the minimal irrigation season. Figure 17 shows monthly reductions in water consumption. The consistency in savings across irrigation season is most likely due to the installation of both a timer and Turf Removal project. Turf Removal sites typically see higher savings in summer due to installing CA Friendly plants, which need less summer irrigation, while the WBIC helps to irrigate that landscape efficiently throughout both seasons. In Figure 17, the mean post-installation curve is consistently smaller than the pre-installation curve, and the pre-installation upper whiskers reach a much higher range than post-installation. This shows that after the Turf Removal project and installation of the WBIC, there is a less extreme use of water. In most months, January and March through November, the median post-installation use is nearly less than or equal to the lower quartile use of pre-installation consumption.

Table 8. Turf Removal and WBIC Water Savings

	LSM Pre (GPD)	LSM Post (GPD)	Savings per Site (GPD)	Site % Reduction	# of Devices per site	Device Savings	P-Value
Overall Savings	326	240	87	27%	693 sqft	0.125 gpd/ sqft + 1 timer	<0.0001*
Peak Irrigation	381	277	104	27%	693 sqft	0.150 gpd/ sqft + 1 timer	<0.0001*
Min. Irrigation	252	178	74	29%	693 sqft	0.106 gpd/ sqft + 1 timer	<0.0001*

*Statistical Significance

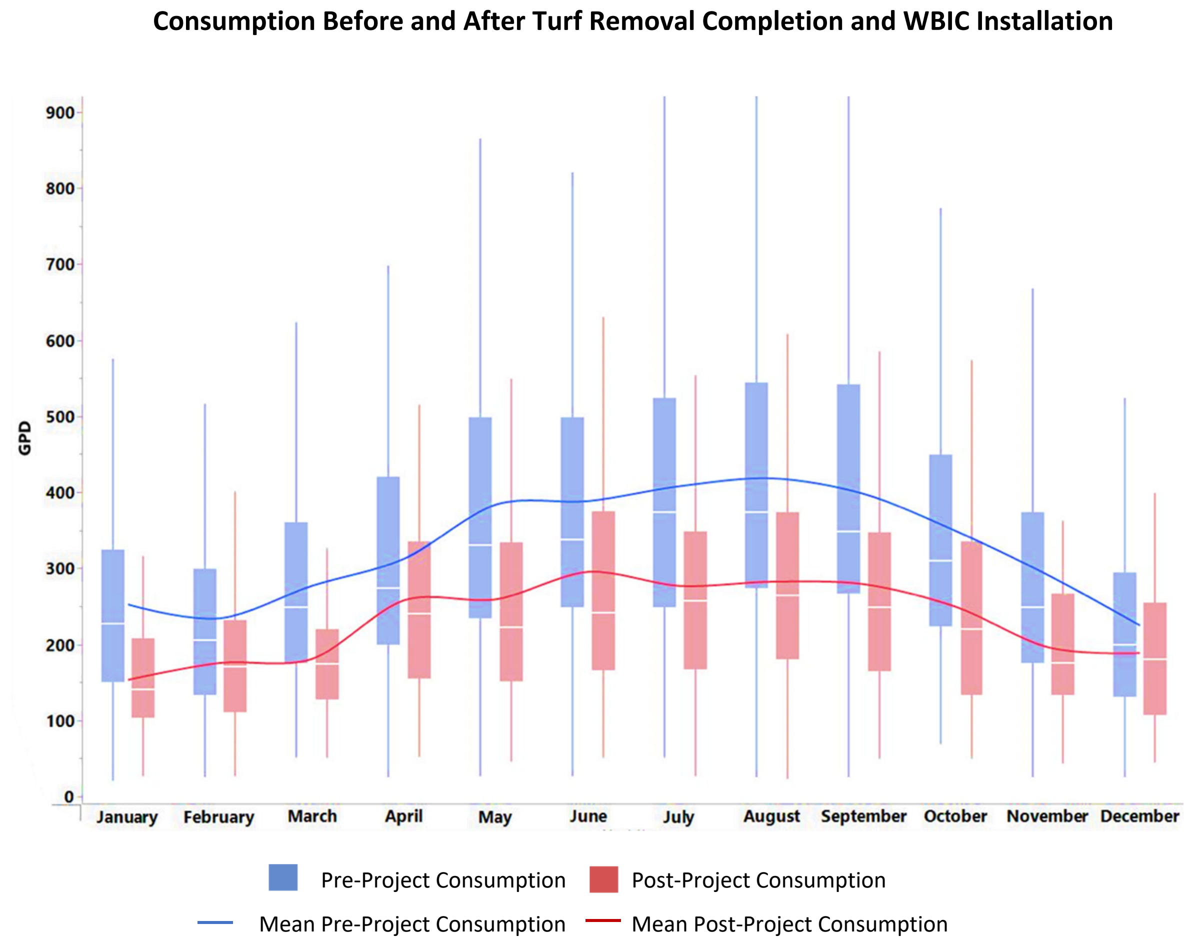

Figure 17. Monthly consumption for sites that completed a Turf Removal project and installed a WBIC.

