

RECLAMATION

Managing Water in the West

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Technical Review Report – 5th Edition



U.S. Department of the Interior
Bureau of Reclamation
Lower Colorado Region and
Technical Service Center

May 2015

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The U.S. Department of the Interior protects America's natural resources and heritage, honors our cultures and tribal communities, and supplies the energy to power our future.

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Technical Review Report – 5th Edition

prepared by

**Southern California Area Office
Lower Colorado Region
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and

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Technical Service Center
Denver, Colorado**



**U.S. Department of the Interior
Bureau of Reclamation
Lower Colorado Region and
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Disclaimer

Nothing in this report constitutes endorsement by the Bureau of Reclamation of a particular product or method. A significant portion of the information presented in this document was provided by the product manufacturers' representatives. Some of this information was verified by third parties as appropriate and as possible given the scope of the review. Every effort was made to accurately incorporate the information provided and to avoid errors and oversights, but it is recognized some may exist. The Bureau of Reclamation plans to continue to update this report periodically, and any identified deficiencies will be corrected in the next edition. Errors, omissions, and new product information should be reported to Mark Spears at 303-445-2514 or jspears@usbr.gov or to Reclamation's Southern California Area Office at 951-695-5310.

Introduction

Water agencies implementing water use efficiency programs have long struggled to achieve quantifiable and reliable water savings. Historically, programs targeting landscape savings have focused on education pertaining to irrigation system maintenance, irrigation scheduling, and climate appropriate plantings. Although these efforts have garnered savings, much potential exists for further landscape irrigation efficiency improvements.

In the late 1990s, the Irvine Ranch Water District, Municipal Water District of Orange County, and Metropolitan Water District of Southern California learned of an emerging irrigation management technology using weather-based irrigation scheduling devices. This technology removes the need to make manual scheduling adjustments because the “smart” device adjusts the schedule automatically as weather changes. A water savings evaluation of this technology was implemented, which is known as the “Residential Weather-Based Irrigation Scheduling – The Irvine ET Controller Study.” This evaluation identified an average single-family home savings rate of 37 gallons per day (IRWD, 2001).

In an effort to address nonpoint source pollution, a second weather-based irrigation scheduling study was performed to evaluate the linkage between improved residential irrigation management and reduced dry-weather runoff. The *Residential Runoff Reduction Study* (R3 Study) reported comparable water savings of 42 gallons per day per single-family home (IRWD, 2003). Savings at nonresidential sites were 545 gallons per day. The R3 Study also quantified a reduction in runoff ranging from 64 to 71 percent (%). With this change in runoff volume, concentrations of pollutants did not change; therefore, pollutants were reduced by a like amount.

Although soil moisture sensors have been used in agricultural and research applications for many years, this technology only recently has been applied successfully in the landscape irrigation field. Initial attempts to use soil moisture sensors to control landscape irrigation were unsuccessful due to the state of the technology, maintenance requirements, and cost. Within the past several years, soil moisture sensor technology has advanced significantly with accurate and maintenance-free systems being offered by several companies at competitive prices. Recent study findings indicate water savings resulting from soil moisture-based smart systems are similar to those discussed above for weather-based systems (Allen, 1997; Cardenas-Lailhacar et al., 2005; DeOreo et al., n.d.; and Mecham, n.d.).

Water agencies throughout the country recognize smart irrigation control as an emerging tool to achieve landscape water savings and reduce nonpoint source pollution. When the first study began, the study team was aware of only a few smart technologies. Today, over 20 smart irrigation control manufacturers exist, and the technology continues to evolve at a rapid pace.

In 2003, the Municipal Water District of Orange County approached the Bureau of Reclamation (Reclamation), Southern California Area Office, and requested an objective evaluation of weather-based residential irrigation scheduling technologies available to consumers. A technical review was performed to document the overall status of weather-based residential technologies and provide general descriptions of these products. The purpose of the review was to compile existing information and allow water agencies to quickly gain knowledge about the technologies for use in their residential incentive programs.

The results of the review were published in Reclamation's May 2004 Technical Review Report, *Weather-Based Technologies for Residential Irrigation Scheduling*. Since 2004, Reclamation has monitored the status of the products reviewed in the original report and researched many other smart irrigation scheduling products, including soil moisture sensor-based and small commercial products. An updated technical review report, entitled *Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices*, was published in August 2006, which included information on smart irrigation control products by 26 companies that were available as of June 2006. Second, third and fourth editions of the *Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices Technical Review Report* were published in August 2007, September 2009 and July 2012, respectively.

This fifth edition technical report includes information on smart irrigation controller products by 24 companies. This information was current as of October 2014. Since the fourth edition, products by six additional companies have been added (Brilliant Integrated Technologies, OnPoint EcoSystems™, Signature Control Systems, Rachio, Skydrop and UgMo™) and one company has been removed because its products are no longer available (Aqua Conserve®). Three other companies were removed since they were not able to provide updated information for this edition (Hydrosaver™, Toro®, and Tucor). Also, two manufacturers with weather-based products in previous editions now have new soil moisture-based products that are included in this edition (Hunter® and Rain Bird®). Reclamation is aware of three smart controller manufacturers that are not included in the report (DIG Corporation, RainMachine, and Water Optimizer). Efforts to contact these manufacturers or receive information for this report were unsuccessful. Reclamation intends to update the report on an approximate 2-year cycle in an attempt to keep information current and incorporate as much new product information as possible.

Smart Irrigation Technology Overview

Smart irrigation control systems typically include either a stand-alone controller or an add-on device that interfaces with a conventional clock-type controller. The weather or soil moisture-based technologies incorporated into these devices allow them to function similar to a thermostat. Like a thermostat, the devices permit irrigation to occur when needed rather than on a preset schedule. Regardless of the specific method or technology, the concept is for the appropriate irrigation quantity to be applied at the appropriate time.

Most of these systems are available in a variety of sizes appropriate for small residential to large commercial applications. For this report, a device with more than a 12-station (zone) capacity is considered large residential or light commercial. In most cases, light commercial products possess the same features as the residential products, but have greater station capacity. Larger industrial-type commercial products possess high station capacity and offer additional features such as flow sensing, surge and lightning protection, multiple master valve circuits, concurrent station operation, and other sophisticated features.

Computerized central control system type products are beyond the scope of this review. These consist of multiple “satellite” controllers that are controlled through a centralized computer system allowing for monitoring and control of multiple irrigation system parameters including flow rates, pressures, pumps, master valves, etc. from a single location. Several of these systems are mentioned since they are offered by the companies that sell stand-alone devices. Also, some of the stand-alone controllers reviewed possess central control system-type features.

SWAT Testing

In an effort to set an industry conservation standard, the Irrigation Association[®] (IA) has organized the Smart Water Application Technologies[™] (SWAT) initiative. This initiative functions as a partnership among water providers, the irrigation industry, and other related organizations with constituents from public entities and private companies. The first products for which testing protocols have been developed are for climatologically based irrigation control products. The current climatologically based testing protocol (8th Draft) was approved in September 2008 and has been implemented for testing. The current draft soil moisture sensor calibration protocol (3rd Draft) was released for public review in August 2011. This testing protocol combines Phase 1 Draft 8 and Phase 2 Draft 4 testing protocols into one testing protocol. Appropriate comments from the 30-day public comment period for Draft 2 have been incorporated into Draft 3, which will now be the testing protocol for soil moisture sensors and soil moisture-based controllers.

The Center for Irrigation Technology at California State University – Fresno (CIT) has been conducting SWAT smart controller benchmark testing. Climatologically based testing began in 2004. The testing is done in a laboratory environment using a “virtual landscape” that is subjected to a representative climate based on weather station data. The purpose of the testing is to evaluate the ability of a device to adequately and efficiently irrigate the virtual landscape without over watering. Although actual irrigation does not occur, the test measures the irrigation quantities prescribed by the device for six different zones with varying site conditions (soil and plant types, ground slope, sun/shade, irrigation system, etc.) The test duration is for 30 consecutive days with total minimum rainfall and evapotranspiration (ET) of 0.4 and 2.5 inches, respectively. Testing results are summarized in performance reports (performance summaries and technical reports), which are posted at www.irrigation.org/SWAT/control_climate as test results are released by manufacturers. The summaries include percentage scores in the categories of Irrigation Adequacy and Irrigation Excess. The technical reports include details associated with these scores.

Soil moisture sensor calibration testing that began in 2003 is also done at CIT. Testing is in a laboratory environment to evaluate the sensors’ ability to provide a consistent calibration curve or set points between drying cycles and between individual sensors. The manufacturer provides 20 sensors, and 3 are randomly selected for testing. Testing, performed over a 6- to 8-month period, is conducted on samples of fine, medium, and coarse textured soils. Certain samples are tested at various temperatures (-5, 15, 25, and 35 degrees Celsius [°C]) and with soil moisture water at conductivity levels at 2.5 and 5.0 decisiemens per meter (ds/m). Certain samples also undergo numerous wet/dry and freeze/thaw cycles in the development of calibration curves. Regression and confidence level analysis results are presented in the calibration reports that are posted at www.irrigation.org/SWAT/control_sensor as results are released by the manufacturer.

At the time of this report (January 2015), performance reports for 37 weather-based controllers by 18 manufacturers had been posted, and calibration reports for 9 soil moisture sensors by 7 manufacturers had been posted. The reports are available at <http://www.irrigation.org/SWAT/swat.aspx?id=298>. SWAT’s Technology and Promotions Working Groups are not apprised of products undergoing testing at CIT until the manufacturer releases test information to SWAT. Reports then are compiled, and both groups must approve them prior to posting. It is unknown how many of the other weather-based controller and soil moisture sensor products have been submitted for testing. Testing per the SWAT protocols and release of test results are voluntary by manufacturers. A few manufacturers have indicated concerns regarding the SWAT testing and reported they will not submit their products for testing unless certain protocol changes are made. Whether or not a device has been submitted for SWAT testing and the

status of the testing, when a performance or calibration report is not posted, is discussed in this report only if this information was made available by the manufacturer.

While the above discussion is focused on irrigation controllers, the SWAT program also is intended to test other water-efficient product categories for residential and light commercial landscape use. Draft protocols have been completed for add-on devices, rain sensors, and regulating sprinklers, and protocol development will begin in the near future for multiple stream, multiple trajectory sprinkler nozzles.

U.S. Environmental Protection Agency WaterSense Program

In 2006, the U.S. Environmental Protection Agency (EPA) introduced its voluntary public-private partnership WaterSense program. The mission of WaterSense is to protect the future of our Nation's water supply by promoting water efficiency and enhancing the market for water-efficient products, programs, and practices. WaterSense helps consumers identify water-efficient products by labeling those products that meet water efficiency and performance criteria. The program is in the process of developing a specification to label weather- or sensor-based irrigation control technologies, including weather-based controllers. WaterSense is evaluating the potential for adopting the SWAT protocols discussed above to certify these products.

On November 3, 2011, EPA published its specification for testing and certifying weather-based irrigation controllers; and manufacturers can now submit products for testing by independent laboratories. EPA considered the existing SWAT protocols and worked closely with the IA to develop the WaterSense specification for smart controllers. The specification applies to stand alone controllers, as well as add-on and plug-in devices that work with existing clock type controllers. EPA defines plug-in devices as add-on devices that are designed to connect only to a certain brand of controller. (See discussion under "Stand-Alone Controller Versus Add-On Device" in the "Weather-Based Control Product Features and Comparison Criteria" section of this report.)

At the time of this report (January 2015), eleven manufacturers of weather-based irrigation controllers had received EPA WaterSense certification for some or all of their smart controller products. These products are listed at http://www.epa.gov/watersense/product_search.html?Category=5.

Reported Water Savings

Most of the product descriptions in this report discuss water savings. In some cases, water savings associated with various studies and demonstration projects are discussed. In most cases, the water savings discussed are as reported by the manufacturer. It is discussed if water savings related study reports were submitted as part of this review and/or if the reports are publicly available. It is significant to understand that water savings can be calculated by numerous methods, and verification can be difficult.

In some cases, the reported water savings are average values for multiple installations; and in other cases, savings for a selected site are reported. Regardless of a product's reported water savings potential, actual savings will vary significantly from user to user depending on weather, irrigation system and site conditions, and previous irrigation practices. It is imperative that weather conditions be considered when calculating water savings. A properly installed irrigation system (piping and sprinkler heads) with acceptable distribution uniformity is critical to realizing water savings and maintaining a healthy landscape.

No Rating of Products

No attempt has been made to rate the products relative to each other. Certain comparison criteria are discussed, and it is left to the reader to research further and determine which products may suit various applications most appropriately.

Weather-Based Irrigation Control System Principles

All of the weather-based products reviewed operate on the principle of scheduling irrigation as a function of weather conditions. Most of the products use real-time or historical weather data to schedule irrigation based on evapotranspiration (ET), which is a function of weather conditions and plant type. ET is defined as the quantity of moisture that is both transpired by the plant and evaporated from the soil and plant surfaces (Allen et al., 2005).

The American Society of Civil Engineering's (ASCE) standardized reference ET equation (Allen et al., 2005) parameters are maximum and minimum air temperature, net solar radiation, average vapor pressure, and average wind speed. Vapor pressure can be calculated from humidity, dry and wet bulb, or dew point data; and solar radiation can be derived from pyranometer or sunshine recorder data. The standardized reference ET equation is widely recognized as one of the best methods for estimating ET. Other less accurate equations also are used that require only temperature and solar radiation parameters, and solar radiation is sometimes estimated as an average value based on historical data for a given site latitude. The problem with using estimated solar radiation values is the significant variability due to cloud cover is neglected, and solar radiation is obviously an important parameter in ET calculation. Some of the products evaluated use these empirical ET equations in their scheduling algorithms. It is significant to consider which equation is used with regard to ET estimation accuracy, or what parameters are measured if the equation used is not referenced.

Each of the weather-based irrigation scheduling systems evaluated utilize microprocessing devices that calculate or adjust irrigation schedules based on one or more of the following parameter sets: weather conditions (temperature, rainfall, humidity, wind, and solar radiation), plant types (low versus high water use and root depth), and site conditions (latitude, soils, ground slope, and shade). Some of the systems are fully automatic, and others are semiautomatic. The semiautomatic systems typically require the user to enter a base daily irrigation schedule, and then the device determines the frequency (which days) irrigations occur or adjusts run times. Some of the semiautomatic system manufacturers provide guidelines for establishing the base schedule and others do not.

A significant factor in comparing the products that use real-time weather data is the quality of the data used. The cost to install and maintain a complete weather station onsite to collect the data necessary to use the standardized reference ET equation is prohibitive in most cases. Two techniques are used to collect current weather data as alternatives to onsite weather stations. Specifically, irrigation

demand is calculated either using a limited set of onsite measurements or using a full set of weather station data from a remote site. There are tradeoffs associated with both methods.

If only a limited set of data is used to calculate ET with onsite sensors, the accuracy of the calculated ET may be poorer than ET calculated with a full set of weather station data. Conversely, if the remote weather station data used are not representative of the irrigator's site, the calculated ET value and/or rainfall sensing or measurement may not be accurate. Some of the weather station data being used may not be adequate for ET calculation. Specifically, some weather stations being used do not measure radiation but calculate it from other parameters; and some stations are not properly located for ET parameters data collection.

Certain products reviewed use onsite temperature measurements combined with historic monthly ET or solar radiation data in the daily ET calculation. The historic data used are a function of the site location. An obvious consideration with this technique is the accuracy of the historic data relative to a specific site. In one case, only five sets of data are available for the entire United States.

Several of the products reviewed calculate ET using a full set of remotely collected data from local weather stations or a network of weather sensors. The weather station data are collected from public and/or private weather stations. The weather station and sensor network data are processed by a centralized computer server and transmitted to the irrigation sites. There are ongoing service provider costs associated with the operation of the weather stations, sensor networks, computers, and information transmission systems associated with these products. These costs either are absorbed by water entities or are paid by the users.

In some cases, compelling study results were submitted by the manufacturers showing accurate ET calculation and/or significant water savings associated with their product as discussed under the product descriptions. In addition to the SWAT testing discussed above, a science-based evaluation of four of the weather-based products reviewed was conducted by the University of California Cooperative Extension in 2003; and the results are reported by Pittenger et al. (2004). Most studies to date have evaluated individual products rather than comparing the performance of multiple products. Given the general lack of data, it is difficult to draw conclusions about the overall performance of one product or technique versus another.

Weather-Based Control Product Features and Comparison Criteria

Significant weather-based controller product components and features are discussed below. The discussion also identifies different methods used to achieve similar results by the various products and associated advantages and disadvantages.

Installation

Although most of the manufacturers recommend professional installation and programming of their products, several indicate installation and programming of its residential models can be done by “do-it-yourself” type homeowners. Most of the individuals associated with residential product demonstration programs and pilot studies who were interviewed during this review expressed concerns about homeowner installation and programming. Based on the review of installation and programming instruction materials only, it appears some devices could be more difficult to install and program than others. The degree of difficulty to install any of the products can vary significantly depending on site-specific conditions. It appears that all of the commercial products should be professionally installed. Installation and programming instructions are available for many of the products at their Web sites. All potential customers should review this information when shopping for a device regardless of whether they plan to do their own installation and programming.

In the development of smart irrigation device promotion programs, water agencies should consider requiring professional installation or requiring users to attend workshops to receive training before performing self-installation.

Stand-Alone Controller Versus Add-On Device

The primary component of most of the products reviewed is an automatic irrigation controller in place of a traditional clock type controller. Alternatively, several of the products include a receiver or scheduler that is connected to an existing controller. In some cases, the lower cost of the add-on device is a significant attraction. Regardless of cost, the quality of an existing controller should be a factor when considering replacement. If the existing controller is a high quality unit with adequate features, an add-on receiver may be an attractive alternative. The level of automation is limited with some of these units relative to some of the stand-alone controller systems. Specifically, some devices only prescribe irrigation frequency or adjust preset run times and do not automatically

calculate run times. Certain add-on devices are designed to connect only with a certain brand of existing controller; and the EPA WaterSense Program defines these as plug-in devices.

Irrigation Schedules and Run Time Calculation and Adjustment

Some of the products reviewed will automatically generate irrigation schedules and run times for various zones as a function of sprinkler application rate, plant and soil types, slope and sun/shade conditions, and distribution uniformity. The ability of the automatic controllers to accurately generate an efficient schedule is dependent on the controller, the user's knowledge of the landscape parameters, and proper programming. Other devices require a base irrigation schedule with specific run times that are entered by the user. In which case, the user must manually calculate run times based on experience and/or guidelines provided by the manufacturer. Some of these controllers adjust the preset run times based on weather conditions, and others only control the irrigation run frequency. The product descriptions identify the manufacturers that provide guidelines for determining appropriate run times for the devices that require a base schedule. Automatic run time calculation can be a significant advantage if the required programming inputs are known and the controller calculates accurately.

Regardless of automatic or manual run times, many of the products have a fine-tune feature that allows adjustment of station run times by a percentage factor or by minutes giving the user the ability to compensate for inadequate run times.

Application Rates and Distribution Uniformity

Some of the products reviewed allow the user to enter actual sprinkler application rates versus preprogrammed rates based on irrigation type (spray, rotor, drip, etc.). Application rates can be measured by the user if not provided by the sprinkler manufacturer.

The irrigation system's distribution uniformity or efficiency factor (typically a percentage) describes the effectiveness of the sprinkler head coverage and reflects the quality and layout of the sprinklers. This setting allows the controller to compensate for low uniformity. The majority of a system with low distribution uniformity must be over irrigated for all areas to receive adequate water.

Irrigation Run and Soak Cycles

All of the stand-alone controllers reviewed provide multiple run and soak times to limit runoff. Some calculate them automatically by zone, based on soil and ground slope conditions, and others require manual programming. Of those that require manual programming and for the add-on devices, certain manufacturers provide guidelines or computer programs for calculating the times. Regardless of automatic or manual calculation, by zone multiple run/soak cycles ability is an advantageous feature.

Landscape Establishment/Fertilizer and Syringe Programs

Some stand-alone controllers provide landscape establishment or fertilizer programs that allow for programming high irrigation quantities for a certain timeframe before reverting to the weather-based programming. Plant establishment programs can preclude over-irrigation and runoff occurring for extended periods due to a landscape contractor programming for establishing a new landscape.

Syringe programs are designed for installation and system testing purposes. The program provides a convenient means of executing a short run time for each station.

Crop Coefficients

All of the controllers that automatically calculate run times can use preprogrammed crop coefficients set by the manufacturer by plant type. Some provide the user the option of programming custom crop coefficients. This can be advantageous since crop coefficients typically vary geographically.

Rain Sensors and Gauges and Rain Interrupt or Delay

Most of the products reviewed include a rain sensor or rain gauge with the system or as an optional add-on accessory. These controllers have a rain interrupt and/or delay feature triggered by the sensor, gauge, or an irrigation schedule adjustment feature that delays irrigation as a function of rainfall measured. Some of the products' only interrupt ongoing irrigation when significant rainfall is detected, and others initiate an adjustable preset irrigation delay period with or without the ability to interrupt ongoing irrigation. The more sophisticated systems interrupt ongoing irrigation and adjust the irrigation schedule based on the amount of rainfall measured. Although no documentation was reviewed for this report on the measurement accuracy of different types of rain gauges and sensors, it is

assumed that the tipping bucket type gauges are generally more accurate than hygroscopic type rain sensors that have an absorbent material that expands when wetted and electronic or conductor type rain sensors. The quality and accuracy of tipping bucket type gauges on the market also varies significantly.