Drip Irrigation Only

Sites participating in the S2D Program only saw a statistically significant reduction of water consumption, and on average reduced water consumption by 22% and 85 gpd. The average S2D project size was 723 sqft, meaning sites saved 0.118 gpd/sqft or about 43 gallons per year per square foot. When analyzed by irrigation season, Drip sites saw higher savings during the peak irrigation season. However, in terms of site percent reduction, there was not a large difference between peak and minimal irrigation season savings. This most likely is due to the extreme efficiency of drip irrigation, and the inefficiency of most spray nozzles. Participants were irrigating inefficiently with spray heads both during summer and winter months, meaning more water than what the landscape actually needed was applied to keep plant material healthy. Once converted to drip, they are able to decrease the amount of water used, while providing the amount of water needed by the landscape to keep it healthy. See Table 9 for complete results.

Table 9. Drip Irrigation Water Savings

	LSM Pre (GPD)	LSM Post (GPD	Savings per Site (GPD)	Site % Reduction	# of Devices per site	Device Savings	P-Value
Overall Savings	379	294	85	22%	723 sqft	0.118 gpd/ sqft	<0.0001*
Peak Irrigation	440	348	92	27%	723 sqft	0.128 gpd/ sqft	<0.0001*
Min. Irrigation	300	228	72	24%	723 sqft	0.099 gpd/ sqft	<0.0001*

*Statistical Significance

Figure 18 shows monthly consumption before and after converting from spray to drip irrigation. Post-installation median and mean monthly use is consistently less than use before converting irrigation. The relative consistency of savings across the entire calendar year is visible when comparing the difference between mean trend lines representing pre and post-installation use. Additionally, the top range of the upper whisker is generally less post-installation and, in many cases, is significantly less than pre-installation values. This is especially apparent in June, July, and September, and even during the winter month of January. The minimal amount of water consumed (bottom range of lower whiskers) generally decreased as well, meaning that on average sites were able to lower their minimum use.

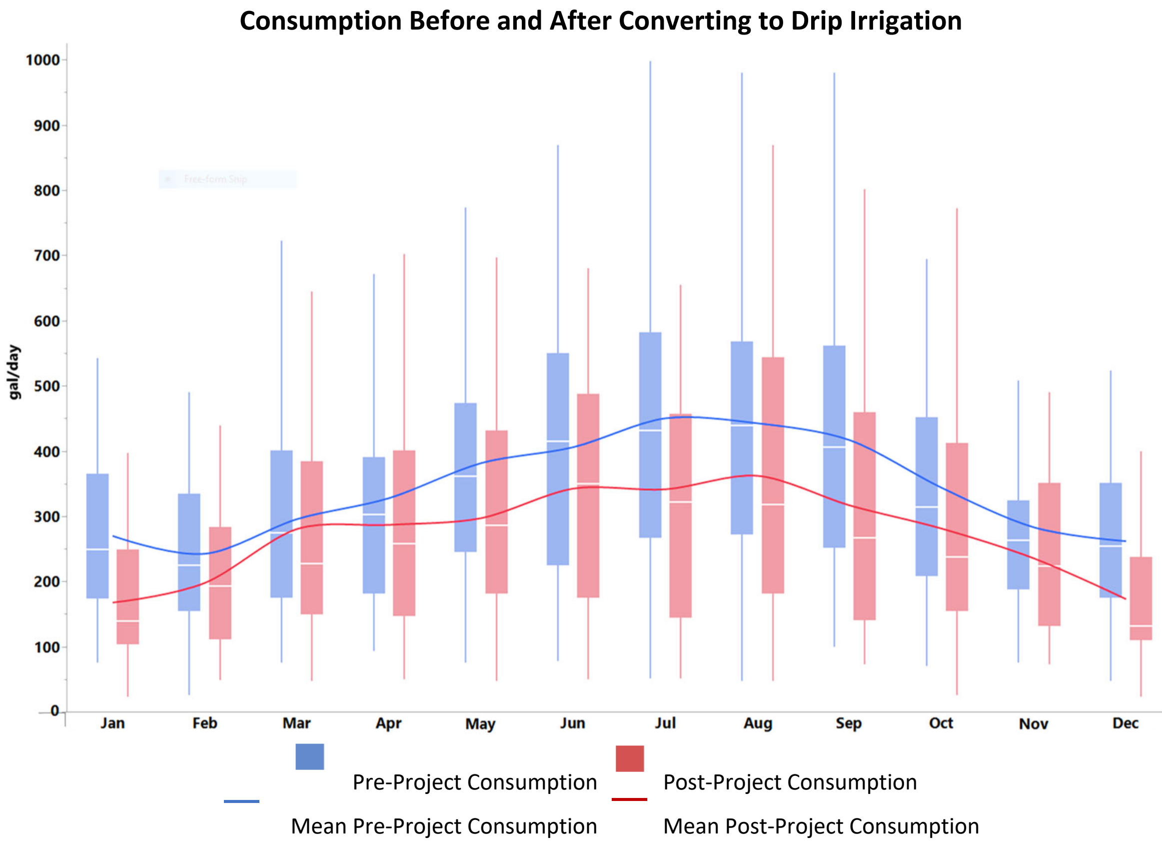

Figure 18. Monthly consumption for S2D participants.

Drip Irrigation and Turf Removal

A statistically significant reduction in customer water consumption can be seen for those who completed Turf Removal and a S2D projects, see Table 10. Overall, consumption was reduced by 86 gpd per site, on average, which is a 26% reduction of all use. The average project size for both Turf and Drip projects was 723 sqft, meaning customers saved 0.124 gpd/sqft.