Some of the receiver type systems have the ability to initiate a rain interrupt/delay or adjust the irrigation schedule based on rainfall detected or measured at a nearby weather station. Other receiver type systems use an onsite rain sensor or gauge that has the advantage of detecting or measuring rainfall that actually occurs at the site.

Other Sensors

Some of the products reviewed include standard or optional solar radiation, humidity, wind, temperature, and flow sensors. In addition to calculating irrigation demand using temperature data, some of the devices interrupt or delay irrigation when wind and/or temperature conditions are adverse to irrigation.

Alternatively, some of the systems delay irrigation based on wind and temperature conditions measured at a local weather station. Most of the commercial products include flow sensor input terminals. In addition to monitoring to detect for high and low flows indicative of irrigation system problems, some of the controllers' factor flow conditions into automatic scheduling decisions.

Power Supply and Surge and Lightning Protection

With one exception, all of the stand-alone controllers include a power transformer that converts 110-120 volts of alternating current (VAC) to 24 VAC. The transformers are either hardwired inside the controller cabinet (internal), or plugged into a power outlet (external). The Alex-Tronix controller operates on a pulsed 9 volts of direct current (VDC) using battery power. The add-on scheduling devices operate on either 24 VAC, 9 VDC, or 12 VDC; and either receive power from the existing controller or from an external transformer. Most of the transformer devices include some type of current overload protection such as a fuse or breaker switch. Some controllers include lightning and/or surge protection or offer these as an optional feature. Surge and lightning protection limits damage to the controller's circuitry from transient voltage, current from the power source (surge), and from the valve circuits (lightning).

Station Circuit Rating, Wiring, and Terminal Wire Sizes

The compatibility of the existing electrical circuits (wiring from the controller to the station valves) should be considered in selecting a replacement irrigation controller. If the station wire terminals on the controller will not accept the

existing wire, adapters must be used. Also, the circuit current capacity required for an existing system should be checked prior to installing a new unit. Reports from demonstration studies indicate installation problems associated with insufficient circuit capacity to operate some irrigation valves with high circuit resistance.

The traditional wiring system (circuitry) used for most controllers consists of a common and a dedicated wire from the controller to each valve and sensor. Some controllers use “two-wire” circuitry that consists of a single pair of wires connected to all of the valves and sensors in the system. These systems require the installation of a decoder device for each valve and sensor. Applications include large systems and linear systems (e.g., highway corridors) with large quantities of wiring required for traditional circuitry.

Clock Mode Operation

Most of the controllers reviewed will operate in a standard clock mode. Some of them can be programmed for clock mode operation by station. One of the controllers that receive a scheduling signal does not have clock mode capability. Therefore, if the signal subscription is cancelled, the controller must be replaced.

Display and Data Review

It is advantageous for a device to have a large, easy-to-read display that displays settings and data. Ideally, the data review control should be backlit and easy to use. It should display information by zone for run times, soak times, irrigation amounts, percent adjustments, ET and other weather information, watering window, and irrigation history.

Nonvolatile Memory and Batteries

All of the products reviewed have nonvolatile memory to protect their programming during power outages. Some of the products also include a backup battery for maintenance of the date and time during power failures. Those that do not include a backup battery provide this backup protection within the nonvolatile memory.

Warranty and Reliability

All of the products reviewed come with a warranty. Warranty periods are discussed separately in the review of each product. In some cases, the manufacturers' warranty periods vary for its different products. Although the warranty periods may or may not be indicative of the life expectancy of the products, in some cases there appears to be a correlation between the cost and overall quality of the product to the warranty period. It is assumed that the cost of a product somewhat reflects the quality of the construction materials and electronic components. Hence, the less expensive residential devices should not be expected to last as long and function as reliably as the more expensive residential and commercial products. Since most of the devices are relatively new products, it is difficult to speculate on how long they should last.

Depending on site conditions and maintenance, the weather sensors and other outdoor components may be vulnerable to degradation due to exposure to the elements. The availability of replacement sensors and their costs should be considered for those systems with onsite weather sensors.

Weather-Based Product Descriptions

The following product descriptions address operational characteristics and features and include discussions of available information from demonstration and pilot studies relative to documented water savings and operation. Each of the manufacturers was provided with copies of the product descriptions for their input prior to being incorporated into this report.

Accurate WeatherSet

Accurate WeatherSet (WeatherSet™) is located in Winnetka, California. WeatherSet has manufactured commercial weather-based irrigation controllers for landscapes, golf courses, and greenhouses since 1979. The company started development of its first residential controller prototypes in 2000 and began marketing the residential controllers in September 2001. All



WeatherSet controllers utilize a solar sensor and rain sensor to automatically adjust irrigation schedules. The solar sensor, designed and fabricated by WeatherSet, measures solar radiation that is the major factor affecting the controller's ET calculation.

The WeatherSet controller is called the Smart Timer™, and it comes in 8-, 12-, 16-, 24-, 32-, 40-, and 48-station models. The Smart Timer is a stand-alone controller with no ongoing service costs and does not require communication with remote servers to obtain weather data or irrigation schedules. The controller calculates ET with input from an onsite solar radiation sensor. WeatherSet reports the solar sensor has functioned reliably in demanding environmental conditions to control greenhouse and outdoor misting systems since the late 1980s. Outdoor installation of the solar sensor has performed for over 20 years in cold climates such as Wisconsin and high humidity climates like southern Florida.

Operational Features

The WeatherSet controller calculates a daily ET estimate based on solar sensor SunFall™ measurements that are logged by the controller on a 2-minute frequency. The solar sensor must be installed in a mostly sunny location to function accurately. Adaptive control logic allows the controller to function with

some shading. From their work with commercial controllers, WeatherSet reports that SunFall reduces by about two-thirds from a clear day in summer to a clear day in winter, and that their five self-adjusting programs follow these changes.

The calculated ET information is combined with rain sensor data and user programmed information to schedule irrigation. To program the controller for automatic adjustments, the user assigns each station to one of three programs, which are labeled Flowers™, Lawns™, and Shrubs™. The Flowers, Lawns, and Shrubs programs are for shallow-, medium-, and deep-rooted plants, respectively. A fourth program, called LWU (low water use), will deliver water to California native plants that expect no rain from May through September and winter rains from October through April. A runoff limit, in minutes per hour, may also be entered for each station to stop runoff. The user enters a “MAX Run” time for each station, and the Smart Timer automatically adjusts the watering days and run times for each valve. The controller has a manual start function and an optional irrigation history review function (“H-Option”). With the H-Option, the controller keeps a running tab of total run time for each station.

The controller’s hygroscopic rain sensor is an Ecologic RainBrain™. The rain sensor signals the controller to interrupt irrigation in its rain shutoff mode, and the rain sensor signals are also used by the controller for irrigation scheduling. The WeatherSet controller is preprogrammed to account for the duration that the rain shutoff circuit has been interrupted when scheduling irrigations.

The WeatherSet irrigation controller provides seven different runoff limits that are set for each station. A maximum cycle run time of 2, 4, 6, 8, 11, 15, 20, and unlimited number of minutes per hour may be set for each valve. The default cycle limit factor is 4 minutes per hour. As an example, if the controller calculates a total 12-minute run time for a station, this station will be irrigated in three 4-minute increments over a 3-hour period with the default setting. For stations that generate runoff, WeatherSet recommends the user measure the time required to cause runoff (using the manual run mode), divide the time by 2 and use that time to choose the runoff factor for the station. The runoff factor may be shut off to allow continuous watering when required. For example, valves controlling drip systems in LWU programs may best be watered with the runoff limit shut off.

Descriptions, Prices, and Warranty

Two Smart Timer residential controller models and seven outdoor commercial models are available. The indoor controller cabinets are constructed of aluminum with dimensions of 5.5 by 7.5 by 1.5 inches, and the indoor power transformer is an external plug-in type unit. The lockable outdoor cabinets are constructed of zinc plated steel with powder coating and stainless steel hinges, and they come in three sizes. The respective dimensions for 8- to 12-, 16- to 24-, and 32- to 48-station models are 9 by 10.5 by 4 inches, 10.5 by 9.5 by 4.5 inches, and 14 by 12

by 4.5 inches. The outdoor models include internal power transformers. The 16-station and larger models include flow sensor connectivity, station circuit testing, and surge/lightning protection features. The station circuit current rating for the indoor units is 0.75 ampere and 1.5 amperes for the outdoor units. All models' station circuit terminals will accommodate wiring sizes from 12 to 20 gauge. The controller's program memory is nonvolatile, and the timekeeping microprocessor chip uses a 3.3-volt coin-type battery that has a reported life of 10 years.

Low volume rebate program prices are summarized in table 1. (Retail prices are approximately 150% higher.) The prices include the solar and rain sensors. The controllers are available directly from WeatherSet by telephone (818-993-1449) or e-mail (www.weatherset.com). The company also plans to distribute the product through select specialty irrigation contractors. The Smart Timer controllers come with a 3-year warranty.

Table 1.—WeatherSet Prices (Includes Solar and Rain Sensors)

Controller Type	Model No.	Price
8-Station	ST8P	\$168
16-Station	ST16P	\$198
24-Station	ST12P	\$480
32-Station	ST32P	\$640
40-Station	ST40P	\$800
48-Station	ST48P	\$960
Solar and Rain Sensor Unit		\$50
Irrigation History Function	H-Option	\$35

Installation

WeatherSet reports that 95% of homeowners included in the Municipal Water District of Orange County, California, rebate program using the Smart Timer installed the controller themselves. Based on this, it appears that the typical homeowner can understand and program the WeatherSet Smart Timer. Technical support is available by telephone and through the company's Internet site. At this time, service by factory-trained contractors is limited to California, Oregon, Washington, and Colorado. WeatherSet reports this area will grow as their market expands. The installation and programming instructions, which include directions for locating the solar sensor, appear to be adequate and easy to follow.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

WeatherSet controllers performed exceptionally relative to other products included in a multiyear study of ET controllers that were installed under funding

from the California Department of Water Resources (Aquacraft, 2009). The study results indicate a 33% average water savings, which is 2.5 times more than the next nearest competitor—WeatherSet was one of only two companies that had statistically significant water savings. This study tested thousands of ET controllers purchased, installed, and programmed by homeowners and contractors, which is where water will be wasted or saved. All controllers were tested over 1 year in the field to test for seasonal water savings. The full report may be downloaded by WeatherSet’s Internet homepage. This report is the *only* evidenced-based field study of irrigation controllers

SWAT testing results are not available for WeatherSet. WeatherSet has chosen *not* to submit its controllers for SWAT testing because it believes “SWAT testing does not test for water conservation and only tests for irrigation adequacy.”

Another testing program in Texas shows that WeatherSet’s controllers performed well. To look for seasonal water conservation, the Texas testing program ran for 8 months in 2010. However, it tested only one controller from each manufacturer; that controller was programmed by technical personnel rather than by homeowners and contractors. This testing program found that WeatherSet watered only 6% more than the Texas plants needed. This report may also be downloaded on WeatherSet’s Internet homepage.

Alex-Tronix

Alex-Tronix® is a division of GNA Industries, Inc., and is located in Fresno, California. This manufacturer of agricultural and turf irrigation controllers was established in 1977. Alex-Tronix currently has two battery-powered smart irrigation controllers, the Enercon Plus and the Enercon+ Jr.



The Enercon Plus has been on the market since 2007 and is lithium battery powered. It is guaranteed to provide 25,000 valve cycles with a single lithium battery pack and can operate valves up to 2,000 feet away with a 14-gauge wire. It can operate the Rain Bird TBOS or Hunter Latching Solenoids directly, or most other valves with an available latching solenoid. It is modular with four stations per module, from 4 to 24 stations, and mounted in a stainless steel pedestal with an internally mounted temperature sensor. A standard rain switch (not supplied) input is available. The Enercon Plus has been SWAT tested.

The Enercon+ Jr. is a new battery-powered controller that is also guaranteed to provide 25,000 valve cycles with one lithium battery pack. The smart algorithm and irrigation schedule programming is identical to the Enercon Plus. This model is available with 4, 8, and 12 stations; nonmodular; and is housed in a shorter stainless steel pedestal than the Enercon Plus.

The Enercon Plus uses “Set It, Don’t Sweat It[®]” programming. For smart use, the controller is preprogrammed with summer irrigation schedules and the local Zip code is then just entered. Starting the next day, it adjusts the summer station run times according to the location, time of the year, and current conditions by the percentage of the summer run times. It has four programs with four starts per day, and timing in 1-minute increments up to 24 hours.

Operational Features

The programming capability of the Enercon+ Jr. is identical to the Enercon Plus with four programs, four starts per day, and 1-minute increments up to 24 hours. Both are stand-alone controllers and can accommodate 12- to 18-gauge wire. They both operate nominally 12 VDC pulsed latching solenoids.

Descriptions, Prices, and Warranty

The wholesale Enercon Plus base 4-station unit lists for \$2,212; with each additional 4-station modules listing at \$205; making the list price range from \$2,212 to \$3,237. The 4-station Enercon+ Jr. lists for \$1,549; the 8-station for \$1,749; and the 12-station for \$2,149.



Both models have freeze shutdown capability and have an onsite temperature sensor with estimated solar radiation based on location. All the models have a 2-year warranty. Rain switches are not provided, but recommended.

Installation

Installation of the Enercon Plus and the Enercon+ Jr. is similar to any pedestal-mounted field controller on a concrete slab. Detailed step-by-step installation and setup instructions are included in the owner’s manual, which is available with the controller and at: www.AlexTronix.com.

The Alex-Tronix battery-powered controllers are compatible with Hunter and Rain Bird latching solenoids, as well as the Alex-Tronix latching solenoid. In general, they are compatible with nearly all currently manufactured valves.

Both the smart technology and the restricted watering schedule automation are multiple-patented technologies.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

Alex-Tronix performed a 5-year analytical study comparing their Set It, Don't Sweat It temperature budget calculated irrigation demands at 25 locations to nearby CIMIS stations referencing ET. Results of the study are summarized in the graph shown in figure 1. The plot shows monthly percentage of peak temperature budget demand compared to the monthly percentage of peak CIMIS reference ET.

The Enercon Plus controllers have completed SWAT testing and performance reports are posted at the Irrigation Association Web site. These are the first battery-powered controllers to complete SWAT testing. The city of Indian Wells, in cooperation with the Coachella Valley Water District, completed a 1-year study to determine how much water could be saved in a commercial application with a combination of water saving methods. In addition to using the Enercon Plus controllers, some drip irrigation was used along with more efficient sprinklers and some artificial turf. Results showed that about 75% of the water and costs were saved over the previous year.

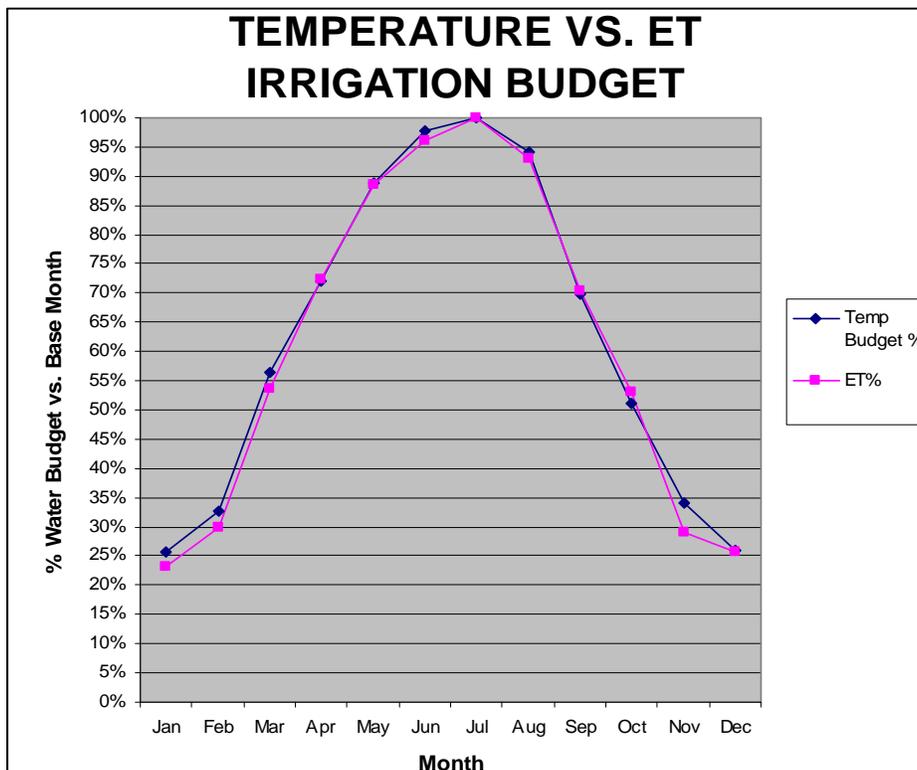


Figure 1.—Alex-Tronix temperature budget compared to CIMIS ET.

Brilliant Integrated Technologies

Brilliant Integrated Technologies, of Ogden, Utah, was founded in 2012 for the single purpose of developing cutting-edge irrigation controls. Its predecessor/current partner company, Brilliant Control Technologies, had extensive experience in fluid process controls (including irrigation) for industrial and municipal applications, and transferred all the irrigation-related talent and technologies to the new venture. The founding engineers and scientists had over 100 years of combined experience in the design and integration of control technologies in municipal irrigation, waste- and culinary-water treatment, food processing, telecom equipment, and aircraft cockpit displays. They were motivated by a common passion for creating technological solutions that address the accelerating growth in demand for water. Eighty-two percent of the company is owned by Veterans and Disabled Veterans.



The common element in the company's growing product portfolio is the use of actual weather data in a proprietary ET-based algorithm to adjust individual zone watering times based on the actual water lost from vegetation and soil in each zone. The advanced water-saving features used in the company's high-end, custom-designed municipal controllers were refined and value-engineered into a moderately-priced controller targeted at residential and small commercial applications: the ICS-ONE™.

Brilliant Integrated Technologies introduced ICS-ONE in the summer of 2014, and reported that by the end of the year it had been installed in 28 states and 8 countries. The controller is operated via an intuitive user Interface that can be accessed by the browser of any Web-enabled device.

The ICS-ONE is a direct replacement for any residential or small commercial time-based controller and provides 16 discrete zones of standard control output (24 VAC) to operate irrigation valve solenoids or interposing relays. The relays can be used to control other 110/220 VAC circuits (e.g., lighting, fountains, spa heaters, etc.). As a self-contained, complete unit, it requires no additional modules or adapters. The device is engineered to work with a wide variety of rain sensors, flow meters, and WiFi adapters, available through the company or third parties.

Operational Features

The controller was designed from inception to work with home automation systems. The ICS-ONE seamlessly integrates into homes with central automation by Crestron[®] (the world's largest whole-home automation company) or Control4[®] (the world's third largest whole-home automation company) to incorporate control of other outdoor elements (e.g., lighting, fountains, heaters, etc.). The hand-held touch screen tablets proprietary to these automation systems will operate the controller in addition to generic Web-enabled devices. The manufacturer anticipates the list of automation partners will continue to grow.

The weather data are provided by the Agricultural Weather Information Service (AWIS), an Alabama-based commercial weather data subscription service with access to thousands of certified weather stations throughout the world, including those of all the Federal and state agencies that report into the national system, as well as thousands of stations maintained by colleges, business campuses, airports, and other entities. The provider then aggregates, compiles, and performs quality assurance checks on the data before feeding it to subscribers via the Internet.

Each weather data file is specific to a controller's electronic serial number and the property's latitude/longitude. The weather data elements include total precipitation, temperature, humidity, wind, and solar radiation (which consider the property's latitude and the date to determine sun angle, plus sun attenuating conditions like humidity, smoke, and cloud cover). The high-resolution weather data for each property may cover an area as small as one-half of a square mile, depending on the property location and the density of weather reporting stations in the vicinity. Typically, the data are accurate and relevant to an area with a radius of 2 kilometers/1.2 miles around the property.

The ICS-ONE checks for updated weather data every 2 hours. When new data are received, it recalculates the water lost by the zone for the prior period, considering all of the weather elements and their effect on the plants and soil in the zone. During the intuitive setup, the user selects from pulldown menus which of the seven vegetation types, five soil types, and three sun-exposure choices best describe the zone. The user also enters—based on either experience or a dedicated test—information such as runtime data, which the controller uses to minimize runoff and water waste.

If the current day is not a scheduled irrigation day, the controller holds the water replacement needs in memory, aggregating up to 7 days. At the next scheduled irrigation day, the device will apply the precise amount of net water lost by the zone since the last irrigation day, breaking the total watering time into numerous soak periods if required to avoid pooling and runoff.

The ICS-ONE irrigation sequence scheduling makes it easy for the user to comply with municipal watering rules by choosing specified days of the week or even/odd dates. The user also sets the “Start or Finish By” time for those dates. In the

latter case, the controller calculates the irrigation sequence start time to ensure that the entire sequence is completed by the desired “Finish By” time, even if the sequence is made complex by numerous “Maximum Soak Time” and “Minimum Soak Interval” limits being invoked.

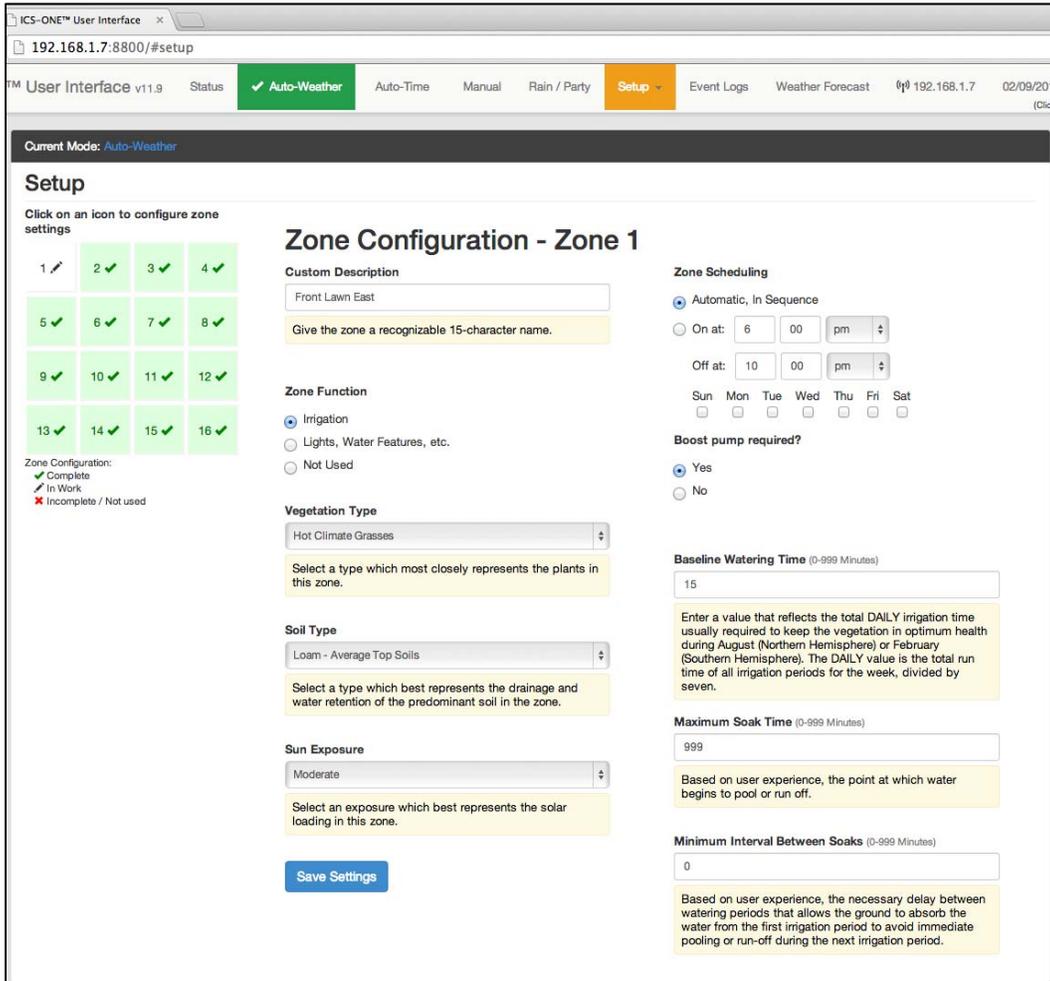


Figure 2.—Brilliant Integrated Technologies user interface example.

Whenever a new feature is developed, the firmware for every ICS-ONE is updated automatically at no cost. An email is sent to every customer in advance advising them of the upcoming changes, including instructions and hints for getting the most out of the new features.

Where more than 16 zones are required, additional units on the same property can use the same weather data subscription. The additional units can be placed strategically to reduce trenching for control wires and pipes. As long as line power and Internet access can be supplied to the unit, there is no limit to the expansion. The user interface for each unit can be viewed as a separate Web

page, or via the Irrigation Control Center application for larger properties (e.g., villas, condominiums, campuses, etc.). The ICS-ONE dashboard overlays the irrigation plan on top of satellite photographs of the property, with dynamic icons to represent zone functional status.

The following list provides a summary of key operational features:

- ◆ Sixteen zone outputs to control any combination of irrigation zones, water features, and exterior lighting circuits. The robust power supply allows each zone to power more than one valve solenoid (if the zone configurations/watering schedules are similar, and if the water supply pressure is adequate).
- ◆ Incorporates coordinated control for one auxiliary irrigation boost pump and/or master shutoff valve paired to each irrigation zone individually.
- ◆ Configured and operated by any Web-enabled device such as a smartphone, tablet, or computer.
- ◆ Intuitive remote control promotes frequent adjustments, which reduces water use and improves plant health.
- ◆ Easy-to-understand modes:
 - Auto-Weather – Complete “set and forget” automatic control of irrigation with daily ET adjustments based on actual weather data.
 - Auto-Time – Time-based irrigation with intuitive remote controls to inspire frequent setting adjustments to improve water savings.
 - Manual – Complete manual control of all zones, providing start on click and stop on command, or after the expiration of the user-entered runtime.
 - Rain/Party – Ability to stop the current irrigation sequence (or cancel the next one) with complete assurance that the following sequence will commence as scheduled. Activated by the user via the user interface, or via the optional rain sensor.
 - Fixed Start and Stop Times (for lighting circuits, fountains, and other auxiliary features) – Allows the irrigation zones to run in sequence for as long as the algorithm determines, while the auxiliary zones run at the times specified by the user.

- Can be mounted at remote distances from the main building near the valve manifolds to save trenching and wiring expense, ideal for incorporating into new landscaping plans.
- Can be retrofitted to replace existing controllers.
- Measures and tracks waterflow rate and usage data with an optional flow meter. An integrated pulse flowmeter input is standard in every unit—no pulse converter required.
- Incorporates a standard rain sensor input that can be configured via the user interface to use either sensor polarity.
- Incorporates an RS-232 communications port to support industry-standard communication protocols, or for the addition of an optional color touch-screen Operator Interface Terminal (sometimes desired by commercial users).
- The controller aggregates the daily water loss and replacement demands for up to 7 days following the last irrigation period. This facilitates setting an aggressive, water-saving irrigation schedule of 1 to 3 days per week. Thus, on the day of irrigation, the plants receive only the net amount of water lost since the irrigation.
- The recalculated water needs are converted to specific watering durations for each zone. The controller then executes the commands at the next watering sequence time selected by the user. The user determines the “when” and the ICS-ONE determines the “for how long.”
- The controller can be programmed to start or finish irrigation at any time. If the user selects the “Finish By” irrigation schedule, the controller will begin irrigation to finish by the commanded time—to the minute—no matter how complex the soak limitations.

Description, Prices, and Warranty

Model prices, descriptions, and options and accessories are summarized in table 2. Brilliant Integrated Technologies offers a 3-year warranty from date of installation. Modular design allows replacement of failed components without having to uninstall the entire device. The unit has been engineered to provide a long useful life (e.g., the zone relays are tested to 10,000 cycles, about 30 years of daily use).

Table 2.—Brilliant Integrated Technologies Model Descriptions and Prices

Model Number/Description	Manufacturer's Suggested Retail Price (MSRP)
4401: WaterSense Certified Irrigation Controller	\$899
4411: 4401 With Certified Control Automation Integration	\$1,499
4421: 4401 With Certified Crestron Automation Integration	\$1,499
Options and Accessories	
Standard Enclosure	ABS thermoplastic rated NEMA 4X with waterproof door seal. Suitable for mounting anywhere, although exposure to direct sunlight should be avoided for the longevity of the enclosure.
Upgrade	Extra ruggedized polycarbonate with waterproof door seal. Suitable for mounting in extreme conditions, including direct sunlight.
Standard Connection	Ethernet via customer-provided cable.
Option	WiFi adapter module.
Standard Interface	Via the customer's Web-enabled device.
Option	7-inch door-mounted color touch-screen interface.
Optional Rain Sensor	Accepts any standard unpowered two-wire sensor.
Optional Flowmeter	Accepts most industry standard flowmeters with native pulse input; additional pulse converter not required.
Weather Data Subscription	\$12 per month; \$132 for 1 year; \$360 for 3 years.
Physical Dimensions	
Height	12.25 Inches
Width	8.75 Inches
Depth	6.00 Inches
Shipping Weight	5.90 Pounds
Inputs/Outputs	
Electrical Input	110 / 220 VAC
Control Output	16 Zones; 24 VAC at 1.5A Total
Output Wire Gauge	12 to 24 American Wire Gauge (AWG)
Boost Pump Control	Yes; activation of relay via Zone 16
Master Valve Control	Yes; activation of solenoid or relay via Zone 16
Data Output	Yes; RS-485
WiFi Protocol	Institute of Electrical and Electronics Engineers (IEEE) 802.11g/n
Warranty	
Three years from date of installation. Modular design allows replacement of failed components without having to uninstall the entire device. The unit has been engineered to provide a long useful life (e.g., the zone relays are tested to 10,000 cycles, about 30 years of daily use).	

Installation

The device can be mounted anywhere that line power, valve control wires, and Internet connection are present (local area network [LAN] cable preferred; WiFi optional). The actual setup and operation is accomplished via smart device by connection to the Web-based user interface. Therefore, the user does not need readily physical access to the device after setup. No special expertise or tools are required for installation. The manufacturer reports homeowners, electricians, and landscape contractors should be able to install the device, including connecting the low voltage outputs to existing valve control wires, in less than 1 hour. Installers will benefit from having previous experience with making network connections. Technical assistance via telephone or email is available.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

The ICS-ONE has received WaterSense certification based on testing by an independent laboratory, which used the “SWAT 8th Testing Protocol” with minor modifications as required by EPA. Brilliant Integrated Technologies and the Irrigation Association are discussing the possibility of using those test results to earn SWAT certification without additional testing.

Brilliant Integrated Technologies maintains that declaring a numerical water “savings” as a measure of smart controller effectiveness is a questionable metric, because:

- The “reference” controller or situation for the comparison is rarely defined
- The “savings” depends on how much water is being wasted by the controller and user against which it is being compared.

The company lists savings of 31 to 77% based on an 18-month comparative study that lasted two irrigation seasons. Findings of this study are discussed below:

- In the EPA WaterSense certification test, the ICS-ONE applied precisely (+/- 2%) the amount of water that the test reference formula calculated as optimum, making the ICS-ONE performance a fair benchmark for further comparative testing.
- Using the ICS-ONE as the reference, different types of users of “dumb” controllers applied grossly differing amounts of water, all in excess of the ICS-ONE. Therefore, the ICS-ONE would have saved differing, but significant, amounts of water.
- A “conscientious user” was an informed, attentive user who: 1) honored water-saving scheduling guidance; 2) set appropriate irrigation runtimes for each zone; and 3) diligently adjusted those settings each month to

match changing water needs. These users were in the tiny minority of all users observed in the study. They used 45% more water than the ICS-ONE over the irrigation season, and would have saved 31% of their total water consumption by allowing the ICS-ONE to make daily runtime adjustments based on actual weather data.

- ◆ At the other end of the observed range of users, an “irresponsible user” was represented by a significant number of the many properties sampled. These users: 1) did not honor municipal watering rules; 2) did not set runtimes appropriate for the actual needs of the plants; and 3) did not readjust settings each month to match the seasonal water needs). Therefore, they used 330% more water than the ICS-ONE commanded. The ICS-ONE would have saved 77% of their total water use.

- ◆ In the absence of a much more comprehensive study, there is no way to accurately measure the prevalence of each of these user types nation-wide to determine a theoretical “average” savings.

- ◆ The complete test report is posted on the Web site at: www.BIT-USA.com. Table 3 shows the tabulated results.

Table 3.—Comparative Study Test Report Tabulated Results

User Type	Water Used (gals)	Excess Over ICS-ONE (gals)	Excess Over ICS-ONE (%)	Potential Savings With ICS-ONE (%)
ICS-ONE Reference	315,000	n/a	n/a	n/a
Conscientious User	456,000	141,000	45%	31%
Distracted User	503,000	188,000	60%	37%
Typical User	589,000	274,000	87%	47%
Unaware User	765,000	449,000	143%	59%
Irresponsible User	1,353,000	1,038,000	330%	77%

A similar study will be independently conducted by at least one university beginning in the spring of 2015, which will also compare ICS-ONE performance against other smart controllers.

Calsense

Calsense[®], started in 1986, is a Carlsbad, California-based company that manufactures water management systems for large commercial customers. Since its startup, the company has specialized exclusively in water management systems using weather-based irrigation, real-time flow monitoring, moisture sensors, and a wide variety of communication technologies. Calsense markets its products to municipalities, school districts, universities, transportation departments, and other high volume landscape irrigators. Calsense provides free onsite training with its products and emphasizes their commitment to customer service, support, and successful utilization of its products.



Calsense has a true hosted Web-based software that a user can make “real-time” programming changes and update controllers from any computer with Internet access, broadband card, WiFi network, etc., and thus can be mobile with a laptop or iPad and have all the power and flexibility needed when managing large project sites. Calsense *does not need* a dedicated computer with downloaded software on that one computer and offers several options with many communication options when managing irrigation and landscape.



Figure 3.—Calsense’s Command Center for the Web.

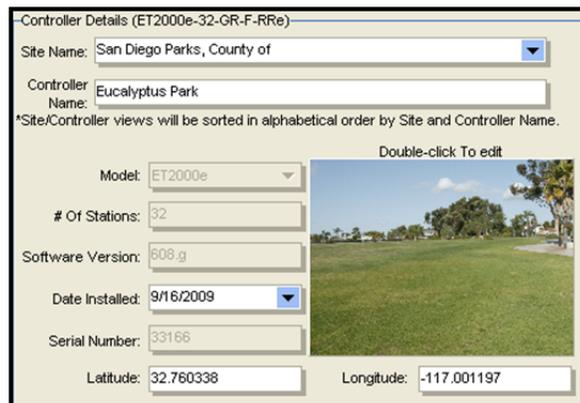
System reports include complete records of the details for every irrigation cycle, water usage versus water budget amounts, the gallons and percentages of water savings, and what events and changes have happened at the controller. Additionally, system administrators have management reports listing sites and users for their company.

Benefits of using Calsense's Command Center for the Web include:

- No software installation needed
- Users can access their data from anywhere
- Data are stored on Calsense servers
- Software is updated automatically and transparently
- Database is safeguarded through automatic backups

The Calsense ET2000e controller functions either as a stand-alone unit or as a field controller component for their resource management central control system. The Calsense Command Center software or the Command Center for the Web software are the central component options for the Calsense Resource Management System.

The Calsense WeatherSense provides the user with real-time daily ET data collected from multiple sources and weather datasets through the use of the Internet, so that automatic ET adjusts can be made at the controller level. The Command Center software will share the appropriate daily ET values based on the latitude and longitude of the controller location. Calsense offers this feature at a no-charge cost to our customers.



Operational Features

The ET2000e can automatically adjust daily irrigation schedules with onsite reference ET measurements from the optional Calsense ET gauge, real-time data, or with historic average monthly ET. (Use of weather station or WeatherSense data require computer interface to calculate ET and communicate it to the controller.) California Irrigation Management Information System (CIMIS)-based historic monthly average values are preprogrammed into the controller, as well as historical average ET for other states applications, or the user can enter monthly values to serve as a backup ET source. Measurements from an optional tipping rain bucket are incorporated into the irrigation schedule calculation to

account for effective precipitation. Irrigation can be interrupted in the event of rain and high winds with the use of optional switch-type sensors. A soil moisture sensor can be used with the ET2000e also and override the decision determined through onsite ET. (See Calsense discussion under the “Soil Moisture-Based Product Descriptions” section of this report.)

In the ET scheduling mode, the user programs the controller’s run times based on field knowledge for the time of year and soil moisture content. This base schedule is adjusted daily as a function of weather conditions. Monthly ET adjustment percentage factors are fine-tuned for each station depending on plant types, sun/shade conditions, and soil moisture content. Crop coefficients can be entered as well for each month for seven different kinds of plant material. Cycle and soak times are programmed manually into the base schedule to minimize runoff.

The “-F” controller option is the ability to interface with up to three flowmeters and master valves wired to a single controller. Now with new software engineering the -F option, in conjunction with a bypass manifold install, the controller is able to read and monitor low flowing station zones on a large mainline. This feature dynamically manages flow through the appropriate size flowmeter using actual flow rates, not expected flow rates, providing accurate flow monitoring, specific station alerts, and detailed water usage reports.

A Calsense flowmeter, Model FM, can be connected to the controller to continuously monitor flow through the irrigation mainline and learn each station’s flow rate automatically when irrigation occurs. This feature detects and alerts the user to mainline breaks, no flows, high flows (due to broken risers and/or pipes) for each individual station, and low flows due to pressure drops, malfunctioning valves, and/or clogged heads.

Flow management is a standard feature, whereas the controller can optimize the water window and irrigate stations based on the mainline system capacity.

The unique *FLOWSENSE*[™] option on an ET2000e controller allows flexible system design and efficient retrofitting of existing irrigation systems. The option allows multiple ET2000e controllers to share one or multiple points of connection and communicate the data between the units without the need of a central computer. Setup and operation is done at the controller in the field. Calsense has developed the *FLOWSENSE* option to include cooperative communication and shared management features that allow the following:

- ◆ Manage the number of valves “ON,” based upon flow capacities
- ◆ Shorten water windows
- ◆ Eliminate scheduling conflicts between multiple controllers
- ◆ Eliminate relays when sharing pumps or master valves with several controllers
- ◆ Pump performance managed for electrical savings

An optional remote control receiver board is integrated into the ET2000e allowing the user to activate valves and view operational details without going to the controller. The Calsense Remote SENSE remote control transceiver allows the user to view valve-on, area description, flow rate, electrical use, and remaining time. Editable station information on the hand-held includes total minutes, minutes per cycle, soak in time, expected flow rate, square footage, set nowater days by station and by program, perform master valve overrides to open or close the master valve for a specified period of time, control lighting, clear a mainline or master valve override from the controller status screen, and operate the radio in either English or Spanish. The keypad is user-friendly and provides for immediate intuitive operation.



A water volume budget feature determines when monthly use, with projected usage, will exceed the programmed monthly budget and alerts the user before the month ends. This capability helps maintain water rates and keeps staff accountable to a water management program. Table 4 and figure 4 show data from an actual site that demonstrates the utilization of the water budget feature and shows the correlation between historical and measured ET. The adjusted budget shown is the result of the automatic scheduling performed by the controller. The controller also possesses a laptop computer interface for field uploads and downloads so that detailed reports can be produced and potential expansion to a central system can be evaluated.

Table 4.—Table Correlation Between Historical and Measured ET

Calsense 2075 Corte del Nogal, Suite P Carlsbad, CA 92011-1415 (800) 572-8608 November 03, 2011 9:51:25 AM Water Management Mar/01/2010 - Apr/30/2011 University of Texas, Austin Open Area 608.f									
Date	# of Days	*CONTROLLER HISTORICAL ET	ACTUAL ET TABLE	ADJ %	**CONTROLLER BUDGET GALLONS	***ADJUSTED BUDGET GALLONS	****USAGE ACTUAL GALLONS	SAVINGS GALLONS	PERCENT SAVED
Mar-2010	31	4.82	4.79	-1 %	86,106	85,560	29,452	56,108	66 %
Apr-2010	30	5.27	4.63	-12 %	249,043	218,938	98,129	120,809	55 %
May-2010	31	7.55	7.07	-6 %	356,788	334,171	268,340	65,831	20 %
Jun-2010	30	8.28	6.80	-18 %	391,286	321,273	261,395	59,878	19 %
Jul-2010	31	8.12	5.15	-37 %	383,725	243,405	202,873	40,532	17 %
Aug-2010	31	8.20	5.83	-29 %	514,060	365,788	310,323	55,465	15 %
Sep-2010	30	6.22	4.07	-34 %	408,394	267,574	168,635	98,939	37 %
Oct-2010	31	4.93	3.16	-36 %	323,694	207,521	128,811	78,710	38 %
Nov-2010	30	3.08	1.80	-41 %	202,227	118,432	75,161	43,271	37 %
Dec-2010	31	2.08	1.82	-12 %	136,569	119,605	80,123	39,482	33 %
Jan-2011	30	1.93	1.81	-6 %	127,080	119,035	75,646	43,389	36 %
Feb-2011	28	2.66	3.62	36 %	174,650	237,353	83,894	153,459	65 %
Mar-2011	16	2.22	3.05	37 %	145,719	200,271	55,052	145,219	73 %
TOTAL	380	65.35	53.60	-18 %	3,499,341	2,870,451	1,837,834	1,032,617	36 %

ET values and usages set to zero when budget is zero
 *County and city settings for controller are Travis and Austin
 ** Controller Budget was Calculated at 100% of Controller Historical ET.
 *** Adjusted budget uses actual ET to modify the controller budget.
 **** Usage based on: Test usage, manual usage, scheduled usage, noncontroller usage, radio remote usage

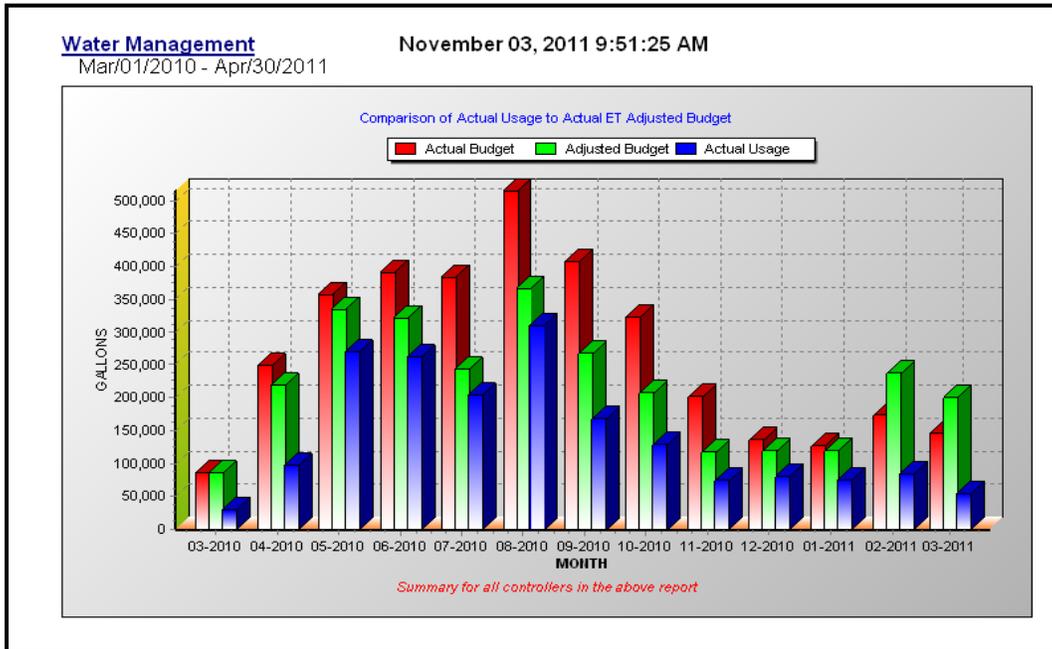


Figure 4.—Figure correlation between historical and measured ET.