Table 10. Turf Removal and Drip Irrigation Water Savings

	LSM Pre (GPD)	LSM Post (GPD	Savings per Site (GPD)	Site % Reduction	# of Devices per site	Device Savings	P-Value
Overall Savings	337	250	86	26%	723 sqft	0.124 gpd/ sqft	<0.0001*
Peak Irrigation	389	279	109	28%	723 sqft	0.158 gpd/ sqft	<0.0001*
Min. Irrigation	264	211	54	20%	723 sqft	0.077 gpd/ sqft	<0.0001*

*Statistical Significance

Savings were highest in the peak irrigation season, where participants saved 28% and over 100 gpd per site. This translates to savings of 0.158 gpd/sqft during the peak irrigation season, and 58 gpy. Figure 19 represents pre and post installation consumption by month. Each month consumption decreased in terms of mean, median, and upper whisker ranges. In May, June, July and September, the post installation upper whisker range starts at or below where the lower whisker range begins for pre installation consumption. The large savings generated by these sites is especially noticeable when comparing the mean trend lines during summer months. Additionally, the post installation consumption curve is much smaller, signifying less water is being used for irrigation, which causes the curve to move upwards in warm, dry months.

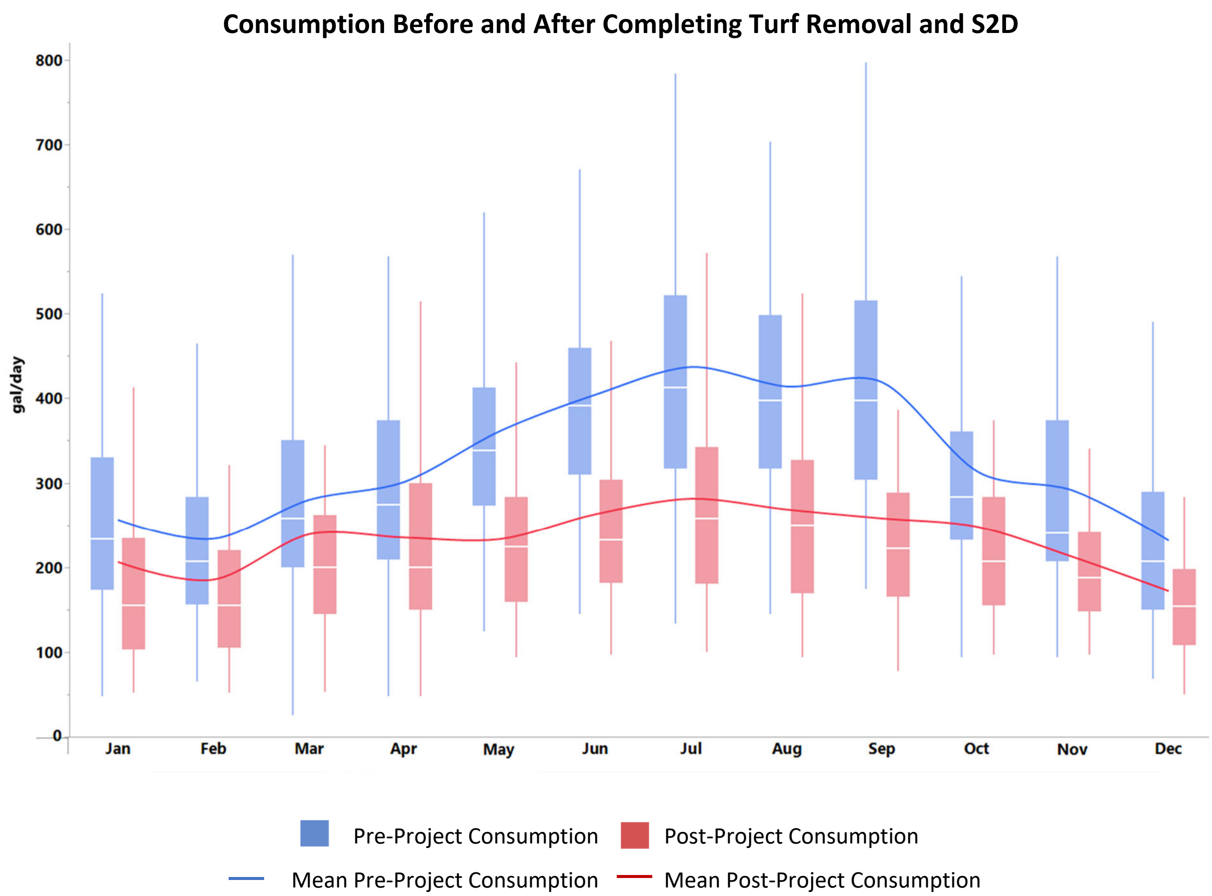

Figure 19. Boxplots representing monthly consumption before and after completing Turf and S2D.

Device Group Comparison

When looking at all water savings by device group, two distinct groups of consumption patterns emerged, one encompassing WBICs and Rotating Nozzles, and the other consisting of Turf Removal and S2D. WBIC only, Rotating Nozzle Only, and WBIC and Rotating Nozzle sites are similar in terms of actual consumption and in water savings, see the left six bars of Figure 20. This group is distinct from Turf Removal Only, S2D Only, Turf and S2D, and WBIC and Turf sites, which are also similar with each other and generally had lower overall use and higher savings reductions, see the right eight bars of Figure 20.

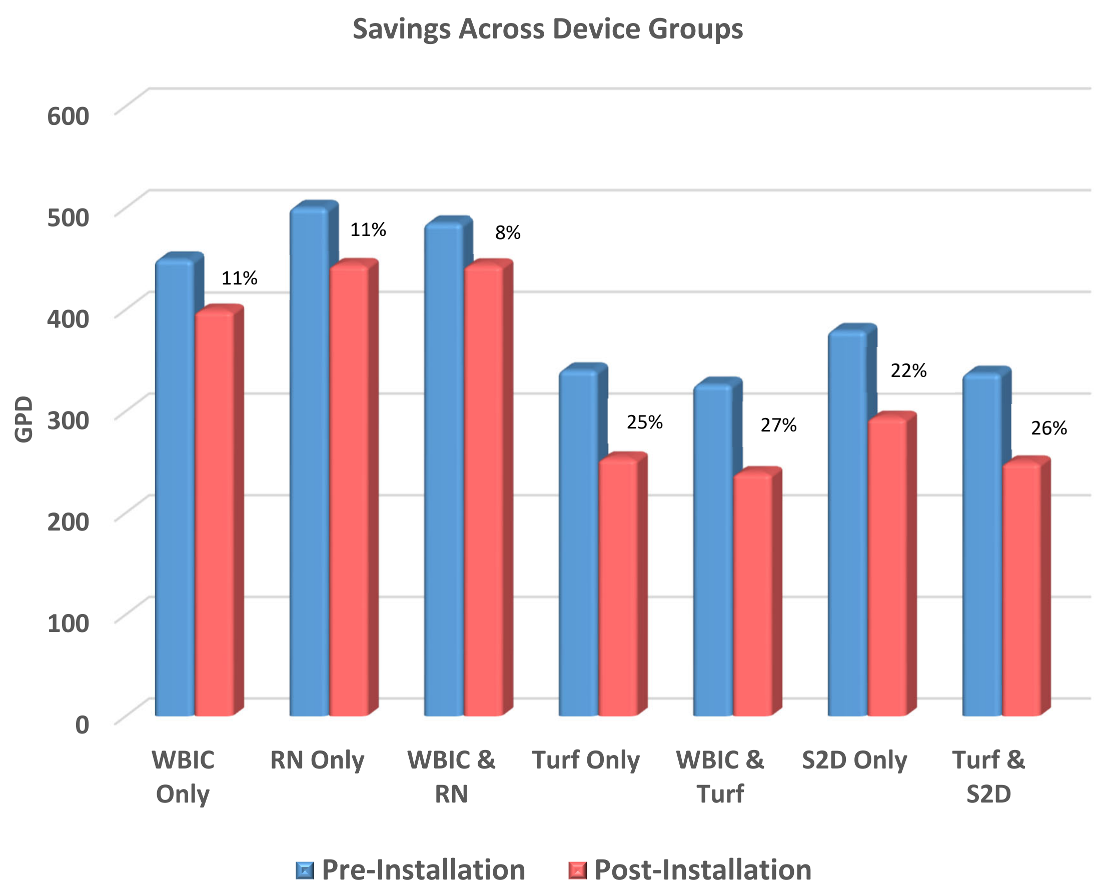

Figure 20. Changes in water consumption by device group.

Sites that installed a WBIC and completed a Turf Removal Project saved the most water overall compared to the other device groups and saw higher savings in both the peak and minimal irrigation seasons. The WBIC Only projects saved more during minimal irrigation months, and the Turf Removal Only sites saved more during peak irrigation months, which is most likely why the combination of the two reduces consumption the most year round. WBIC and Turf Removal sites had a slightly higher savings rate than Turf Only sites; however, there was no statistically significant difference between them in terms of gpd per site savings and percent reduction. There is a statistically significant increase in water savings between WBIC Only sites to WBIC and Turf sites in terms of both gpd per site and percent reductions savings, see Table 11.

Table 11. Device Group Comparison

	P-Values	
	% Reduction	**GPD/Site**
WBIC Only to **WBIC & RN**	0.2767	0.7653
RN Only to **WBIC & RN**	0.2218	0.5698
WBIC Only to **WBIC & Turf**	0.0005*	0.0026*
Turf Only to **WBIC & Turf**	0.301	0.4095
S2D Only to **Turf & S2D**	0.0555	0.1742
Turf Only to **Turf & S2D**	0.3433	0.504

*Statistical Significance

The WBIC Only and Rotating Nozzle Only sites saved slightly more than the sites that installed both devices; however, there was not a statistical difference between the savings of WBIC only sites and WBIC and Rotating Nozzle sites or Rotating Nozzle Only and WBIC and Rotating Nozzle sites. Turf Removal and S2D sites saved more than S2D Only sites, although at a 95% confidence interval, there was no statistical difference between the two; although, the p-value representing percent reduction is very low, 0.0555 as shown in Table 11.

With the exception of WBIC Only to WBIC and Turf Removal sites, when comparing single measure sites to sites that implemented that measure plus another (two measures), there was no statistically significant difference in water savings. The water savings of no other single device increased significantly when adding a second measure.

Evaluation Discussion

Overall, the CLWUE Program was successful in terms of quantifiable water savings and in long-term program development. The Process and Impact Evaluations validate each other through quantified, statistically-significant water savings and survey responses that participants themselves are experiencing the need to use less water to maintain or make a positive change to their landscape. The majority of survey participants indicated they may not have implemented the water savings measure if not for the rebate received through CLWUE, achieving a Program goal of incentivizing customers to implement BMPs who otherwise would not have done so. Customer feedback shows the Program is generally viewed favorably and was a positive experience that may encourage participation in future programs. Steps that are suggested for the future to improve upon the Program includes an increased marketing effort and increasing the resources available to the public.