Extensive current and historic irrigation information can be viewed at the display or downloaded from the controller. The controller monitors and keeps a record of all site water usage by month for up to 2 years. Scheduled irrigation usage is recorded on a station-by-station basis and on a total controller basis for the current month and the previous month. Unscheduled water usage (pressing the manual water or test key) and noncontroller water usage (e.g., quick-couplers, manually bleeding valves, etc.) is recorded separately showing how the water is being applied.

Calsense now offers a new integrated Geographic Information System (GIS) viewer included in the latest version of the Calsense Command Center software. This feature visually represents a user's controllers on a map using existing GIS data. Highly customizable, this feature shows the status of each controller, including mainline breaks and flow alerts through the use of color-coded icons. Additional information about each is also available via a built-in legend and by right-clicking controllers on the map.

Descriptions, Prices, and Warranty

The ET2000e is available in 6-, 12-, 16-, 24-, 32-, 40-, and 48-station models. The controllers have two additional outputs for master valve and pump circuits. In addition, the controllers may be ordered with hardware and software for four additional 24 VAC outputs for the operation of lights, gates, water features, etc. These outputs are controlled independently from the irrigation programs.

The controller has seven regular programs and several syringe/propagation programs. A maximum number of start times or repeats per station is determined by station total minutes (programmed or ET-calculated) and by a fixed set run time per cycle and a fixed set soak time between cycles. The cycle and soak times are set manually. The user selects 7-, 14-, 21-, or 28-day watering schedules to accommodate watering requirements, and no water days can be designated for each program. Programs can operate simultaneously based on the system capacity of the mainline and flow management. The ET2000e typically is installed by a landscape contractor, and then Calsense provides programming assistance to the user following the landscape establishment period.

The ET2000e has several enclosure options that include single- and double-wide heavy-duty stainless steel units. The front panel includes an ergonomic key layout and a large 16-line by 40-character LCD display (English or Spanish). The controller has nonvolatile memory, and the clock maintains time during power outages without the need for a backup battery—it is powered through an internal transformer. The controller accepts up to 14-gauge wire, and the station current capacity is 1.5 amperes. Optional AC powerline overload protection consists of a sealed unit suitable for outdoor installation and carries full Underwriters Laboratories Incorporated (UL) approval. Optional transient (lightning and surge) protection is provided with the TP-1 board. The transient protection board can be purchased either with or without an outdoor cabinet. The ET2000e will detect, alert, and identify open and shorted circuits in field wires and solenoids. The affected station is skipped until repaired.

Calsense products are available from many distributors located throughout the United States. A list of these distributors is available on the Web site at: www.calsense.com. Current prices for all ET2000e models and certain accessories are summarized in table 5. Calsense offers a 10-year limited warranty.

Table 5.—Calsense Products Price Summary

Product Description	Model Number	Price
Controllers		
6-Station ET2000e Controller	ET2000e-6	\$1,075
8-Station ET2000e Controller	ET2000e-8	\$1,400
12-Station ET2000e Controller	ET2000e-12	\$1,945
16-Station ET2000e Controller	ET2000e-16	\$2,150
24-Station ET2000e Controller	ET2000e-24	\$2,550
32-Station ET2000e Controller	ET2000e-32	\$3,100
40-Station ET2000e Controller	ET2000e-40	\$3,515
48-Station ET2000e Controller	ET2000e-48	\$3,950
GPRS Cell Modem	-GR	\$1,590
Wireless Ethernet Modem	-WEN	\$1,250
ET Gauge	ETG	\$1,375
ET Gauge Controller Interface	-G	\$470
Rain Gauge	RG-1	\$595
Rain Gauge Controller Interface	-RG	\$470
Wind Gauge	WG-1	\$575
Wind Gauge Controller Interface	-WG	\$470
Soil Moisture Sensor	1000-S	\$210
1-Inch Brass Flow Meter*	FM1B	\$595
1.5-Inch PVC Flow Meter*	FM1.5	\$510
Transient Protection	TP-1	\$285
Enclosure for TP-1	TPB	\$225
AC Line Protection	TP-110	\$185
*Other brass and polyvinyl chloride (PVC) flowmeter sizes are available up to 3 inches.		

Installation

Calsense recommends professional installation of the ET2000e, and installation time varies significantly depending on site conditions.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

Although Calsense has not participated in any outside studies or demonstration projects, its track record speaks for itself. During Calsense’s 23 years of existence, they have developed a large database on its products’ performance and customer success.

Calsense submitted data for this report prepared by their in-house research and development department showing average water savings of 22 and 33% for two typical installations. Calsense reports an overall average water savings rate of approximately 37% depending on past water usage and project history.

Although the controller models have evolved, the Calsense ET scheduling technology has been in place since 1992. Many of the Calsense systems installed since that time continue to function today. Several articles written by end users in Calsense's niche market testifying to the successful operation of their Calsense systems were submitted for this report. The ET2000e has completed SWAT testing and a performance report is posted on both the Calsense and Irrigation Association Web sites.

Calsense provides potential clients with a reference list of all past and current users so that they can learn of their personal and professional experiences. In some cases, Calsense loans controllers to potential clients to demonstrate its system. The ET2000e provides a complete water management system as a stand-alone field controller, which can easily be expanded into a central control system.

Cyber Rain

Cyber Rain, Inc., is based in Encino, California, and began business in 2006. The Cyber Rain XCI is a stand-alone weather-based wireless irrigation controller that accesses weather forecasts via the Internet and automatically adjusts irrigation scheduling. The controller is scheduled and



monitored via the Internet through a reportedly easy-to-use and intuitive interface. An unlimited number of controllers can be remotely scheduled, operated, and monitored through a single Internet account. A free App is available to operate and monitor Cyber Rain controllers via an iPhone, Android, or Blackberry smartphone. Water usage and savings are tracked and reported.

Operational Features

The XCI can be installed as a new controller or one that replaces an existing clock-type controller. Cyber Rain supplies a small device called an "Access Point" that is plugged into a router so that Cyber Rain can access the Internet. The Access Point communicates with an unlimited number of Cyber Rain controllers through their own two-way wireless network. The standard 2.4-GHz 802.15.4 radio can communicate up to 200 feet, while the longer-range 900-MHz radio can reach up to 1 mile. Users can schedule, operate, and monitor

Weather- and Soil Moisture-Based Landscape Scheduling Devices

their Cyber Rain controllers through any Internet-connected computer or smartphone. Schedules and user commands are automatically sent via the Internet to the Access Point, which wirelessly communicates them to the Cyber Rain controller. All irrigation activity is wirelessly communicated back from the controllers to the Access Point and is reported back to the user. The XCI is programmed on a personal computer (Macintosh included) using a Web browser and all scheduling operations can be performed through the Web user interface as shown in figure 5 below. In addition, users have the option to run valves using the buttons on the controller.

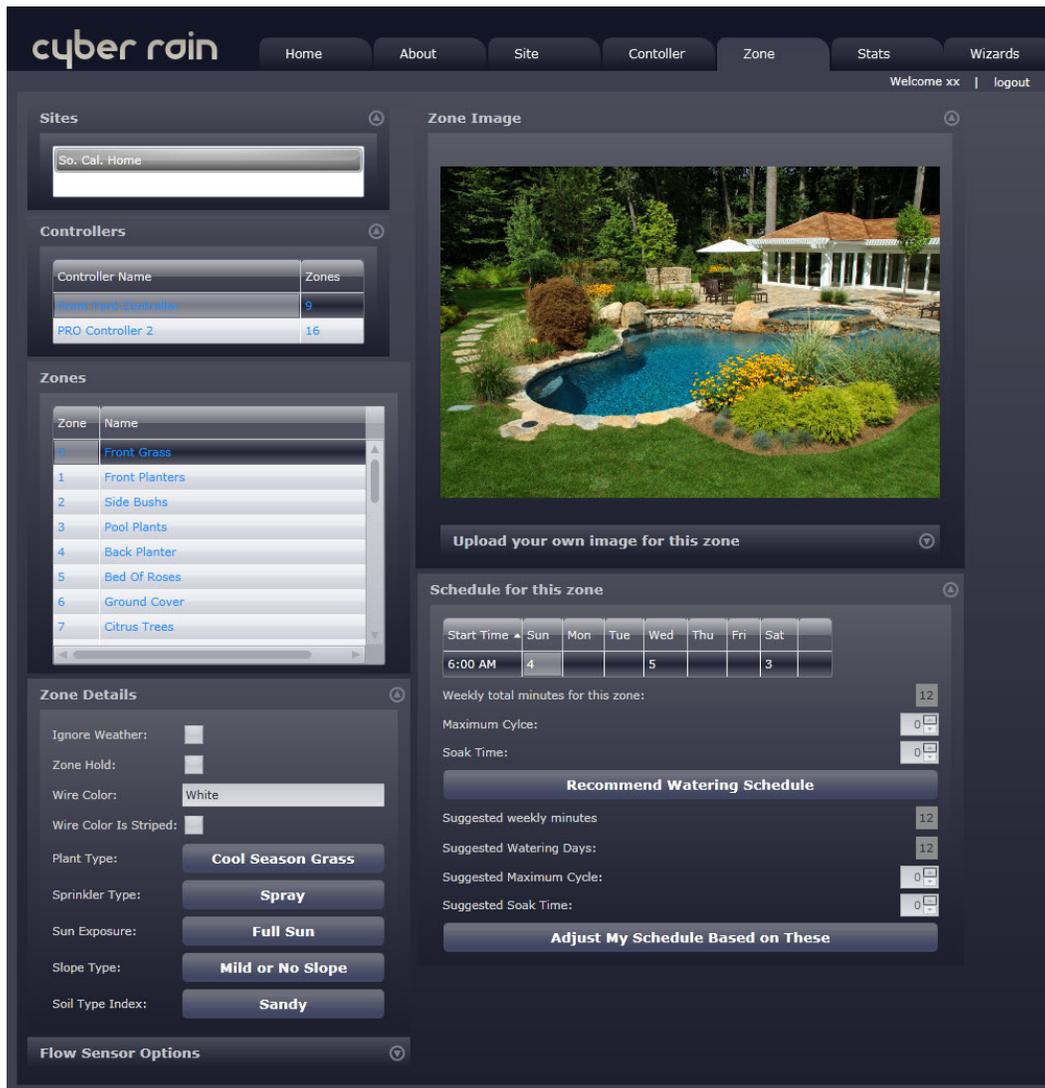


Figure 5.—Cyber Rain Web interface example.

Cyber Rain offers 8-, 16-, and 24-station controllers. For larger requirements, additional controllers can be added and operated from a single Access Point. Multiple Access Points can be managed from a single Internet account, allowing central controller of multiple sites. Controllers can be located 200 feet from the controller using the standard radios and up to 1 mile away using the longer-range radio, depending on environmental conditions.

Valve circuits are connected to the controller via a pluggable terminal block harness and the controller is mounted on the wall. After the Access Point is plugged into a router, Cyber Rain's Smart Scheduling Wizard automatically finds nearby controllers and guides the user through a short setup process. Custom zone names can be entered by the user as text such as "Rose Bushes" or "Front Grass." Cyber Rain's wizard will pre-populate a watering schedule using information about the user's landscape and location. This schedule can be easily modified by adjusting the number of watering minutes per day across four start times. Restricted watering schedules, such as limiting watering to certain hours of the day or blocking watering on certain days, are also available.

After the initial setup and schedule entry, minimal further user intervention should be required. Cyber Rain automatically checks the weather forecast every few hours on Weather Underground. Irrigation schedule adjustments are calculated based on temperature and humidity and wirelessly transmitted to the controller. If rain is forecasted, irrigation is suspended until it stops raining. An optional rain sensor can also be easily attached.

Weather adjustments are transmitted automatically—the user does not need to be online nor does a computer need to be on. If the Internet is not available, the system reverts to irrigation schedule adjustments based on a built-in Watering Index. The Watering Index is based on historical temperature, precipitation, and other weather patterns (the potential evapotranspiration or "PET") for a given geographical area.

The XCI includes a cycle and soak feature to eliminate or reduce runoff when landscapes are sloped. Individual zones can be put on a temporary hold for a user-defined number of days. An antifreeze feature automatically suspends all watering when the temperature forecast approaches the freezing point. Cyber Rain maintains a log of all water usage and displays a variety of water usage and saving reports and graphs.

The XCI includes built-in diagnostics features. The current on each valve is measured during watering with email alerts automatically sent if the current is outside the typical range and automatically shuts off if it is too high. The temperature within the controller is similarly monitored and controlled. Communication between the controller and the Internet is checked every hour.

And, if an optional flowmeter is attached, the controller can detect breakages or blocks causing abnormal flow patterns, automatically alerting the user and shutting off any broken valves.

Cyber Rain can be operated and monitored from a smartphone using a free App. Users can manually turn on/off valves and check the system status. Users can also take pictures of each zone, which are automatically uploaded into the Cyber Rain software for easy zone identification.

Description, Prices, and Warranty

XCI controllers are available in 8-, 16-, or 24-station XCI models. A wireless USB Access Point device that connects to the user’s router is needed to communicate between the Cyber Rain Web-based software and the XCI controllers. If additional zones are needed, another controller can be installed and operated from the same Access Point. Additional Access Points can also be added to a user’s account and managed through the same software. In this way, multiple sites and large properties can be centrally controlled from any Internet-connected computer.

The XCI is constructed with a weatherproof NEMA box and is suitable for outdoor installation. Its dimensions are 12 by 12 by 6 inches and it includes a 4-line by 20-character LED display panel. Stainless steel and indoor only enclosures are also available. Station circuit capacity is 1A and the controller accepts wire sizes up to 14-gauge solid or 16-gauge stranded. The XCI has nonvolatile memory to retain programming during power outages and its clock is maintained during power outages with a super capacitor and a real-time clock chip. Surge and lightning protection is provided with metal oxide varistors (MOV) and extra inductors on each circuit.

The pricing of the XCI professional controllers vary depending on the number of zones and range of the radio. Optional antennae are available to further increase the range between the Access Point and XCI controllers.

XCI Component	List Price
8 zone controller – 2.4 GHz	\$850
8 zone controller – 900 MHz	\$1,500
16 zone controller – 2.4 GHz	\$1,000
16 zone controller – 900 MHz	\$1,800
24 zone controller – 2.4 GHz	\$1,150
24 zone controller – 900 MHz	\$2,100
Access Point – 2.4 GHz	\$400
Access Point – 900 MHz	\$900

Cyber Rain has a 30-day “satisfaction or money back” guarantee, plus a 2-year limited manufacturer’s warranty. There are no monthly fees or additional charges for basic software functionality. Software updates and feature enhancements are free.

Installation

Professional installation is recommended for commercial installations, particularly those with longer-range radios and/or antennae. Professional installation is not required for residential, indoor models.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

Cyber Rain reports systems installed during January 2008 through May 2013 reported an average water savings of 34%. No study data are available on the XCI. Cyber Rain was SWAT tested in February/March 2008 and performance reports were posted in April 2008.

All Cyber Rain products have been awarded EPA’s WaterSense certification.

ETwater Systems

ETwater Systems, Inc., (ETwater®) based in Novato, California, is a manufacturer of weather-based irrigation controllers for the residential and commercial markets. ETwater was incorporated in 2002 and began manufacturing controllers in March 2005. The company manufactures in California and distributes its system throughout the United States.

ETwater offers a full range of controllers and plug-and-play retrofit devices for either new construction or upgrade of conventional controllers, all of which operate under its centralized weather-based irrigation management system. ETwater’s Web-based design permits management and monitoring of multiple sites from any computer, smartphone, or tablet.



ETwater’s system schedules irrigation based on ET and precipitation data received from existing weather stations and user-programmed information associated with specific landscape features. Currently, ETwater’s system uses a

data network of over 9,000 public and private weather stations, most of which are located in populous areas.

Operational Features

The two-way communication service provides features similar to a central control system. For example, the “Global Changes” feature is suited to the needs of a water manager responsible for multiple controllers at multiple sites. A site can be organized into groups of stations with similar landscape characteristics; then, a few keystrokes will make changes that apply to all stations within the group. For example, if a water manager needed to change the run time for all 200 turf stations on a large commercial site to comply with drought restrictions, it would take a couple of minutes to create a group that contains all turf stations, enter a new water budget percent, save the change, and update the schedules for all 200 stations.

To improve water management decisions, the “ETwater Manager” includes a reporting tool that provides custom reports of irrigation activity, performance, and settings. For any site or controller, for any time period, it takes a few clicks to create and view a “Run Time Report” on minutes of irrigation, by controller, in relation to weather (reference ET). The “Over/Underwatering Reports” display a simple graph that flags controllers or stations that may need attention, along with help text that offers specific suggestions for resolving problems online. The “Landscape Report” summarizes all landscape settings, by station, for quick reference online or in the field.



Additional features of the ETwater Manager include:

- **At-A-Glance Dashboard:** A new dashboard feature provides a single, at-a-glance view of alarms, controller status, and schedules across all controllers on all sites.

- ◆ Water Budgeting Toolkit: Calculates water usage and provides graphs and reports to track a site's water usage against monthly water budgets to identify overwatering.
- ◆ Troubleshooting: A new filtering tool provides instant access to critical data such as high-flow faults and faulty valve wiring.
- ◆ Bundled Configuring: A new configuration tool allows managers to configure multiple zones with similar landscape characteristics at one time.
- ◆ Customized Alerts: Alert preferences can be customized for each user's preferences.

With ETwater's system, ET and precipitation data are automatically retrieved daily from the weather station network by the ETwater central server. The data are obtained from existing weather stations that provide localized weather, most often available at the town or even the suburb level in most metro areas. A WeatherBug[®] weather station can be installed onsite, and the onsite data are utilized via the ETwater central server as discussed below. In addition, weather data from certain other public and private weather stations can be used. Rainfall forecast data can be used to automatically suspend irrigation *before* it rains.

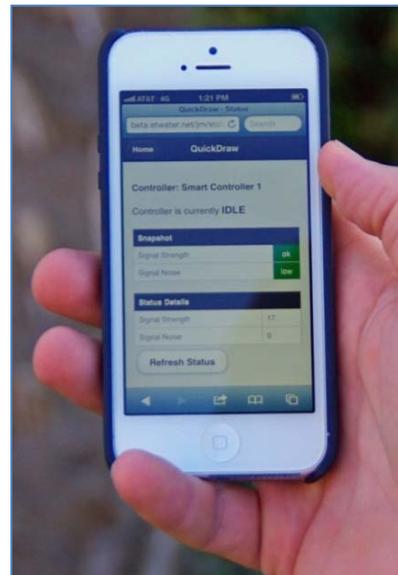
The ETwater central server automatically processes the ET and rainfall data in combination with the user-programmed landscape information to develop irrigation schedules. The user enters the landscape information from any computer or tablet with an Internet connection via ETwater's Web site at: www.etwater.com. However, an Internet device is not required at the installation site for the system to function. In commercial applications, the user may access special screens that enable selection of multiple accounts and thereafter select any controller or zone for each account. Scores of accounts may be accessed remotely from any computer or mobile device such as a smartphone or tablet, at any time. The ETwater central server architecture means that ongoing feature enhancements are automatically available to all customers, without requiring hardware upgrades.

Communication between the user's controller and the ETwater central server occurs by wireless connection. The ETwater central server communicates with each field controller on a daily basis to send any required watering adjustments. In addition, all ETwater controllers send a 30-day log of all watering activity so users can review their watering history on ETwater's Web site. ETwater controllers can operate independently if communication to the central server is temporarily interrupted. In such a case, the controller continues to operate using the latest schedule stored in memory and then revises the schedule once communication is re-established with the central server. ETwater controllers can accommodate schedules of any duration and frequency, including schedules that require watering on an infrequent basis (e.g., every 30 days).

To enter landscape information, users go to ETwater's Web site and log into their account using a user name and password. The program interface to enter the site-specific landscape information is set up with a choice of either Windows[®]-based pulldown menus or click-on picture options (e.g., plant type pictures), and it is intuitive and easy to use. The program is well organized and covers a comprehensive set of landscape factors, including plant type, irrigation type or optional application rate, soil type, slope, root depth, sun exposure, and distribution uniformity. User-defined sprinkler precipitation rate (PR) and distribution uniformity (DU) may be entered, or default measures may be selected in the absence of precise PR and DU information. A wide selection of plant types is available. Multiple plant types may be selected for one station, and the program will automatically set the watering schedule based on the plants with the highest water requirement. Irrigation types available include spray, rotor, high efficiency-matched precipitation rate rotors (e.g., MP Rotator[®]), impact, stream spray, drip emitter, bubbler, and subsurface inline tubing. The default distribution uniformity factor is 55% for popup spray heads. The user may specify customized distribution uniformity for any zone. Default root depths for all plant types are provided, but may be changed.

The user may also enter nonirrigation days, adjust the total station run times by a percentage factor, and initiate manual irrigations by station at the controller. The user may review system and irrigation history information on the Web site. The ETwater setup program includes help screens to answer questions common to first time users. Once the user becomes familiar with the program, an advanced setup mode may be used, which offers a more efficient means of programming. Adjustments to specific site factors may be made at any time via ETwater's Web site. Site factor changes will generate new irrigation schedules.

ETwater controllers also have an offline programming feature that allows users to manually set a watering schedule for each station. This feature is intended for use during periods when telephone service is temporarily unavailable (e.g., a newly constructed home prior to sale). Offline programming may be performed at the controller using the keypad and the two-line LCD display. The manual start mode may also be initiated at the controller. ETwater's objective is for the system to automatically generate and execute irrigation schedules. The need for program modification in the field typically is limited.



ETwater provides email alerts when there is a failure of communication between the field controller and central server. It also provides email alerts when manual adjustments are made on the field controller—the user may review such changes and override them remotely from any PC or mobile device, if desired.

ETwater reports that the irrigation scheduling algorithms it uses are based on current state-of-the-art horticultural science. The program reportedly incorporates all landscape factors needed to accurately determine soil moisture depletion and irrigation scheduling. ETwater uses a different algorithm for scheduling sprinkler and drip irrigation stations. The company's proprietary algorithms automatically generate daily schedules for each station with run and soak times based on a station's sprinkler application rate, soil intake rate, and slope conditions. The station run/soak cycles for each irrigation period remain constant, based on replenishment of a 50% plant root zone moisture depletion level. Alternatively, it is possible to override the system's cycle and soak times to accommodate unique field situations. The "User Entered Cycle and Soak" option permits entry of a maximum cycle time and/or a minimum soak time. Irrigations are delayed until a soil moisture depletion level of 50% is calculated, based on the measured daily ET and rainfall. If the user desires more frequent watering, the depletion level may be adjusted downward.

ETwater features include daily watering schedule updates, telecommunication and wireless access charges, ability to remotely monitor and adjust the controller from any PC, email alerts in case of onsite problems, and online- and telephone-based customer service.

The QuickDraw[®] mobile control application, included at no additional charge, lets users control watering via a smartphone. The QuickDraw "Water Now" feature will manually water a station from 1 to 60 minutes. "Instant Suspend" pauses a current watering event for one or all controllers until a specified date. Plus, from any smartphone, tablet, or computer with Web access, QuickDraw users gain instant control to start/stop stations, apply/remove suspensions, and "Connect Now" to update schedules immediately.

If the optional flow monitoring and control feature has been selected, the controller will bypass valves where an alarm condition is read and close a master valve in the event of a catastrophic flow. The user receives an email alert for high flow, low flow, no flow, and leak conditions. Desired high and low flow limits are set online, and the controller "learns" individual station flow during normal watering. ETwater controllers are compatible with most common paddle wheel (e.g., Data Industrial[®]) and turbine (e.g., Netafim[®]) flow sensors or their equivalents.

Recent enhancements to ETwater products include:

- October 2013: ETwater became the first company in the irrigation sector with a PTCRB-certified 3G modem. The upgrade from 2G to 3G modems is a major advance that will allow better coverage and signal strength by providing more cell tower access points and faster connections. The 3G modem capability also enhances the speed of ETwater’s “Over The Air Programming” (OTAP) capability. OTAP is new in the irrigation sector and it enables the software that powers the products to be upgraded remotely, thus allowing ETwater customers to stay current with the latest ETwater features and functionalities without adding equipment or costs.
- July 2013: The QuickDraw mobile control application was made available to all ETwater customers with compatible equipment, with no additional fee.
- November 2012: The QuickDraw mobile control application was enhanced with new features that allow users to obtain real-time flow rates, check valve status, and view station schedules, all directly from a mobile phone or tablet.
- October 2012: ETwater allows customers to choose to incorporate rain fall forecast data into the schedule computation, which for the first time allows for automated suspension of irrigation *before* it rains.
- July 2012: ETwater released a suite of water budget tools that enable customers to monitor and manage water use in real-time with graphs and analytics to communicate actionable water savings data and stay within monthly water budgets. Customers have the ability to define their own water budget or one defined by a local water agency, instead of using the water budget calculated by the ETwater Manager. This is especially significant in areas where water agencies are using water budgets based on various criteria that may not match standard formats. In addition to operating on sites where water volume is monitored by flow sensors, the water budget tools will work in locations without flow sensors.

The ETwater computer interface method of programming and monitoring the system is comprehensive and user-friendly. The water use monitoring option should also be attractive to progressive water agencies interested in quantifying water savings.



Descriptions, Prices, and Warranty

ETwater offers three hardware product lines to transform any landscape into an integrated ETwater smart irrigation system. All three types of ETwater's devices use the same ETwater Manager Web-based smart irrigation management system for quick setup, automated scheduling, and remote monitoring and adjustment.

The ETwater SmartBox™ controller is designed for new construction or when an old system needs to be completely replaced. This is a complete controller in a weatherproof, lightweight, durable, and secure aluminum enclosure that mounts on a wall or pedestal. ETwater controllers are sold in eight-module increments from 8 to 48 stations. In addition to the regular station circuits, the controllers provide a master valve/pump start circuit. The station circuit capacity is 1.1 amperes, and the station terminals will accept 12- to 20-gauge wire.

The retail price for an ETwater SmartBox controller is approximately \$1,800 to \$3,500 for 8 to 48 stations.

The ETwater SmartWorks™ replacement panel upgrades old controllers in situations where the enclosure and valve wiring are still good. This replacement panel installs in less than an hour into existing enclosures, with no need to rewire the valves. It replaces Irritrol MC Plus; Rain Master Sentar, Eagle, Hawk, and Evolution DX2 systems; and many Rain Bird controllers. These panels make installation rapid and sell for less than a full ETwater controller, yielding savings on both installation labor and equipment.

ETwater controllers and panels will accommodate popular brands of rain sensors or rain gauges. The use of a standard rain sensor (approximately \$59) will cause circuit interruption and suspend irrigations when significant rainfall occurs. Remote monitoring features for commercial applications include email notification of any adjustments to a controller; such as suspend, power interruption, failure to connect to the Internet, increase in percent watering for any zone, and flow monitoring. For response to these occurrences, the user may remotely reset or adjust these features from via PC or mobile device such as smartphone or tablet.

The ETwater HermitCrab®, a unique device that upgrades most brands of conventional controller to the same ETwater Web-based technology used by other ETwater controllers and panel replacements. The HermitCrab plugs into the conventional "host" controller via the host's remote control access port. The customer configures stations online with ETwater Manager, and the ETwater central server generates a custom irrigation schedule. Via wireless modem, the weather-adjusted schedule is downloaded daily from the central server to the HermitCrab, which signals the host controller to open and close valves.

In late 2013, ETwater introduced the second generation HermitCrab 2, which is compatible with ETwater's optional "Flow Monitoring Service."

Typical “plug and play” installation time is under 10 minutes because there is no need to rewire valves or make a new power connection. For irrigation managers who are responsible for numerous brands of controllers, installing HermitCrabs offer a common platform solution to efficiently manage hundreds of controllers of various brands at multiple sites from one Web-based ETwater Manager account. The HermitCrab is compatible with over 50 controller models that have a remote access port, including Hunter[®], Irritrol[™], KwikDial[®], Rain Bird[®], Rain Master, Superior/Sterling, and Toro[®]. List price for a HermitCrab is \$875, which includes the first year of ETwater Manager service.

The ETwater Manager service includes daily watering schedule updates, telecommunication and wireless access charges, ability to remotely monitor and adjust the controller from any PC or mobile device, email alerts in case of onsite problems, QuickDraw mobile control application, and online- and telephone-based customer service. The annual service fee is \$219. Optional flow monitoring and control service is \$59 annually.

Since wireless communication allows two-way information transfer, ETwater can manage the information received from individual controllers. This may be beneficial to water agencies by allowing analysis of customer water use data.

ETwater will accept return of nonworking products covered under ETwater’s 3-year conditional warranty, with proof of purchase.

Installation

ETwater reports that its controllers do not require professional installation, although the company recommends professional installation and will provide or recommend factory trained individuals or irrigation contractors to install all units. A typical professional commercial installation should take 1 to 3 hours, which includes a site assessment and discussion of the assessment with the user. Typical residential installations can be completed in less time. The professional installation/consultation cost is estimated to be \$75 to \$225 depending on location, size, and other site conditions. Technical support is available by toll-free telephone (800-685-5505), in addition to the support provided on the company’s Web site.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

ETwater has completed SWAT testing and a performance report is posted on the Irrigation Association Web site. ETwater has earned WaterSense certification for its entire product line, including SmartBox controllers, SmartWorks panels, and HermitCrabs.

ETwater submitted information from three of its large commercial customers documenting significant water savings. ETwater reports overall average water savings in the range of 20 to 50%.

Hunter Industries

Hunter Industries (Hunter®) was established in 1982, and is headquartered in San Marcos, California. Hunter manufactures and distributes a full line of landscape irrigation products worldwide. Hunter offers two weather-based control products to the industry—the ET System and Solar Sync. Both systems consist of weather sensors that gather onsite weather data, and *adjust* irrigation scheduling for Hunter controllers. Both are compatible with most Hunter irrigation controllers equipped with a SmartPort™. The ET System and Solar Sync are not compatible with other brands of controllers. Depending on the controller, the ET System and Solar Sync are suitable for residential and commercial applications.



The ET System creates an irrigation program automatically based on weather conditions measured onsite. The irrigation programs are operated via the compatible irrigation controller and run automatically on water days and at start times set by the user. Compatible controllers include Hunter Models SRC/SRC Plus, Pro-C, ICC, and ACC with SmartPort® technology. The irrigation schedule is based on the ET sensor’s calculated ET value; and programmed plant, soil, slope, sun/shade, and sprinkler type information provide the basis for calculation of the irrigation schedule. The result is a new revised irrigation program every water day, based on the weather conditions measured onsite. Once installed, each zone is scheduled from the ET module, rather than the controller itself.

The Solar Sync is designed to be a simple-to-use, easy-to-install, and affordable option for weather-based irrigation control. The user programs their controller as they normally would, and only a few programming steps are required to set up the Solar Sync options in Hunter controllers. Similar to the ET System, the Solar Sync adjusts irrigation programs automatically based on onsite weather conditions measured by the sensor. The Solar Sync sensor provides climatological data directly to the controller, which uses the onboard “Seasonal Adjustment” feature to adjust application amounts as a percentage. Compatible controllers include Hunter X-Core, Pro-C, PCC, I-Core, and ACC controllers, which all have Solar Sync logic and Seasonal Adjustment built in as standard features.

Operational Features



The ET sensor calculates ET by its daily measurement of solar radiation, air temperature, and relative humidity. The accuracy of the ET calculation can be improved with the addition of an optional anemometer (ET Wind), along with an automatic wind shutdown capability. The ET System will also shut down irrigation if the air temperature drops below 35 °F. The ET sensor includes a tipping bucket type rain gauge, which measures rainfall to one-hundredth of an inch. The user programs the ET sensor to stop irrigation in progress at a specific rainfall depth, and a percentage of the rainfall is accounted for in the irrigation schedule. The ET module calculates specific run times for each zone individually.

To program the ET module, the user first enters the type of controller used, date and time, water days, and start times. Then the site condition settings are made for each station. These settings consist of plant type, soil type, sprinkler type, percent ground slope, sun/shade, and plant maturity. The rain sensor setting is programmed for the minimum amount of rainfall that will cause interruption of irrigation.

Available plant type settings include numerous types of grasses, shrubs, ground covers, vines, trees, perennials, and desert plants. Alternatively, a custom crop coefficient setting can be used in place of plant type. Available soil type settings consist of sand, sandy loam, loam, clay loam, silt, clay, and silty clay. Soil type selection determines both infiltration rate (used for cycle and soak calculation, along with the slope setting) and water-holding capacity of the soil. Sprinkler type can be set to rotor, spray, drip, bubbler, or custom. The custom option allows for entering a sprinkler application rate (0.01-inch-per-hour or 0.254-millimeter-per-hour increments). The ground slope setting is by percentage. Available sun/shade settings consist of full sun, part shade (75% sun), part sun (50% sun), and full shade. The maturity setting is set to either new or established. With maturity set to new, the irrigation quantity is

doubled and then decreases linearly to the normal or established rate based on the plant type. The ET source setting can be set to manual to override automatic ET calculation. The wilt guard feature is programmed either on or off.

The ET module is wired into the controller's SmartPort and, once programmed, it uses the controller's Program "A" to create and run irrigation on water days (except with the Hunter ACC controllers where it works independently of any programs). Each day, the ET System evaluates the current soil moisture depletion level, ET rate, plant type (crop coefficient and root zone), and whether the next day is an allowable watering day. Then, the system performs a "look ahead" on the allowable watering days to see if not watering at that time would deplete soil moisture critically by the time a watering day is scheduled. Irrigation will not occur, however, if the calculated quantity is below the minimum irrigation amount, to prevent shallow watering. The calculation for minimum sprinkler run time is based on the soil type and capacity.

The Solar Sync sensor calculates ET by daily measurement of solar radiation and air temperature. The sensor also integrates Hunter's "Rain-Clik" and "Freeze-Clik" functionality to provide shutdown of the irrigation system during rain and/or freeze events. The ET data from the sensor are sent to the host controller, which uses the seasonal adjustment value daily, thus adjusting all of the station run times in all programs automatically. Solar Sync uses a rolling 3-day average ET for adjustment to prevent overreaction to temporary weather conditions.

From a programming standpoint, the user only needs to program the controller for peak summer watering requirements. Then, set the region where the installation is located (corresponds to regional ET).

The Solar Sync has a global adjustment feature that makes it easy for the user to fine-tune irrigation scheduling. The Solar Sync logic also includes a "No Water Window" feature that allows the user to set a period of time during the day for which irrigation will not occur, and a "Delay" feature allowing a number of days to elapse before ET adjustment begins.

Hunter recommends combining the Solar Sync with the new Soil-Clik™ to maximize its products' environmentally responsive controls.

Descriptions, Prices, and Warranty

The ET module is housed in a weatherproof plastic cabinet and its dimensions are 6 by 4 by 1.8 inches. The ET sensor standard model dimensions are 10.5 by 7.3 by 12 inches, and the ET sensor with ET Wind standard model dimensions are 11.5 by 7.3 by 20 inches. The ET module operates on 24 VAC from the controller's SmartPort and requires no additional AC wiring. It has nonvolatile memory and a replaceable 10-year lithium battery.

The Solar Sync sensor is based on Hunter’s existing Rain-Click sensor design and includes a metal mounting arm and gutter mount. The sensor dimensions are 3 by 8 by 1 inches.

Solar Sync is also available in a license-free wireless version for line-of-sight distances up to 800 feet, when it is not practical to run wiring from the controller to the optimum mounting location. The sensor is roughly the same size as the wired version, but has an encapsulated antenna increasing overall height to 4½ inches. The wireless receiver is mounted next to the host controller with dimensions of 5½ by 1½ by 1½ inches.

The ET System and Solar Sync are available from Hunter distributors worldwide and further information can be accessed at Hunter’s Web site. Table 6 shows the retail price for the ET System basic model is \$490, and the optional ET Wind is an additional \$545. The retail price for the Solar Sync sensor is \$115, or \$215 for the wireless version. The price range for compatible Hunter controllers is from \$150 to \$1,250. The ET System and Solar Sync come with a 2-year warranty.

Table 6.—Hunter Products Price Summary

Description	Model	Price
ET System	ET System	\$490
ET Sensor (sensor only for use with ACC/IMMS Central Control)	ET-Sensor	\$335
ET Wind Sensor (optional)	ET-Wind	\$545
Solar Sync	SOLARSYNCSN	\$115
Wireless Solar Sync	WSS-SEN	\$215

Installation

Installation and programming of the ET System and Solar Sync can be performed by the user or irrigation professional. The module for the ET System can be wall mounted near the controller, and the sensor is installed in the field with full sun and rain exposure. The ET sensor is provided with 100 feet of wire, which is the maximum distance the sensor can be installed from the module.

The Solar Sync’s compact sensor design makes it easy to attach to the eave of a house or on a gutter. The sensor is provided with 40 feet of wire, which can be extended to a maximum of 200 feet. The wireless Solar Sync includes an integrated antenna, with up to an 800-foot range, to a small receiver mounted at the controller. The ET System and Solar Sync owner’s manuals are available at Hunter’s Web site at: www.hunterindustries.com. They contain detailed installation and programming information.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

The ET System's ET calculation algorithm uses the modified Penman-Monteith equation. In creating the ET System's crop coefficients for the various plant type settings, Hunter generally has followed the principles of *Water Use Classification of Landscape Species* as prescribed on the State of California's *Water Use Efficiency* Web site at: <http://www.owue.water.ca.gov/index.cfm>. Use in other states may require some adjustment for crop coefficients, which can be customized in the ET System.

The ET System and Solar Sync have completed SWAT testing and performance reports are posted on the Irrigation Association Web site. The Solar Sync sensor has been tested and has received EPA WaterSense certification with the X-Core, Pro-C, I-Core, and ACC controllers.

Hunter has had 10 to 15 years' experience with ET-based irrigation.

HydroPoint

HydroPoint Data Systems, Inc. (HydroPoint®), of Petaluma, California, is the provider of WeatherTRAK® Smart Water Management products and related services for commercial and residential applications. HydroPoint, incorporated in 2002, offers WeatherTRAK products that combine a wireless daily ET data service with its Scheduling Engine™ irrigation software to update watering schedules at each landscape valve.



All WeatherTRAK controllers integrate proprietary Scheduling Engine software in calculating irrigation run times and schedules. This, combined with daily collection and modeling of local weather conditions, is intended to ensure that the controller applies the right amount of water when and where it is needed.

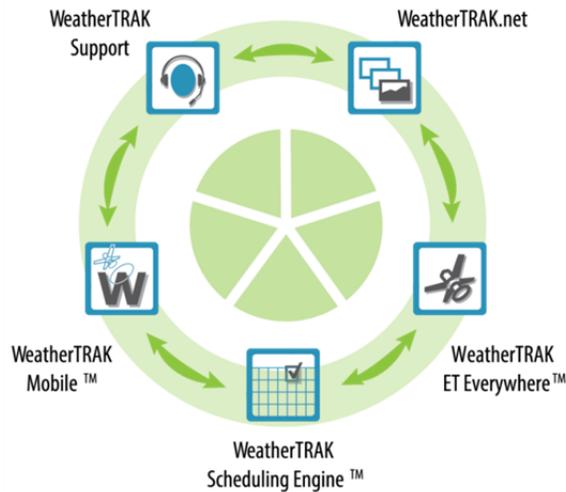
HydroPoint initially introduced the first controller called the WeatherTRAK ET Plus™ in early 2003. Currently, the company manufactures three two-way commercial applications: the WeatherTRAK LC Central, the WeatherTRAK ET Pro3, and the WeatherTRAK ET Pro3 2-wire.

Weather- and Soil Moisture-Based Landscape Scheduling Devices

The WeatherTRAK Central Service product line is available with all WeatherTRAK controllers. The WeatherTRAK Central Service is a fully cloud-based central management tool that allows real-time irrigation visibility anytime, anywhere, and on any device. It provides users the ability to manage a full portfolio, multiple sites, controllers, or stations with remote programming and centralized monitoring.

Operational Features

Product features include customizable 24/7 smartphone alert notifications, automatic fault detection, leak detection, and usage analytics tracking. Comprehensive portfolio management is achieved on WeatherTRAK.net with an interactive dashboard across multiple sites, accounts, and controllers; customizable one-click reporting; and water budget monitoring, as well as irrigation system asset and inventory tracking tools.



The WeatherTRAK Budget Manager Application™ tracks estimated and actual water usage against water bill data for real-time monitoring between billing cycles.

The WeatherTRAK Site Asset Manager application provides an interactive site map and visual inventory of controllers, landscape assets, and water meters using Google Maps and GIS. WeatherTRAK.net is accessed through secure Web- and mobile-user login and browsing.

The WeatherTRAK Central Service also integrates advanced climatologic modeling techniques (developed at Pennsylvania State University) and proprietary software called WeatherTRAK ET Everywhere™ to determine site-specific weather conditions down to a 1-square-kilometer resolution.

Near real-time weather data are collected at regular intervals each day from over 44,000+ weather stations and data sources across the continental United States and Hawaii, as well as areas of Canada, Mexico, and Central America. Weather data are also collected from the National Oceanic and Atmospheric Administration (NOAA Fisheries) network, state and county networks, private weather stations, Doppler radar, atmospheric readings, and satellite imagery. The HydroPoint Climate Center validates the weather data and daily transmits calculated ET through cellular-based wireless communication.