The results of this analysis show statistically significant water savings across all devices installed through the CLWUE Program. Generally, those who installed Rotating Nozzles or a WBIC experienced greater savings in the minimal irrigation season, and those implementing a Turf Removal or S2D project experienced greater savings in the peak irrigation season. Savings were also higher for Turf Removal and S2D, except for sites implementing a Turf Removal project and a WBIC. Savings, in general, were higher for sites doing Turf Removal or S2D; however, while savings are higher for these Programs, they are also more expensive and time intensive for participants. WBICs and Rotating Nozzles are still a worthy water savings investment to help those not interested in a landscape change or starting a large project.

When comparing water savings for sites that implemented one measure in comparison to two, there was a statistically significant difference between WBIC Only sites and WBIC and Turf Removal sites only. These findings imply that to maximize water savings, the best chance of achieving a significant increase in savings is for someone to install a WBIC and complete a Turf Removal project, as opposed to only installing a WBIC. Savings did increase from S2D Only to Turf Removal and S2D, and from a Turf Removal Only to Turf Removal and WBIC; however, savings did not increase from WBIC Only or Rotating Nozzles Only sites to WBIC and Rotating Nozzle sites. This may be caused by poor programing or a lack of knowledge regarding the timers and nozzles, especially when used in tandem. In the future, providing more resources and assistance on how to properly program and use the WBICs and Rotating Nozzles should be considered to potentially increase savings resulting from the installation of the devices.

Process Analysis Challenges

The customer survey results were positive, but also inherently contain some human error and bias. Naturally, some customers seemed to have difficulty separating any feelings of dissatisfaction with program management or process from questions pertaining to perceived results from the project. Additionally, those who responded are the most likely to have strong opinions about the Program and specifically, are more likely to have positive feelings about the Program, which is why they feel more compelled to participate. These factors can potentially affect survey results; however, such imperfections are to be expected with customer surveys and are not considered to be abnormal in this instance.

Impact Analysis Challenges

Weather and Drought Response

There are several factors that may potentially influence the statistical analysis results. Most prominently, the consumption data used in the analysis overlaps the latest California drought, which prompted Governor Jerry Brown to declare the drought a state of emergency in January 2014. Shortly after, water restrictions were imposed, and customers throughout Orange County were asked to conserve water and to irrigate their landscape only on days specified by their retail water agency. During this time, a large amount of drought awareness and water conservation messaging was issued to the public, asking residents to do their part to save water and help the region make it through the drought. Most projects were completed between December 2015 and December 2016, meaning pre-project consumption generally spanned from January 2010 to late 2015, and post-project consumption generally spanned from early 2016 to mid-2018. During the post-project consumption time frame, April 2017, Governor Brown lifted drought orders in most of the state, including Orange County. This means that as a whole, pre-installation consumption includes use occurring before, during, and after the drought and post-installation may include consumption occurring during the drought, but mostly consumption occurring post-drought. Because of this timing, it is possible that consumption patterns were affected by factors other than the devices implemented. However, because most post-installation consumption occurred during or post-drought, it is not thought that restrictions caused water savings to be overestimated.

To address weather and climate's effects on consumption, the data was evaluated by irrigation need (climate), as opposed to daily or weekly weather. A recent MWDOC analysis found that water consumption by rebate program participants was not statistically different during a wet year versus a dry year, and that climate was a more impactful driver on water consumption then weather. Additionally, consumption data available from MWDOC's retailers spans anywhere from a 25 to 60 day period. Normalizing data at this granularity can misrepresent weather events. For example, rainfall or a spike in temperature may change consumption patterns for only a few days, but affect the precipitation/temperature average for the entire month, potentially inaccurately showing over or under watering for the month. To maintain the integrity of the data received, savings by climate (irrigation season) was incorporated into the analysis as opposed to incorporating weather normalization into the analysis methodology.

Other Considerations

The data used in this study was evaluated to ensure it met a number of requirements before it was used. This determined a level of accuracy and precision; however, it did reduce the population size of the test groups. The most common reason for data to be deemed unusable was because not enough time had lapsed since the customer completed their project, meaning there was a not a full year of post-project consumption to use in the analysis. In the future, these sites will have a longer water use history available and could be revisited to expand the population size and evaluate any consumption changes for customers included in this analysis. Reanalyzing sites used in this study could be helpful in evaluating drought bounce back and how that may relate to irrigation patterns.

CLWUE Program Water Savings

The CLWUE Program water savings goal was to save 1,160 AFY and 12,783 AF over the life of the improvements. This goal was surpassed, with the projects implemented saving 1,160.6 AFY and 14,211 AF saved the life of the devices. The water savings calculations are shown below by device.

WBIC

MWDOC consistently conducts evaluations at the completion of a program term. As a means to continuously track the long-term success of this type of rebate program, these results are compared, and water savings are attached to a device based on all applicable data. Table 12 summarizes the previous irrigation timer evaluation results and includes the results from this evaluation.

The primary objective of impact evaluations such as these was to measure the amount of water saved throughout the course of the program. A statistical analysis of the collected data was performed in order to provide insight into the characteristics of sites that participated in the program and determine if a reduction of water use was due to device installation.