WeatherTRAK controllers independently calculate irrigation schedules for each valve station on a site. The controller does not use preset irrigation schedules input by the user. Instead, it asks a series of questions to define the site-specific and environmental variables that influence watering requirements. The controller is programmed by entering the following station-specific information: sprinkler type, sprinkler efficiency, precipitation rate, plant type, root depth, soil type, microclimate (sun or shade), and slope (including if the valve is at the top, middle, or bottom of the slope). The schedule for each station is adjusted daily according to the local weather data received via the ET Everywhere service.

With these inputs, the WeatherTRAK controller calculates an irrigation schedule for each irrigation valve. Soil moisture depletion tracking, triggered at a user-definable target management allowed depletion (MAD) level (along with daily ET updates), allows the controller to adjust schedules as the weather changes. The number of water days, minutes, and cycles (with appropriate soak times between cycles) are generated automatically and change as weather and water needs fluctuate. The WeatherTRAK controller has an 8-week scheduling window. This allows for infrequent watering of low water use or native plants.

Programming options for all WeatherTRAK controllers include either simple sequential stacking of stations based on a user-defined start time and allowed water window, or the ability to run multiple programs/stations simultaneously with various start times. The WeatherTRAK ET controllers can also run a fully user-defined schedule for plant establishment or grow in periods. Field users can either use the controller, WeatherTRAK Mobile (a free mobile application), or a universal remote to check the irrigation system on a valve-by-valve basis. An adjust feature provides percentage adjustments (in 5% increments) to increase or decrease the run time for any station. The controller accepts rain, rain/freeze, and flow sensors. All WeatherTRAK controllers are flow-enabled with the ability to stop mainline breaks, station breaks, or leaks for normally open and normally closed master valves systems. Independent master valve and pump start functions are also available on the commercial series line to address site-specific requirements, including the type of master valve. A rain pause mode allows the user to shut off irrigation for up to 200 days. The user can also manually send a “rain pause” to one or more controllers. Nonwatering days can be selected. A “help” mode alerts the user to HydroPoint's customer support toll-free telephone number (800-362-8774) to answer questions and walk users through any situation occurring on the site.

Other features include inputs for crop coefficient values, community water restrictions (odd/even or selected watering days), and unlimited programs. The independent station adjust feature allows for individual station adjustments from -50 to +25% in 5% increments. All WeatherTRAK controllers have heavy-duty surge protection on a 24-VAC output board. WeatherTRAK controllers have nonvolatile memory and do not require a backup battery to maintain date and time information. The controller terminals will accept 10- to 22-gauge wire.

Descriptions, Prices, and Warranty

All WeatherTRAK controllers are programmed on a on a backlit touchpad display screen that walks the user through menus of specific setup choices. Three two-way commercial applications are available: the WeatherTRAK LC Central, the WeatherTRAK ET Pro3, and the WeatherTRAK ET Pro3 2-wire. Also, 1 year of WeatherTRAK ET Everywhere subscription service is included with the purchase of all controllers. Additional multiyear subscriptions can be purchased, up to 10 years.

The WeatherTRAK LC Central is enclosed in a cabinet made of extruded high-impact plastic with key lock entry and dimensions of 12 by 8 by 5-3/4 inches. All WeatherTRAK LC Central models include a manual valve test program to identify open valves and short circuits as a standard feature.

It is ideal for small footprint sites such as hotels, retail centers, and restaurants, as well as light commercial and high-end residential applications.

The WeatherTRAK ET Pro3 is offered in a wide range of enclosures based on application and customer needs. It is available in 12- to 48-modular design station counts with 6-station modularity for easy expansion.

This is further augmented by a large number of chassis or preassembled components on a frame that can be installed easily in an existing enclosure for retrofit applications.

WeatherTRAK ET Pro3 2-wire solution reduces install and wire costs with WeatherTRAK decoders and a 48-station capacity for versatile site design.

WeatherTRAK Pro3 2-wire supports two master valves and flow sensors with line surge protection every 500 feet. It is offered with a 1- to 48-station capacity.

WeatherTRAK controllers are available from HydroPoint and local distributors. A distributor search engine is accessible via the HydroPoint Web site at: www.hydropoint.com.



 **WeatherTRAK® ET Pro3™**



WeatherTRAK controllers come with a standard 5-year warranty or extended warranty option; unlimited access to <https://www.weathertrak.net> Central Internet Management software; a free WeatherTRAK Mobile smartphone App; and toll-free, bilingual telephone customer support (800-362-8774), Mondays through Saturdays.

A full listing of WeatherTRAK ET controllers and accessories can be obtained via the HydroPoint Web site at: www.hydropoint.com. Current prices for popular WeatherTRAK controller models are included in table 7. For current pricing on all controller models and accessories, call HydroPoint at the above toll-free number and select the voice prompt for “sales.”

Table 7.—WeatherTRAK Model Descriptions and Prices

Description	Prices
WeatherTRAK LC Central (6, 12, and 18 stations)	Starting at \$1,599
WeatherTRAK Pro3 (12 to 48 stations)	
WeatherTRAK Pro3 2-Wire (1- to 48-station capacity)	
WeatherTRAK Flow Link	
WeatherTRAK Central Service	

Installation

Typical WeatherTRAK controller installation times, as seen in public agency studies and distribution programs, range from 1 to 2½ hours, depending on the size of the landscape covered and controller enclosures or pedestals used. HydroPoint offers professional services to help large and small customers with field assessments of existing controller equipment, initial programming and training, and quarterly followup services as a trusted third party advisor to ensure the maximum water savings and product usage. Technical support is available by a toll-free number, the HydroPoint Web site (www.hydropoint.com), and through field-certified contractors.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

WeatherTRAK controllers have been tested in 25 public agency settings since 1998. HydroPoint reports the overall results from these tests indicate significant water savings (16 to 58%) and reductions in runoff (64 to 71%). Information provided by HydroPoint about several of these studies is summarized in table 8. WeatherTRAK controllers are also EPA WaterSense certified.

Table 8.—Summary of WeatherTRAK Demonstration Projects*

Test Sponsor	No. of Test Sites
Irvine, California	80
Los Angeles Department of Water and Power	540
Boulder, Colorado	10
Colorado State University, Ft. Collins	3
University of Las Vegas, Nevada	15
Santa Barbara, California	200
Lake Arrowhead, California	78
Victor Valley, California	12
Marin, California	8
Park City, Utah	24
Santa Clara Valley Water District, California	125
Newhall County Water District	25
*SWAT performance summaries and technical reports for WeatherTrak controllers were posted in 2006 and are available at: www.irrigation.org/SWAT/control_climate .	

Irrisoft

Irrisoft, Inc. (Irrisoft™), offers water management solutions for residential and commercial irrigation systems through the Weather Reach Water Management System. Irrisoft defines quality as “Consistent Effective Performance” and are driven by three objectives:



1. Save money by improving irrigation scheduling efficiency with automation.
2. Beautiful landscapes enhance the quality of life and must be watered right.
3. Save time by automating landscape water management.

Irrisoft was an early pioneer in smart irrigation control technology. In 2001, Campbell Scientific, the world’s leader in weather stations, joined with Irrisoft, a green industry software company. The synergy between the two companies continues to produce effective innovative solutions to improve automated water management.

Irrisoft's first product, the WR-7 Weather Reach Receiver, proved the innovative system effectively automated water management for existing sprinkler controllers. In 2005, Rain Bird partnered with Irrisoft. The next generation WR-7 became Rain Bird's ET Manager. In a joint development project, the ET Manager cartridge for the LXM controllers was produced, which integrated weather-based control. Rain Bird turned to Irrisoft because Weather Reach technology is a sustainable solution built on reliable high-quality Campbell Scientific weather stations. Irrisoft's continued efforts resulted in the Weather Reach Controller Link, released in 2012. The Weather Reach Controller Link converts existing controllers to smart, weather-based automation. With Wi-Fi onboard, this Internet-based smart irrigation control device also offers remote Web monitoring.

Irrisoft innovations brought many industry firsts:

- ◆ Wireless broadcast of weather data to irrigation control equipment, United States Patent 7,403,840.
- ◆ Advanced method to quantify effective rainfall.
- ◆ Hourly soil moisture balance modeling.
- ◆ Irrigation scheduling software incorporating the capabilities of industry controllers.
- ◆ Onsite rain measurement input to smart add-on device.
- ◆ Smart control device capable of retrieving weather conditions via the Internet.
- ◆ Weather signal as a public service to conserve water.

Operational Features

The Weather Reach Water Management System is guided by three principles:

1. Accurate ET From Shared Weather Data
2. Effective Rainfall
3. Managed Allowed Depletion

Accurate ET From Shared Weather Data: Weather Reach uses hourly sensor measurements from precision instruments to automate irrigation control. A weather station requires routine maintenance to assure accurate hourly

measurements. It is not practical or necessary for every property to have its own weather station, as the information can be easily shared to thousands through a wireless Weather Reach signal broadcast or Internet communication. Four climate measurements drive the Weather Reach Water Management System; these are:

1. **Solar radiation** (solar energy) is the primary energy source driving both evaporation and transpiration from plants
2. **Wind** accelerates evaporation. Increased air movement increases evaporation, particularly when the air is dry.
3. **Humidity**, the amount of moisture in the air, affects the rate of evaporation.
4. **Temperature** also affects evaporation. Temperature measurements must be coupled with wind and humidity measurements to accurately measure evaporation.

These climate conditions affect how much water evaporates from the landscape. Evapotranspiration (ET) is the amount of water that evaporates from the soil and transpires from plant leaves. The internationally accepted ASCE Standardized Reference Evapotranspiration equation is used in Weather Reach Water Management products. ET science has been used, refined, and trusted for over 50 years. Weather Reach brings this science to landscapes to achieve the benefits of climate controlled irrigation.

The Weather Reach Water Management System delivers accurate weather data to smart irrigation controllers that calculates ET accumulation on an hourly basis, and processes it into a running ET balance. Weather data are retrieved from four sources:

1. Campbell Scientific (Irrisoft's parent company) weather stations; recognized world leaders in ET weather stations.
2. Public ET weather station networks such as: AgriMet, CIMIS, FAWN, CRONOS, UTNET, etc.
3. Commercial weather network managers such as: ExactET and WaterLogic. Commercial providers charge customers for weather data. Costs are dependent on the network manager for a given area. A list of current signal providers is maintained at: <http://www.weatherreach.com>.
4. U.S. National Weather Service: Recent advancements at NOAA allow access to complete hourly weather data for any location in the United States.

Effective Rainfall: Automated irrigation scheduling depends on ET and rain measurements. In some parts of the country, rain plays the primary role in replenishing lost soil moisture, while in arid climates rain supplements irrigation. Rain is a bigger variable and, in many places, there is more rain than evaporation, which makes the rainfall measurement the most important.

Weather Reach Water Management products use rainfall measurements along with ET to control watering schedules. Simple rain shutoff devices fail to provide accurate irrigation scheduling. They ignore small rain storms, and do not have the capacity to adequately delay watering after large rain storms. Knowing how much rain has entered into the root zone is essential for getting optimum results. Weather Reach Smart Control quantifies effective rain using three tools:

1. **Maximum Hourly Rain Limit** – Rain in excess of this limit is considered to be runoff.
2. **Saturation Allowance** – The amount of water soil can hold when saturated.
3. **Moisture Balance** – For each program, the moisture balance tracks the amount of water since the last rain storm or watering. Rain and irrigation are added to the moisture balance. Evaporation depletes soil moisture. Once soil moisture is depleted to the allowed level, it will allow watering.

The Weather Reach Controller Link accepts rainfall measurements from one of three sources.

1. An onsite tipping rain gauge.
2. A community rain station, sharing accurate measurements for thousands of residents.
3. Local weather station.

The most accurate way to get a precise rainfall measurement is to use an onsite tipping rain gauge. A tipping rain gauge measures the amount of precipitation. Rain falls into a collector on the top and funnels it to a tipping “bucket” or spoon. Once the bucket fills with water it tips, causing a momentary switch closure. As it tips, the bucket is emptied and water drains out the bottom of the gauge. Depending on the gauge, each “tip” or switch closure represents either 0.01 inch or 1 mm of rain. The Weather Reach controllers count each tip.

Managed Allowed Depletion: To promote a deep healthy root system, soil moisture must be depleted to an allowed level. This draws air into the root zone. *Best Management Practices*, published by the Irrigation Association, suggest that moisture levels should be depleted by 50% before watering.

The cycle of deep, less frequent watering promotes a deep healthy root system. If the plant root zone is kept at or near a saturated condition, the roots remain shallow because they are deprived of essential oxygen. For years water managers have used the "Checkbook Method" of irrigation scheduling, which compares ET to a "withdrawal" of moisture from the soil moisture balance, while rainfall and irrigation are considered "deposits" (Smith, 1997). Once the "balance" reaches the allowed depletion level, the irrigation system must make a "deposit" to replenish soil moisture.

Figure 6 demonstrates the application of the Checkbook Method. ET depletes soil moisture so it is deducted from the soil moisture balance. Rainfall and irrigation replenish soil moisture, adding to the moisture balance. To assure that oxygen is drawn into the soil, moisture levels are depleted to an allowed level. Soil type and rooting depth are used to determine the allowed depletion and irrigation amount. In this example, 0.50 inch is determined to be the optimum irrigation amount. The result is four deepwatering cycles in 2 weeks.

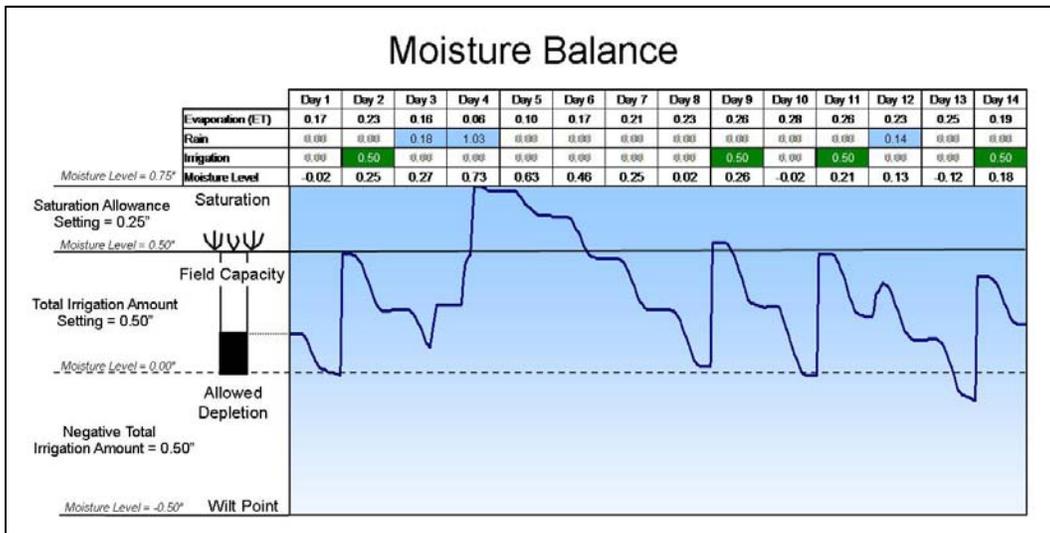


Figure 6.—Checkbook Method demonstration.

Descriptions, Prices, and Warranty

The Weather Reach Controller Link, Irrisoft’s newest product, connects to an existing sprinkler controller to provide climate controlled irrigation. Weather data are retrieved via the Internet through the device’s Wi-Fi and Ethernet capabilities. This provides a means to share current weather data from one well-maintained precision weather station with thousands of irrigation systems. To manage program frequency, the Weather Reach Controller Link uses hourly weather data to calculate ET, and then applies ET and rain to a program’s moisture balance. The Weather Reach Controller Link uses program start sensors to know when to

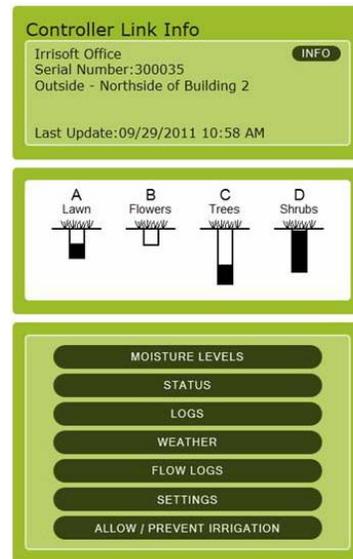
interrupt or enable the valve common allowing or suspending irrigation as needed. The Weather Reach Controller Link supports four programs, with no limitation to the number of stations.

The Weather Reach Controller Link also supports a flow sensor. Flow sensing is used to:

- Track water use.
- Enable the Weather Reach Controller Link to shut off watering when a high flow condition occurs, such as a pipe break.
- Allow email notifications to be sent concerning any unexpected flow conditions.

Weather Reach Access is an optional online remote management service for the Weather Reach Controller Link. Weather Reach Access can be managed from any device with Internet access, such as a PC, tablet, smartphone, etc. With a subscription to Weather Reach Access water managers can:

- Check watering status, logs, ET, and rainfall.
- Make changes to settings and allow or prevent irrigation.
- Set up email alerts for weather conditions, irrigation, flow, and connectivity issues.



Irrisoft offers a warranty for 12 months subject to various conditions. Please see www.irrisoft.net for additional information.

Installation

The Weather Reach Controller Link installation is easy enough for a do-it-yourselfer, but Irrisoft recommends installation by a professional water manager or irrigation contractor who understands landscape conditions and irrigation system capabilities. The Weather Reach Controller Link is an add-on device that can be installed in less than an hour. Weather reach products have a 1-year warranty.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

For the last 12 years, numerous customer reports have consistently proven Weather Reach products save water. Water saving results reported by customers have ranged from 20 to 70%. Typical expected savings is 30 to 40%. The Weather Reach Controller Link is EPA WaterSense certified.

Irritrol

Irritrol™ is a brand of professional irrigation products manufactured by The Toro Company (Toro®). Toro, which was established in 1914, is a Fortune 1000 internationally recognized supplier of irrigation and landscape products. Toro's corporate headquarters are located in Bloomington, Minnesota, and its Irrigation Division resides in Riverside, California. Toro



acquired the Irritrol brand of products in the early 1990s. The Irritrol Smart Dial series of residential and commercial controllers utilize the ET Everywhere™ data service and WeatherTRAK® Scheduling Engine™ irrigation software to update watering schedules at each landscape valve. Irritrol is a partner with HydroPoint Data Services, Inc.

The Smart Dial series entered the market in 2005, and currently includes seven controllers comprised of residential and light commercial models for 6, 9, 12, and 24 zones (plus a pump/master valve circuit). Irritrol also offers a Smart Dial module to convert existing Rain Dial™ Plus controllers to Smart Dials, eliminating the need for controller replacement and rewiring. All WeatherTRAK-enabled controllers integrate Scheduling Engine software that reportedly matches the Irrigation Association standard for “Best Management Practices” in calculating irrigation run times and schedules. This, combined with daily collection and modeling of local weather conditions, attempts to ensure that the controller applies the right amount of water when and where it is needed.

The WeatherTRAK system collects weather data each day from over 40,000 weather sources across the United States, including the NOAA Fisheries network, state and county networks, and private weather stations. The WeatherTRAK system integrates advanced climatologic modeling techniques developed at Pennsylvania State University and proprietary software called WeatherTRAK *ET Everywhere*™ to determine site-specific weather conditions down to a 1-square-kilometer resolution across the entire continental United

States. This methodology of data collection, modeling, and sending is the most independently studied and validated product offering within a standard deviation of .01 inch of daily ET.

The HydroPoint Data Center validates the weather data and transmits calculated ET through three paging servers providing overlapping coverage of the United States to ensure signal reception.

Operational Features

The Smart Dial controller calculates irrigation schedules for each valve station on a site independently. The controller does not require the use of preset irrigation schedules input by the user. Instead, it asks a series of questions to define the site-specific and environmental variables that influence watering requirements. The controller is programmed by entering the following station-specific information: sprinkler type, sprinkler efficiency, precipitation rate, plant type, root depth, soil type, microclimate (sun or shade), and slope (including if the valve is at the top, middle, or bottom of the slope). The schedule for each station is adjusted daily according to the local weather data received via the ET Everywhere service.

With these inputs, the Smart Dial controller calculates an irrigation schedule for each irrigation valve. Soil moisture depletion tracking, triggered at a 50% depletion level (adjustable), along with daily ET updates, allows the controller to adjust schedules as the weather changes. The number of water days, minutes, and cycles (with appropriate soak times between cycles) are generated automatically and change as weather and water needs fluctuate. The Smart Dial controller has an 8-week scheduling window. This allows for infrequent watering of low water use or native plants.

Programming options for all Smart Dial controllers include sequential stacking of overlapping start times or the ability to run multiple programs simultaneously depending on the product series. The Smart Dial controllers have a manual feature providing any amount of time setting for plant establishment or to check the irrigation system on a valve-by-valve basis. A rain pause mode allows the user to shut off irrigation for up to 14 days during or after rain for the residential series and up to 200 days for commercial series. The HydroPoint Data Center can also be contacted to automatically “rain pause” controllers and groups of controllers using the wireless data service. Nonwatering days can be selected.

Other features include inputs for crop coefficient values and community water restrictions (odd/even or selected watering days). The independent station adjust feature allows for individual station adjustments from -50 to +25% in 5% increments. The controllers are compatible with Irritrol’s wired and wireless rain and rain/freeze sensors, which eliminate irrigation during rainfall and freezing weather, if added as an optional accessory.