Table 12. Smart Timer Efficiency Research

Study Title	Author	Sector	GPD Savings	% of Total Water Use	% of Outdoor Water Use
Residential Runoff Reduction Study, 2004	A&N Technical Services, T. Chesnutt, Ph.D.	Res.	41	10%	-
		Comm.	545		21%
Commercial ET-Based Irrigation Controller Water Savings Study, 2006	A&N Technical Services, T. Chesnutt, Ph.D.	Comm.	601	-	22%
MWDOC SmarTimer Rebate Program Evaluation, 2011	A&N Technical Services, T. Chesnutt, Ph.D.	Res.	49	9%	-
		Comm.	727		28%
OC Smart Irrigation Timer Rebate Program, 2014	M. Baum-Haley, Ph.D.	Res.	59	11%	18%
		Comm.	320	-	10%
Evaluation of MWDOC's CLWUE Program*, 2018	R. Waite	Res.	50	11%	-

*Current analysis

Monthly meter read data was requested for each site from the retail water agency. Historical water use was requested for a least three years prior to the intervention point and one year following. The intervention point is designated as the point in time when the device was purchased/installed. Water savings was determined by comparing the gallon per day water use prior to and following the intervention point. This methodology enabled a direct comparison of water use based on comparable irrigation need and system consistency when utilizing weather normalization (see Table 12). This specifically allows for the ability to compare not just the net water savings for the sample as a whole but, additionally, to pairwise the analysis for each site, resulting in the categorical water use. Additionally, the water use at intervention sites was compared to a control group, exposing all samples to the same confounding factors such as weather, conservation campaigns, etc.

The results from this Evaluation have been added to the table, and generally fall in line with previous water savings studies. Based on this research, residential sites are estimated to save 49.6 gpd per timer, and commercial sites 549.8 gpd per timer. These savings rates are in line with those established by the Metropolitan Water District of southern California and this Evaluation.

The goal of the WBIC Program was to install 980 smart irrigation timers and to save 362 AFY and 3,625 AF overall. This goal was surpassed with the implementation of 3,031 timers saving 611.6 AFY and 6,116 AF over the ten year life of the devices.

Rotating Nozzles

The spray head is a common sprinkler typically utilized in landscape irrigation for smaller or bedded areas. Conventional fixed spray heads have shorter throws than conventional rotary sprinklers (rotors). Conventional spray heads also have application rates higher than other sprinkler types, meaning greater amounts of water are applied in a shorter period of time.

Multi-stream, multi-trajectory (MSMT) rotating nozzles distribute water via a number of individual streams of varying trajectories that turn slowly, as compared to a fixed spray nozzle or a single stream rotor utilized for irrigating larger areas. An MSMT rotating nozzle is a high(er) uniformity spray nozzle and, therefore, is often referred to as a high-efficiency sprinkler. It is an alternative nozzle that can fit on a conventional spray body because these nozzles are threaded for easy retrofit.

The most touted benefit resulting from the use of MSMT rotating nozzles is an increase in distribution uniformity. For landscape plants with a uniform water requirement and equidistant spacing/density, uniform water application is desirable. The majority of studies have been focused on the low-quarter distribution uniformity (DU_{lq}) improvements, where the potential for water savings is derived from the percent of water reduction attributed to improving uniformity of application.

According to the Metropolitan Water District of Southern California, retrofitting a fixed spray head with a rotating nozzle will result in 2.357 gpd per nozzle, which is based on their most up to date savings analysis. At the time the CLWUE proposal was written, the standard water savings rate for a rotating nozzle was 3.57 gpd per nozzle. This savings rate was used to calculate the nozzles water savings goal; however, for this final evaluation the 2.357 gpd per nozzle rate is being used to calculate savings.

The goal of the Rotating Nozzles Program was to install 86,000 nozzles, savings 344 AFY and 1,720 AF over the life of the Program. Through CLWUE, using the adjusted water savings rate, 51,806 nozzles were installed saving 139.3 AFY and 344 AF over the five year life of the devices.

Turfgrass Conversion

The average annual water savings for Turfgrass conversions was initially calculated utilizing the theoretical irrigation requirement (TIR) water need, taking local evapotranspiration (ETo) and rainfall (Pe) into consideration. As part of this analysis, the crop coefficients (Kc) varies from turfgrass (0.8) versus a California Friendly landscape comprised of low water need plants (0.3).

$$TIR = (ETo \times Kc - Pe) / IE$$

WS = (TIR final – TIR initial) / TIR final

where,

WS = Water Savings (%)
IE = Irrigation Efficiency (%)

Figure 21 depicts the general relationship between the theoretical irrigation requirement and potential reduction of water for various Kc values[1].