Descriptions, Prices, and Warranty

The indoor controller models' cabinets are constructed of polypropylene plastic, while the outdoor units are comprised of Lexan. The dimensions of the indoor models are 7.5 by 6.5 by 3.3 inches, and the dimensions of the outdoor models are 7.5 by 9.5 by 5.8 inches. The controllers have a large (3.5- by 0.8-inch) LCD information display, dial type controls, and a copy button for simplifying setup. All controllers include internal Underwriters Laboratories/Canadian Standards Association (UL/CSA)-listed transformers. The current capacity for each zone circuit is 0.5 ampere. The current capacity for the pump/master valve circuit is 0.375 ampere, with total controller capacity of 1.0 ampere for 6, 9, or 12 stations and 1.2 amperes for 24 stations. The controllers will accept wire sizes from 12 to 18 gauge. The nonvolatile memory maintains programming, and the backup battery maintains the date and time, during power outages.

Other controller features include surge protection up to 6 kilovolts and valve malfunction detection. The irrigation schedule, irrigation history, and program review can be viewed with the LCD information display. In addition to the wireless rain and rain/freeze sensors, an external bow tie antenna kit, pump starter relay, and wired rain sensor are available as optional accessories.

A snap-in Smart Dial module is also available which directly interchanges with a user's existing Rain Dial™ Plus controller panel to convert it to a WeatherTRAK enabled controller. A converted controller possesses all of the same features as the Smart Dial controllers.

The Smart Dial controllers, modules, and accessories may be purchased from authorized Irritrol distributors and retailers. Table 9 summarizes the 2009 suggested list prices for controllers and accessories. Actual pricing may vary; contact Irritrol (800-634-8873) for current pricing. To make a Smart Dial controller weather-based requires the ET Everywhere service, which is provided by WeatherTRAK. The ET Everywhere annual service agreement is \$48 for the 6- to 12-station residential controllers and \$84 for the 24-station controller as discussed in the "HydroPoint" section of this report. The Smart Dial products come with a 5-year warranty.

Table 9.—Irritrol Smart Dial Controller, Module, and Accessory Prices

Description	Model	List Price
6-Station Indoor Controller	SD600-INT	\$325
9-Station Indoor Controller	SD900-INT	\$370
12-Station Indoor Controller	SD1200-INT	\$417
6-Station Outdoor Controller	SD600-EXT	\$365
9-Station Outdoor Controller	SD900-EXT	\$412
12-Station Outdoor Controller	SD1200-EXT	\$458
24-Station Outdoor Controller	SD2400-EXT	\$909
6-Station Module (Rain Dial™ Plus upgrade)	SD600-MOD	\$247
9-Station Module (Rain Dial™ Plus upgrade)	SD900-MOD	\$288
12-Station Module (Rain Dial™ Plus upgrade)	SD1200-MOD	\$330
Bow Tie Antenna	SD-ANT	\$52
Wired RainSensor	RS500	\$32
Wireless RainSensor	RS1000	\$98
Wireless Rain/Freeze Sensor	RFS1000	\$125

Installation

The Smart Dial controllers do not require professional installation, although trained installation is recommended. Typical installation times range from 1 to 2½ hours, depending on the size of the landscape covered and mounting issues. Installation should include a site assessment and discussion with the user about the site’s irrigation system and how the controller operates. Installation and setup instructions are included in the owner’s manual. A *User’s Guide* with DVD is available upon request. Technical support is available from Irritrol at its Web site (www.irritrol.com), by toll-free telephone (800-634-8873), and through field certified contractors.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

Smart Dial controllers have undergone SWAT testing and performance reports are posted on the Irrigation Association Web site. Irritrol has also received WaterSense certification. WeatherTRAK-enabled controllers have been tested in 22 public agency settings since 1998. HydroPoint reports the overall results from these tests indicate significant water savings (16 to 58%) and reductions in runoff (64 to 71%). These studies are discussed in the “HydroPoint” section of this report.

OnPoint EcoSystems

OnPoint EcoSystems (OnPoint™), based in Palo Alto, California, and founded in 2012, manufactures both weather- and non-weather-based irrigation controllers for residential and commercial markets.

WaterSage™ is OnPoint's weather based product line. WaterSage controllers are accessible anywhere from any device (smartphone, tablet, and computer) using the myOnPoint™ Web service for

programming, controlling, and reporting. They retrieve location-specific weather data daily from sources across the United States, such as CIMIS, NOAA, FAWN, Agrimet, and others. There are no subscription fees for controller access and weather data. The company's products are manufactured in the United States and are available from an increasing number of distributors.



Connect WaterSage to a local WiFi network and it automatically pairs with the myOnPoint “Cloud” service. Access the controller from any Web browser on any device for real-time programming and control. A “landscape wizard” allows the user to select the plant, exposure, slope, soil, and irrigation types most closely matching each hydrozone (zone). The wizard then calculates the recommended run time (consistent with the geographical location of the controller) and maximum cycle and minimum soak times to avoid runoff. Run times are optimized every water day based on daily ET and precipitation data computed from a local weather source and each zone's landscape profile.

The landscape wizard offers three pre-configured modes—full water, conserve, and drought—to get run time recommendations consistent with the conditions at the controller location. WaterSage also provides an event log and variety of reports to assess irrigation history, forecast, and controller activities.

WaterSage also provides an expert mode for customization of each zone. Water conservation managers, irrigation contractors, and water auditors can set variables such as soil characteristics, root depth, landscape and crop coefficients, and emitter precipitation rates to match the exact zone conditions.

Available in 8- and 16-zone versions, WaterSage is a compact (approximately 6.5 inches wide by 4 inches high) and reportedly powerful weather-based irrigation controller. Larger zone installations use multiple 8- or 16-zone controllers. Valves can be turned on manually from the front panel of the controller, but all programming is done from the Web interface.

OnPoint reports WaterSage makes weather-based irrigation control easy to access, simple to program, and straightforward to understand; all with no subscription fees.

Operational Features

Enter “<http://myonpoint.com/>” into any browser, and then enter the username and password of the controller to access it. Then, create a desktop/main page icon for easy access the next time. For a contractor managing multiple controllers, a list of all controllers is displayed and the contractor simply clicks on the desired controller.

Programming consists of setting the allowed water days (days of the week, odd, even, or interval), entering the start time, and using the landscape wizard or expert mode to define each zone. The recommended run time and cycle and soak times are displayed and can be modified. Multiple programs are available to assign different water days to different zone types. Weather and “Water Window” restrictions can be applied per program.

An optimized water schedule for each zone is created every water day using EPA certified algorithms, zone landscape characteristics, and the local ET and precipitation data accumulated since the last water day. The optimized run time for each zone will be divided into multiple cycles as needed, with appropriate soak time between cycles. Analytic algorithms are then used to ensure the day’s overall scheduled time is minimized by organizing zone ordering, cycle and soak times, water window, and other factors to create an efficient irrigation plan.



WaterSage supports the creation of multiple seasons. Up to six entire irrigation schedules can be saved to the cloud and accessed at the click of a button. Seasons are used to create new planting schedules, modifications for different times of the year, saving the original schedule set by a contractor, or to tweak schedule settings without losing the original “golden” schedule.

A built-in electrical current meter detects and provides alerts for valve wiring and valve electrical issues, including disconnected wires, high current, and shorted wires or valves. If a short circuit is detected, the controller will skip the shorted valve, continue to run all other valves, and report the zone with the valve issue. Surge protection protects against power fluctuations and shorted valves and wiring; and lightning protection is available on some models.

The date and time are set automatically and adjusted for daylight savings time. There are no batteries or fuses to replace or dispose. In addition, all controller settings are retained in nonvolatile memory so after loss of power the controller returns to normal operation. If the controller cannot connect to myOnPoint (WiFi or Internet access is down), WaterSage continues to water based on historical weather information.

WaterSage provides two sensor inputs, one for a click-based sensor (rain, freeze, etc.) and the other for sensing flow. The rain click sensor input supports normally closed and normally open sensors and provides for a rain sensor delay adjustment (note sensors are not included). Master valve operation is also supported.

Multiple users can access the controller simultaneously to assist with training, support, and troubleshooting. In addition, each function on the controller includes detailed onscreen help.

New capabilities can be downloaded directly to the controller with no user intervention required.

Descriptions, Prices, and Warranty

WaterSage is available in 8- and 16-zone models. Both models are housed in compact 6.62 by 1.25 by 3.5 inches (without antenna) indoor enclosures. An outdoor enclosure is required to protect the controller from rain. Because of its small size, WaterSage is often installed in the outdoor enclosure of the controller it is replacing. Larger zone applications require multiple controllers.

The retail price range for WaterSage is \$550 to \$1,150 depending on functionality and options. There is no subscription fee for Web access or weather data. A 2-year warranty is provided.

Installation

OnPoint reports installation and programming of WaterSage can be performed by the typical residential user or irrigation professional. An installation wizard provides step-by-step WiFi and user account setup. No networking knowledge or WiFi router changes are required.

Removable connectors simplify replacing an existing controller. Remove the connectors from WaterSage, disconnect and attach the wires from the old controller to the WaterSage connector one at a time, remove the existing controller and mount WaterSage in its place, and then insert the wired connectors back into WaterSage. Supported wire gauges range from 14 to 20 gauge. Lower gauge wire requires a special configuration.

When mounting WaterSage in the previous controller's outdoor enclosure (if that enclosure is metal), an outdoor wiring kit (available from OnPoint) is required.



Track Record, Water Savings, WaterSense Certification, and SWAT Testing

WaterSage is EPA WaterSense certified and is included in numerous water authority rebate programs.

EPA certified algorithms (based on SWAT) are used along with location-specific ET and precipitation data to achieve water savings typically in the 20 to 50% range.

More information on WaterSage , including purchase options, can be found at www.onpointeco.com.

Rachio

Rachio is a technology company out of Denver, Colorado, that is developing new water management products with the goal of making it easy and affordable for homeowners to have beautiful, sustainable landscapes. Iro, Rachio's first product introduced in 2014, is an intelligent irrigation controller that is powered by Rachio's cloud-based software that can be controlled through a Web-based dashboard and an intuitive Android or iPhone App.



Operational Features

The Iro modernizes the entire irrigation system as a new controller or one that replaces an existing clock-type controller by providing homeowners with a product experience that empowers them to control their irrigation system with less time, less water, and less money so they can spend more time enjoying their yard. Rachio reports that the Iro is easy to install and takes only minutes to set up. During setup, the homeowner's smartphone sends a signal to the Iro (blinkup), connecting it to the Internet through a WiFi network through which it then

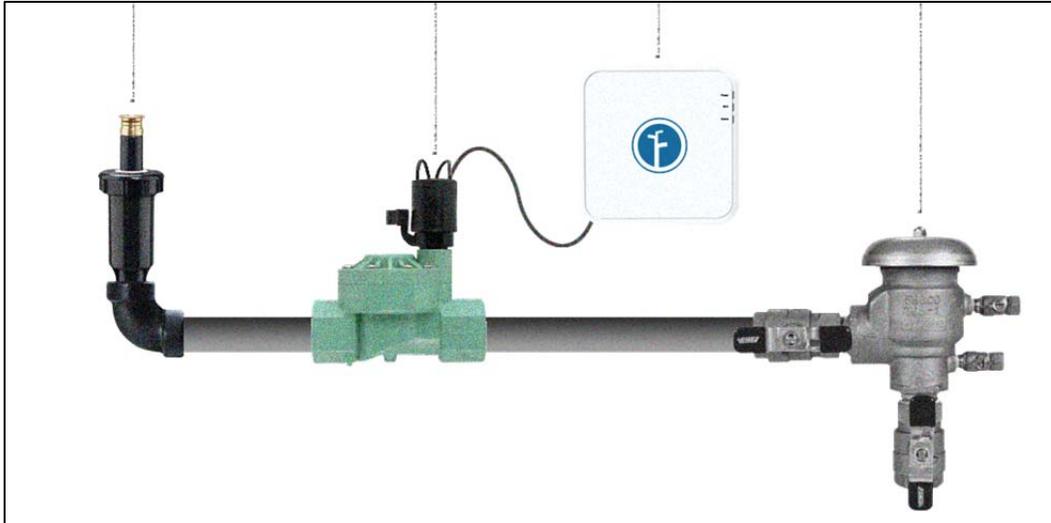
communicates securely with Rachio's cloud-based software. At that point, homeowners can connect to their yard from anywhere in the world through an intuitive, fast smartphone App or through a Web dashboard. With the push of a button, sprinklers can be turned on instantaneously from anywhere in the world. In addition to fully customizable and instantaneous control, Iro can be set to automatically adjust irrigation schedules. Automated scheduling is optimized for water efficiency and landscape health by taking into account numerous variables including weather, seasonality, landscape characteristics, water budgeting, and vegetation. Additionally, it learns from the customer's adjustments over time, allowing them to personalize the balance between water use and the "level of health" in each zone of their yards.

To enter landscape information, users go to the smartphone App or Web dashboard and log into their account using a username and password. Rachio reports the Iro's interface of programming and monitoring the system is intuitive and easy to use. The program is reportedly well organized and details all landscape factors such as plant/vegetation type, irrigation application rate, soil type, slope, and sun/shade exposure. Additionally, advanced settings including available water, root depth, soil moisture depletion, and application efficiency/distribution uniformity may be entered (default measures will be assigned in the absence of custom advanced settings). After the initial setup and schedule confirmation, no further user intervention should be required.

The Iro will automatically check the weather forecast and issue adjustments based on ET and precipitation data to match soil moisture depletion. Weather and schedule adjustments are transmitted automatically; the user does not need to be online nor does a computer need to be on. The Rachio cloud-based software communicates with each Iro controller on a daily basis via WiFi to send any required watering adjustments. Iro controllers can operate independently if communication to the Rachio cloud is temporarily interrupted. In such a case, the controller continues to operate using the latest schedule stored in memory and then updates the schedule once communication is re-established with the cloud.

The Iro can accommodate schedules of any duration and frequency, including schedules that require watering on an infrequent basis (e.g., every 21 days) and/or restricted watering schedules. The user may also assign custom zone names, i.e., "Front Lawn" or Back Lawn," can adjust the total station run times by a percentage factor (seasonal adjustment), and initiate manual irrigations by zone. The Iro's irrigation scheduling algorithms are based on university-tested practices that incorporate all landscape factors needed to accurately determine soil moisture depletion. Iro's Smart Cycle will automatically schedule cycle and soak irrigation events to eliminate or reduce runoff when landscapes are sloped and/or the infiltration rate of the soil is less than that of the precipitation rate of the nozzle for the given zone. A virtual rain sensor will suspend irrigation events if rain is forecasted within the next 24 hours. A virtual freeze sensor automatically suspends irrigation events when the temperature forecast approaches the freezing

point. An onsite rain sensor can be installed (not included) to cause circuit interruption and suspend irrigations when significant rainfall occurs; the Iro controller will accommodate popular brands of rain sensors or rain gauges. The Iro maintains a log of all water usage and displays a variety of water usage and saving reports. This water use monitoring should be attractive to progressive water agencies interested in quantifying water savings. Rachio's cloud-based software allows for ongoing feature enhancements that are automatically available to all customers, without requiring hardware upgrades.



Descriptions, Prices and Warranty

Iro controllers are available in 8-zone (\$249) and 16-zone (\$299) models. In addition to the regular station circuits, the controllers provide a master valve/pump start circuit. If additional zones are needed, another controller can be installed and operated from the same user's account and managed through Rachio's cloud-based software. Multiple sites and large properties can be "decentralized" controlled from any Internet-connected device. The Iro is designed for indoor installation. Its dimensions are 2.165 by 7.25 by 7.25 inches. Weatherproof enclosures are available for outdoor installation. The Iro controller works with the majority of 24 VAC irrigation systems. The Iro controller's connection base (wall mount) can accept up to 8- or 16-zone wires, a master valve or pump start relay, and common wire(s).

- 💧 WiFi: 2.4Ghz only, 802.11 b/g/n (note WPA2 Enterprise is not supported).
- 💧 Mobile Device: iOS 7.1 (or later) or Android 4.3 (or later) smartphone or tablet.
- 💧 Login: A free Rachio account is required to control the Iro.

Weather- and Soil Moisture-Based Landscape Scheduling Devices

Rachio has a 30-day “satisfaction or money back” guarantee, plus a limited 2-year manufacturer’s warranty. Software and firmware updates are free and are automatically pushed to your smartphone and Iro hardware.

There are no ongoing subscription fees for use or access to Rachio’s cloud-based software.

Installation

Typical “plug and play” installation time is under 30 minutes because there is no need to rewire valves or make a new power connection. Iro controllers do not require professional installation, although the company recommends professional installation or irrigation contractors to install outdoor units.

A typical professional installation should take 1 to 3 hours, which

includes a site assessment and discussion of the assessment with the user. The professional installation/consultation cost is estimated to be \$75 to \$225 depending on location, size, and other site conditions. Technical support is available by toll-free telephone in addition to the support provided on the company’s Web site.



Track Record, Water Savings, WaterSense Certification, and SWAT Testing

The Iro system has completed and passed WaterSense certification testing. Documentation is available on the EPA Web site. A performance report of the test is available upon request. Rachio also plans to submit the Iro for SWAT testing should SWAT officials not accept the performance report from WaterSense certification testing. Rachio reports overall water savings in the range of 20 to 50%. Rachio is an EPA WaterSense partner.

Rain Bird

Rain Bird Corporation (Rain Bird®), based in Glendora, California, began business in 1933. Over 13,000 Rain Bird products are sold in more than 120 countries. Rain Bird owns more than 130 patents and 30 additional trademarks. For more than two decades, Rain Bird has used weather technology in the golf and commercial irrigation markets with their central control products, including the Maxicom™, SiteControl™, and IQ2 systems.



Rain Bird currently markets several smart controller solutions for conserving water and efficiently watering residential and commercial landscapes. These include the ESP-ET series controllers, ET Manager Cartridge, and the ESP-SMTE series controllers.

The ESP-ET series controller is the combination of a ESP-LX Controller pre-packaged with a ET Manager Cartridge. The ET Manager Cartridge alone is an upgrade for users of the LX controller already. It will work with the existing conventional controller and use hourly weather information transmitted from remote weather stations to calculate net ET or irrigation demand. The weather parameters used in the ET calculation include solar radiation, temperature, wind speed, relative humidity, and rainfall. In addition, an optional rain gauge is available for onsite rainfall measurement and to interrupt irrigation when a user specified amount of rainfall occurs. The result of these measurements is that Rain Bird ET Management products automatically update every hour and only allow the controller to water as needed to maintain proper soil moisture.

The ESP-SMTE series is comprised of three controller models:

1. An indoor model (ESP4SMTEI)
2. An outdoor model (ESP4SMTE)
3. An upgrade model (ESP4SMTEUPG) that can be used to upgrade previously installed Rain Bird ESP-Modular controllers to a smart control system

The ESP-SMTe smart control system consists of an onsite weather sensor and smart controller. The controller is shipped as a 4-station base model that can be expanded to accommodate up to 22 stations using either 6-station or 3-station expansion modules (ESP-SM6 or ESP-SM3).

Operational Features

The ET Manager Cartridge (ETC-LX) is a device that works with the Rain Bird ESP-LXME and ESP-LXD controllers (new or retrofit). It uses the ASCE standardized ET equation to calculate ET on an hourly basis and maintain a user-specified soil moisture balance. Typically, controllers irrigate on time-based (day, time, and minutes to water) schedules regardless of changing weather and landscape needs; whereas the ET Manager Cartridge interrupts the controller only allowing it to irrigate when calculated soil moisture levels reach user set levels. Historical ET by location is also programmed into both units as backup in case weather data are temporarily not available.

To help users create an irrigation schedule and program settings into an ET Management product, Rain Bird offers a free ET Management scheduler. This computer program tailors an irrigation schedule to a specific irrigation controller's capabilities and the characteristics of the irrigation system. The user enters information for each station and landscape characteristics including plant type, soil type, root depth, ground slope, and sprinkler precipitation rates to create the schedule. All calculations are done automatically, and the user has the ability to adjust any of the results for a custom schedule. Once a schedule has been created with the scheduler, it can be printed out and entered into the irrigation controller. The scheduler program can be found on the ET Manager Resource CD or downloaded at no charge from Rain Bird's Web site at: www.rainbird.com.

The optional ETM programming software allows settings for the ET Manager or ETC-LX to be programmed quickly and easily. Users select the appropriate local weather station, site elevation, and available watering days (the ET Management products can accommodate any available or non-available watering day requirement). When the required parameters have been entered, the user can transfer the settings automatically into the ET Manager product through the cable supplied with the programming software kit. This kit is convenient for professionals performing higher volumes of ET Manager or ETC-LX installations. The controller schedule should be set to irrigate every day so that it can properly adjust the settings and watering cycles according to soil type, plant type, altitude, zone, and conditions.

The ESP-SMTe series consists of stand-alone controllers that automatically calculate irrigation demand once programmed for the installation site. To enable the controller to calculate daily reference ET values, the user enters the site location (Zip code or custom values—latitude, elevation, etc.). Based on the

site's location, a daily solar radiation value is determined, and monthly historical values for wind speed and humidity are retrieved from the controller memory.

These three data points (daily solar radiation, historical monthly wind speed, and historical monthly humidity) are combined with daily high and low temperatures that are retrieved from the onsite ESP-SMTe weather sensor.

Using the ASCE reference ET equation, the controller calculates the daily reference ET rate based on daily site-specific solar radiation, temperature data, wind speed, and humidity values. The irrigation frequency and amount of irrigation per zone is determined based on the managed allowed depletion soil moisture tracking method.