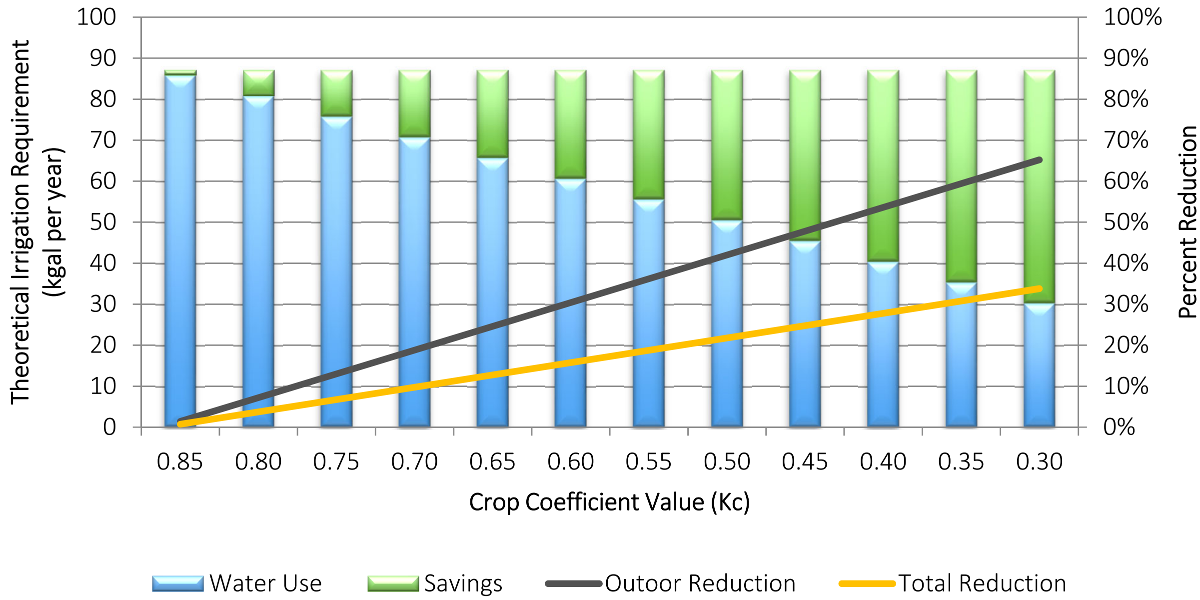

Figure 21. Theoretical depiction of how water savings may increase as turfgrass is replaced.

The daily evapotranspiration and precipitation measurements were collected from the California Irrigation Management Information System (CIMIS) weather station number 75 located in Irvine. Spatially interpolated or "Spatial ETo" values were collected for additional areas on the basis of zip code. The weather normalization technique used the actual weather corresponding to the date of interest rather than a historic average. For the Orange County area, the results are listed in

Annual Average		Assumptions		Theoretical Irrigation Requirement TIR (gallons per ft2 per year)		Potential Savings based on TIR	
P (in/yr)	ETo (in/yr)	Pe (in/yr)	IE (%)	Turfgrass Landscape Kc = 0.8	CA Friendly Plantings Kc = 0.3	Gallons per ft2 per year	Percent
12	47	3.8	60-70	56	14	42	75%

[1] Baum-Haley, M. (2013). Evaluation of Potential Best Management Practices- Turf Removal. Prepared for The California Urban Water Conservation Council.

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Table 13. Orange County Potential Savings

From the data previously collected from onsite inspections at Turf Removal sites within Orange County, the average removal area is 2,000 square feet (residential and commercial sectors combined). This would result in a reduction in annual use from 112,000 gpy prior to the conversion to 28,000 gallons per year post conversion, a savings of 84,000 gpy. On a per square foot basis, this is a savings of approximately 42 gpy per sqft, or 0.121 gpd per sqft. This analysis also concurs with the water savings observed using actual meter data.

Following the theoretical analysis, actual water use at sites was evaluated utilizing historic water use data, as well as the water use data following the turf removal landscape conversion. Metropolitan Water District of Southern California looked at their regional turf removal program and found water savings of approximately 44 to 49 gpd per sqft, or 0.121 gpd per sqft. The results from this analysis fall extremely close to that calculation at 0.122 gpd per sqft. However, the established rate of 0.121 will be used to calculate the Turf Removal water savings achieved through the CLWUE Program.

The goal of the Turf Removal Program was to convert approximately 9.8 acres, or 425,000 sqft, of non-functional turf grass to a CA Friendly landscape, saving 60 AFY and 595 AF over the 10 year life of the projects. This goal was achieved and surpassed with the conversion of 571,479 sqft (13.1 acres) of turf saving 77.5 AFY and 775 AF over the life of the projects.

Drip Irrigation

Most of the water savings research for drip irrigation is focused on water savings without causing stress or reduced quality to the turfgrass and landscape. A notable study was conducted at residential sites with more than 30-months of post installation single-family water use monitoring[2]. The conclusions showed that the homes with drip irrigated areas required less water than if those areas were sprinkler irrigated. The treatment homes with both the adjusted controller run time settings and the incorporation of drip irrigation in the bedding areas used 41% less irrigation water than the control group. This yielded a weekly water savings of 200 to 250 gpd.

Irrigation system efficiency varies based on irrigation method, equipment, and design. Applied water can be lost primarily from evaporation, runoff, or drainage. Evaporation can result from water droplets irrigated into the air, from wet leaves, or from the soil surface. A major source of lost water results in

Annual Average		Assumptions		Theoretical Irrigation Requirement TIR (gallons per ft^2 per year)		Potential Savings based on TIR	
P (in/yr)	ETo (in/yr)	Pe (in/yr)	IE (%)	Turfgrass Landscape Kc = 0.8	CA Friendly Plantings Kc = 0.3	Gallons per ft^2 per year	Percent
12	47	3.8	60-70	56	14	42	75%

[2] Baum, M. C., Dukes, M. D., and Miller, G. L. (2005). "Analysis of residential irrigation distribution uniformity." J. Irr. Drain. Eng., 131(4), 336-341.; Haley, M., Dukes, M., and Miller, G. (2007). "Residential Irrigation Water Use in Central Florida." J. Irrig. Drain Eng., 133(5), 427–434.

runoff from the surface of the landscape. Additionally, water can be lost by deep percolation through the soil profile. Basic system efficiencies are listed below in Table 14.

Table 14. Irrigation Efficiency Percent

Irrigation System Type	Efficiency[a]
Drip/Micro-Irrigation	80 to 95
Landscape Spray Systems	40 to 65
Landscape Rotor Systems	50 to 75
Brass Rotor Systems	60 to 85

Source: Irrigation Association (2007)

Micro-irrigation has less opportunity for losses through transmission. It is applied directly to the root zone and has small wetted soil surface areas, reducing evaporative losses. Applying water at a slower rate will reduce ponding and the subsequent flow from the landscape area, thereby minimizing runoff and eliminating overspray. Deep percolation (water loss) can be minimized through proper scheduling.

Increasing system efficiency will result in water savings by reducing the excess water needed to achieve adequate water within the root zone. The common practice to compensate for system inefficiencies is to apply more water. As system efficiency decreases, the amount of water needed for irrigation use increases. Water savings due to an increase in irrigation efficiency can then be calculated. As the efficiency decreases, the volume of water applied increases, resulting in a negative exponential curve.

The percentage of water lost, or superfluous application, as a result of inefficiency can be calculated for any Irrigation Efficiency with the resulting equation:

$$WL = -1.854 \ln(IE) - 0.2168$$

where,

WL = Water Lost (%)
IE = Irrigation Efficiency (%)

Here, the givens (area, etc.) will not affect the water savings. Therefore, this can be universal within the truncated 35% to 85% irrigation efficiency range. Below 35% efficiency, it is recommended to fix major issues requiring potential redesign/installation. Beyond the 85% efficiency, the impact to potential savings are not significant (Dukes et al., 2006). For example, assume an irrigation zone with stationary spray heads has an initial irrigation efficiency of 40%. If the irrigation efficiency can be increased to 85% by replacing the spray heads with more efficient irrigation equipment, such as drip-irrigation, this would result in a 53% water savings.

In 2017, MWDOC conducted an evaluation of its Spray-to-Drip Pilot conversion program, and results showed residential savings occurred at 0.121 gpd/sqft and commercial savings at 0.095 gpd/sqft. Additional water savings information can be found in Table 15. At the time the CLWUE Propsal was written the associated water savings rate for drip irrigation was 0.125 gpd/sqft. However, as more research has been done, for the purposes of this Evaluation, the water savings rate that will be used is 0.121 gpd/sqft.

Table 15. MWDOC Spray-to-Drip Evaluation Results

Sector	gpd/sqft	gpd/site	% Reduction
Residential Drip Conversion	0.121	85	24%
Commercial Drip Conversion	0.095	473	19%

The goal of the S2D Program was to convert 491,450 sqft of inefficiently irrigated landscape (the estimated equivalent of 41,000 spray heads) to drip irrigation, saving 69 AFY and 334 AF over the 5 year life of the device. Through the CLWUE Program, 10,423 sqft was converted to drip irrigation saving 1.4 AFY and 69 AF over the five year life of the projects.

Sustainable Source Meter Conversion

For each site participating in this Program, upon application the participant was requested to submit consumption history spanning the previous three years. The water savings assigned per site is an average of the three years prior use. Due to the nature of the meter conversions, there is a rate of 100% potable water savings as now all landscapes previously irrigated with potable water are irrigated with a sustainable source, in this case municipally supplied recycled water.

The goal of the Sustainable Source Meter Conversion Program was to convert 50 dedicated irrigation meters to a renewable source, saving 325 AFY of potable water and 6,500 AF over the twenty year life of the projects. Through the CLWUE Program, 50 dedicated irrigation meters irrigating more than 12.6 million sqft of landscape were converted to recycled water saving 330.8 AFY and 6,616 AF over the life of the projects.

Conclusion

Through the CLWUE Program, over 3,000 smart irrigation timers and more than 51,000 high efficiency rotating nozzles have been installed, more than 13 acres of turfgrass has been converted to a CA Friendly landscape, and over 10,000 sqft of inefficiently irrigated landscape has been converted to drip irrigation, and more than 290 acres of landscape is being irrigated with a sustainable source. The implementation of these BMPs will save more than 1,160 AFY and 14,211 over the course of the project lifetimes, surpassing the Program goals.

Customers ranked the Program favorably, noticed they were saving water and maintaining or improving their landscape health, and approximately two thirds of participants indicated that without the water savings incentive they would not have implemented the water savings measure, a strong justification for the rebate format style of the Program. Based on the results of this evaluation, it is suggested that marketing efforts are increased to raise awareness of all of MWDOC's water saving programs to the general public, and to provide additional resources and support for customers participating in the Programs, efforts that MWDOC staff have already started.

Each device group in the CLWUE Program showed statistically significant water savings, with the highest savings coming from sites implementing Turf and a WBIC, Turf and S2D, and S2D. When comparing sites that implanted one water savings measure as opposed to two, the only statistically significant difference occurred from sites only installing a WBIC to sites installing a WBIC and completing a Turf Removal project, meaning water savings will most likely be maximized when a site installing or that has installed a WBIC chooses to also participate in the Turf Removal Program. Overall, the CLWUE Program was a success in terms of water savings achieved and providing a positive experience to the public.