The controller is programmed for "Allowed Irrigation Days." The user selects from the Days of Week, Odd Days –No 31, Even Days, or Cyclical (2 to 14 days) options. The user can set two "Allowed Water Windows" for weather-based schedules, and an optional "Grow-In Water Window" is available for establishing newly planted areas. After a user-set number of days, the controller will automatically convert these zones to weather-based irrigation.

To simplify controller programming, a menu-driven "programming wizard" allows the user to enter default or custom values for each zone. The specific zone parameters include: sprinkler type (precipitation rate and efficiency), soil type, slope, plant type (species factor and root depth), plant water need, plant density, zone microclimate (shade factor), and plant maturity.

The ESP-SMTe onsite weather sensor employs a "tipping bucket" rain measurement device that:

- ◆ Suspends irrigation when it rains based on a user-set threshold
- ◆ Measures gross rainfall

Based on the timing, intensity, and amount of the rainfall event, the ESP-SMTe determines how much rainfall is actually usable by the plant material.

A temperature threshold can be set by the user that will disable irrigation when the ESP-SMTe weather sensor measures temperature below a threshold.

Based on the user-entered sprinkler precipitation rate and efficiency, soil type, and slope, the controller will automatically create a "cycle and soak" schedule for each zone that will prevent water waste and pollution runoff.



The daily weather data (high and low temperature, reference ET, rainfall) for the past 30 days can be viewed on the controller display. The previous 400 events (irrigation events, shutdown events, alarms, notes, etc.) are logged and viewable “by date” or “by zone.” All controller and zone parameter information can also be viewed.

The faceplate text on the backlit display is in English or Spanish. All programmed information is saved indefinitely in nonvolatile memory, and date and time are maintained in the event of a power outage by an internal lithium battery. A Contractor Default Program is retrievable if needed. In the unlikely event that the controller does not receive communication from the sensor for more than a day, the controller will base the irrigation schedule on the highest daily reference ET value over the past 7 days. Up to 6 kilovolts of surge protection is provided.

Descriptions, Prices, and Warranty

The Rain Bird ET Manager Cartridge is a cartridge that snaps into place within the ESP-LX modular controller, as well as a receiver to mount on top of the controller. The dimensions of the cartridge are 5 by 6.5 inches. The cartridge can be purchased preinstalled, referred to as the ESP-ET series controller. In some cases, the receiver will require a remote mounting kit to receive a consistent weather signal.

Current suggested list prices for the ET Management products and accessories are summarized in the table 10.

Table 10.—Rain Bird ET Manager and Accessories Prices

Description	Model No.	Price
ET Manager Cartridge	ETC-LX	\$658
ESP-LXME Controller	ESPLXME	\$338
ESP-LXD Two-Wire Controller	ESP-LXD	\$1,200
ESP12LXME With ETCLX EPA WaterSense Certified	ESPLXME-ET	\$1,000
ESPLXD With ETCLX EPA WaterSense Certified	ESPLXD-ET	\$1,900
Optional Tipping Rain Gauge	ETM-RG	\$230
Optional ETC Remote Mounting Kit	ETM-RMK	\$220
Optional ETM Programming Software Kit	ETM-PS	\$676

The ESP-SMTe series controller consists of 10 color-coded dial positions, an English/Spanish language button, four navigation buttons, a large dot matrix backlit display, and an alarm light. Programming wizards are employed along with menu-driven selections to simplify controller programming.

The CUL-rated transformer has a capacity of 1.0 ampere that will generally allow up to two irrigation control valves plus a master valve/pump start relay to operate at the same time. The station terminals will accept wire sizes from 12 to 20 gauge.

The wire that is connected to the back of the controller panel to the onsite weather sensor provides both power to the sensor (no batteries required) and communication of the weather data from the sensor back to the controller. This power/communication wire can be run over a maximum 200-foot distance.

- Controller Dimensions – 10.7-inch width, 7.7-inch height, 4.4-inch depth
- Sensor Dimensions – 6.0-inch width, 8.8-inch length, 5.9-inch height
- Materials – Ultraviolet rated ABS and ASA plastic resin and stainless steel hardware

Current suggested list prices for the ESP-SMTe series products and accessories are summarized in table 11.

Table 11.—ESP-SMT Series Prices

Model	Description	Price
ESP4SMTEI	Four-station/zone smart control system for indoor installations. Includes the controller and onsite weather sensor.	\$275
ESP4SMTE	Four-station/zone smart control system for outdoor installations. Includes the controller and onsite weather sensor.	\$305
ESP4SMTEUPG	Smart control system to upgrade ESP-Modular controllers. Includes smart controller panel and onsite weather sensor.	\$215
ESP-SM3	Three-station expansion module to expand the ESP-SMTe.	\$52.50
ESP-SM6	Six-station expansion module to expand the ESP-SMTe to a maximum of 22 stations/zones.	\$98.50

Rain Bird products are available from any authorized Rain Bird Wholesale Distributor Branch location. A distributor search engine can be accessed at Rain Bird’s Web site. All Rain Bird controller products come with a 3-year trade warranty.

Installation

Although installation by a Rain Bird trained professional is strongly recommended, Rain Bird reports installation may be performed by some homeowners. A comprehensive online-tutorial for the ESP-SMTe series is available at: www.rainbird.com/ESP-SMTe. Installation and programming instructions in English and Spanish are provided with the controller.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

Rain Bird has field tested its smart controller products at numerous locations throughout the United States, and SWAT test performance reports are posted for the ET Manager, ET Manager Cartridge, and ESP-SMTe series.

Rain Bird reports ESP-SMTe field test contractors that participated in its field test survey gave an average score of over 4.5 out of 5.0 in the “ease of use” rating, with some individuals indicating that it was easier to use than a traditional time-based controller.

Rain Bird is a registered partner in the WaterSense Program and both ESP-SMTe and ESP-ET are EPA WaterSense certified.

Raindrip

Raindrip (a division of National Diversified Sales, Inc.) is located in Fresno, California, and offers a broad range of drip/micro-irrigation products and automatic watering timers for the residential market. For more than 30 years, Raindrip has been a leader in efficient irrigation solutions producing innovative irrigation products such as the SimpleDrip™ 1-2-3 drip conversion system and the recently introduced WeatherSmart™ and WeatherSmartPRO™ smart irrigation controllers that entered the market in 2009. These controllers can be used with traditional solenoid valve-controlled underground irrigation systems for watering turf and other landscapes with popup or stationary sprinklers, as well as with drip/micro-irrigation devices.



WeatherSmart and WeatherSmartPRO were designed and built to meet the needs of homeowners who want a simple, modern, yet inexpensive weather-based irrigation control solution with no monthly fees. The Raindrip RSC600IS WeatherSmartPRO is a six-station landscape and turf irrigation smart controller that includes a wireless weather sensor. It is a feature-rich, self-adjusting smart irrigation controller that uses a wireless weather sensor to gather real-time, onsite temperature and rainfall information to automatically adjust and/or suspend irrigation watering throughout the year. The RSC6001 WeatherSmart is also a six-station controller with most of the features of the WeatherSmartPRO, except that its weather-based control function is based on historic weather data preprogrammed into the controller.

Operational Features

The WeatherSmartPRO uses proprietary patented and patent-pending technology; some of which has been used in smart controllers since 2002. The controller determines and uses a water budget ratio to automatically adjust watering run times on a daily basis. This ratio is calculated using current time of year and weather sensor data that include outside temperature and measured onsite rainfall; as well as geographical location (Zip code), solar radiation, and other historical weather data preprogrammed into the controller.

The included weather sensor communicates wirelessly with the controller using industry standard radio frequency communication protocols. Temperature readings and other operational information are sent to the controller every 15 minutes. The sensor sends rainfall information to the controller immediately once a sufficient amount of rain is measured. The controller uses information from the weather sensor to automatically adjust watering run times; temporarily stop irrigation for rainfall events; suspend irrigation when the outside temperature drops below 40 degrees; display connection status of the sensor; and notify the user when batteries are low in the sensor.

During rainfall events, the controller calculates a rainfall irrigation shutdown duration. The calculation uses the amount of rainfall measured by the weather sensor and historical weather data for the geographic location (Zip code). The shutdown duration timer is displayed for the user to know how long the controller has suspended irrigation.

Communication range tests through various multiple obstructions have been proven successful to distances exceeding 75 feet. A recommended sensor distance from the controller is typically within 50 feet, depending on type and number of obstructions. One weather sensor can be used to control multiple controllers for larger, higher station count installations.

The controller keeps the user informed of various operational information and system status using the large backlit 3- by 2-inch display and audible notifications. The controller displays water savings (daily and year-to-date), measured rainfall (daily and year-to-date), and shutdown duration times during rain events. Other system information includes outside temperature, low temperature shutdown (when activated), low battery indicators for the controller and sensor, valve wire fault/short detection by zone, and sensor connection status.

Programming and managing the WeatherSmart and WeatherSmartPRO is reported to be simple and are accomplished using four buttons and a modern navigation pad/enter button methodology. The controller prompts the user for various settings and water schedule information to be entered throughout the setup and water schedule programming sequence. This is initiated by using two buttons under the removable door at the bottom of the controller, “settings” and “edit schedule.” Managing manual watering interruptions or exceptions is done by using two buttons near the top of the controller, “auto run” (on/skip/off) and “water now” (start/stop).

The controller settings are entered by the user and include date, time, Zip code, and optional watering modes (specific days of week, interval days, or odd/even dates). The watering schedule also is entered by the user (number of watering cycles per day, watering durations per cycle, and watering start times). The controller watering schedule is entered using values for the hottest time of the year—the summer season.

Descriptions, Prices, and Warranty

The RSC600IS WeatherSmartPRO is a six-station landscape and turf irrigation smart controller that includes a wireless weather sensor, 110-VAC power transformer wall adapter, mounting hardware, and installation and programming manual. It is compatible and can be used with traditional 24-VAC solenoid valve-controlled underground automatic irrigation systems. The individual station wire circuit capacity is 0.45 ampere with wiring terminals accepting 16- to 24-gauge wire. All of the above applies to the WeatherSmart controller, except there is no weather sensor.

The controller dimensions are 6.5 inches square by 2 inches deep and it is designed for indoor use, but also can be mounted in a weather-resistant timer box for use outdoors. A docking station system is incorporated into the controller and can be undocked for convenient programming. The controller uses batteries to keep the real-time clock current in the event of a power failure and for undocked programming. Settings and watering schedule programming are protected and maintained using nonvolatile memory.

The weather sensor dimensions are 3.5 by 5 by 2.5 inches deep. It uses a tipping bucket rain gauge, temperature sensor, and is designed for outdoor use. Both the controllers and weather sensor are Federal Communications Commission approved and require 2 AA alkaline batteries.

The RSC600IS WeatherSmartPRO features summary:

- ◆ Six stations with up to four independent start times (cycles) per day, per zone.
- ◆ Includes a wireless weather sensor; can be used with multiple controllers.
- ◆ Optimizes and automatically adjusts watering durations by Zip code.
- ◆ Automatically suspends programmed watering schedules when rainfall is detected and when low temperatures occur—less than 40 degrees.
- ◆ Daily and year-to-date water savings and measured rainfall is displayed.
- ◆ Outside temperature is displayed.
- ◆ “Percent Adjust” function for adjusting watering durations for all zones.
- ◆ “Skip” function timer for manual interruption of watering schedules.
- ◆ “Water Now” function timer for manual watering or to test irrigation system.
- ◆ Built-in diagnostics automatically troubleshoots and alerts of wiring short circuit.
- ◆ Easy to read, oversized 3- by 2-inch backlit display.
- ◆ Nonvolatile memory saves program settings in the event of power loss.
- ◆ Audible beep to alert for low batteries, wiring faults, and sensor status.
- ◆ Controller “undocks” to allow for convenient programming.
- ◆ Automatically adjusts for daylight savings.
- ◆ Conventional timer mode (nonsmart) option.

The WeatherSmart and WeatherSmartPRO include a 1-year warranty and are available at home improvement retailers in the Western United States. Retail prices range from \$50 to \$124. Both can also be purchased online at: www.raindrip.com.

Installation

Installation of the Raindrip controllers is reported to be straightforward and can be accomplished by typical residential homeowners.

Controller installation involves adding batteries, mounting the docking station, attaching sprinkler valve wires, plugging in the power adapter, and docking the controller. The controller then steps the user through settings and watering schedule inputs.

Weather sensor installation is accomplished by placing the controller into pairing mode, adding batteries to the sensor, waiting 40 seconds for the self-test, then mounting the weather sensor. Installation times for prewired systems near an electrical outlet can be accomplished in less than an hour.

Installation and technical support is available from Raindrip during extended hours through a toll-free number (877-502-7952). Additional information and details are included in the installation and programming manual and is available for download at: www.raindrip.com.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

The WeatherSmart and WeatherSmartPRO indicate daily and year-to-date water savings on the display of the controller. These savings are based on actual operation when the controller compares the programmed watering schedule to the actual watering applied. Raindrip reports annual water savings of up to 30% by end users over extended periods of time.

The RSC600IS WeatherSmartPRO has completed SWAT testing and performance reports are posted at the Irrigation Association SWAT Web site.

Raindrip is an EPA WaterSense partner and RSC600IS WeatherSmartPRO has received WaterSense certification.

Rain Master

For the past 27 years, Rain Master has specialized in the design and manufacture of commercial irrigation controllers, handheld remote controls, and central computerized irrigation control systems. Located in Simi Valley, California, Rain Master introduced its first ET-based water management system in 1990. In 2002, Rain Master introduced the RME Eagle™, weather-based commercial irrigation controller



that functions either as a stand-alone unit or as a satellite controller component of the Rain Master iCentral™ Internet-based system. The RME Eagle/iCentral system (United States Patent No. 6,823,239) was designed to address the single controller as well as low to mid-sized control system markets.

Rain Master was purchased by The Toro Company® in the summer of 2007, and the products were placed under the company's Irritrol brand. During the summer of 2009, Irritrol/Rain Master introduced an improved version of the RME-Eagle, the Eagle Plus, offering more water saving features, simplified user interface, two-wire capability, and GSM cellular communication technology with its iCentral Internet system.

Rain Master provides several ET source options for the Eagle. ET may be entered manually into the controller; alternatively, the controller may be directly connected to a Rain Master Weather Center EG weather station or receive CIMIS data (California only). When configured with Rain Master's iCentral two-way wireless card, ET may be disseminated over the Internet using Rain Master's ZipET national dissemination weather service, or California users may obtain their daily ET from CIMIS.

Operational Features

When the Eagle's programs are enabled for ET operation, station run times are adjusted automatically on a daily basis when connected to the Internet or a Weather Center EG weather station. (Eagle Plus can also operate with the Weather Center II, which can interface with a tipping bucket rain gathering device.) If daily ET is unavailable, the controller will intelligently utilize average monthly historic ET entered by the user to adjust its daily schedules. Historic ET data by Zip code are available at Rain Master's Web site at:

www.rainmaster.com. The controller computes ET adjustment granularity to the nearest second, which eliminates rounding errors commonly found in controllers that round on incremental minute basis (i.e., a 5-percent programming error can occur based on just a 10-minute run time).

Rain Master's ZipET is an ET data collection and dissemination service for Rain Master iCentral Internet customers. Rain Master collects raw weather information on a daily basis from thousands of Federal Aviation Administration and NOAA Fisheries weather stations throughout the United States. The weather information is validated and converted, as necessary, to generate industry-accepted ET values. The ET values are interpolated by Zip code using a three-dimensional surface regression model. Site-specific ET information then is delivered automatically to each controller via the two-way wireless communications card (iCard). Rain Master's iCentral Web site provides daily reports on all ET weather information that was successfully delivered to each controller (two-way confirmation).

An alternative to the ZipET service is available for users who require the accuracy of an onsite weather station. Rain Master's commercial grade, computer-controlled Weather Center EG measures wind, rain, temperature, solar radiation, and relative humidity and calculates ET at a frequency of 10 seconds. A contact closure signal is transmitted from the weather station to the controller by wired connection to signal accumulation of 0.01 inch of ET. The electrical signals are counted and stored in the memory of the controller, which uses the ET data to adjust the irrigation schedule. The Weather Center EG measuring devices are permanently mounted on a 10-foot-tall, vandal-resistant tower with all connections made within the tower's terminal block. The controller supplies power to the system. The graph in figure 7 shows the accuracy of the Weather Center EG as compared to a nearby CIMIS station.



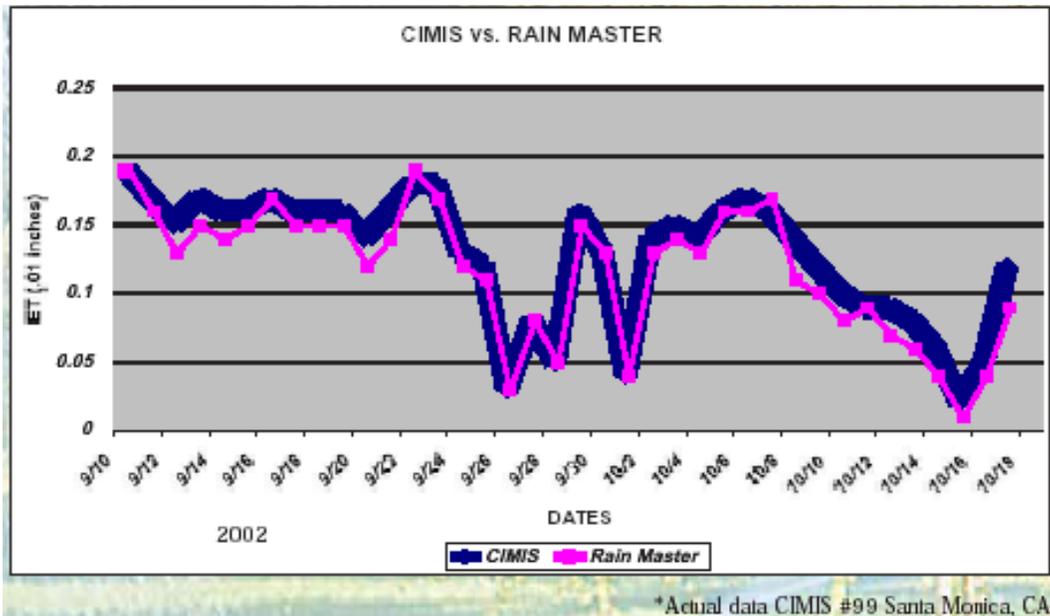


Figure 7.—Rain Master Weather Center EG-ET versus CIMIS reference ET.

The Eagle user also has the ability to manually enter daily ET information at any time. When used in conjunction with historic ET, manually input ET can mitigate for extreme conditions. Utilization of manually entered ET data in conjunction with historical ET data can significantly improve irrigation efficiency. The controller will utilize the manually entered ET value for a period of 1 week and then automatically revert back to the use of the selected ET data source. Manual ET data can be entered at any time; each time it is entered, it will overwrite the last data value stored and supersede all other ET data sources.

When the RME Eagle controller is coupled with the optional two-way wireless iCentral plug-in card, irrigation control and monitoring may be performed via the Internet. Activation of the wireless service to the controller is performed directly from the Rain Master Web site. Because it is wireless, installation is reportedly simple for either new or retrofit applications. A knockout at the bottom of the controller enclosure is provided for mounting the 3-inch antenna.

The iCentral Web site automatically informs the user anytime a field change has occurred, including controller alarms (sensors and wiring fault detection) that are also emailed to the user. The Web site allows the user to command a rain shutdown, modify controller setup information, and manually turn on/off any station or program. The Web site also provides an automatic schedule generator so that users may generate representative irrigation schedules taking into consideration plant type, irrigation system design, and climatic conditions. Once the user enters all the **scheduling constraints** and **station attributes** for a controller, as described below, suitable programs are downloaded throughout the

year in addition to the daily ET adjustments that are sent to the controller. The scheduler algorithms utilize the Irrigation Association “Landscape Irrigation Scheduling and Water Management” equations dated March 2005.

The **scheduling constraints** define the irrigation season, controller water window, stations, programs, the allowable water days that are available for the scheduler, and any hydraulic constraints the system may have.

The **station attributes** include plant type, precipitation rate, soil type, root zone depth, slope, station efficiency, allowable soil moisture depletion, distribution uniformity, and seasonal plant crop coefficients.

In the absence of the iCentral scheduler, the user must program the controller with a base schedule. The base schedule’s total run times and soak/cycle times are adjusted automatically each day by the controller based on ET.

Descriptions, Prices, and Warranty

The RME Eagle controller is available in 6-, 12-, 18-, 24-, 30-, and 36-station configurations. It has four independent programs, each with five start times. The Eagle Plus is available in 8-, 16-, 24-, 32-, 40-, and 48-station configurations as well as a two-wire version that provides up to 200-station capabilities. Water days may be programmed on a weekly basis or by skip-by-day water day cycles with skip days ranging from 1 to 30 days. Station run times may be programmed up to 10 hours in 1-minute increments and may be increased/decreased using the program percent feature from 0 to 300% in 1% increments. Programmable overlap protection provides for programs to be stacked or run concurrently, and provision is made for a separate master valve and/or pump. The controllers have nonvolatile memory, and the time and date are updated without backup batteries. Electronic overload protection is provided with automatic reset (no fuses or circuit breakers). The Eagle and Eagle Plus standard water savings features are summarized in the bullets below.

- ◆ Programmable rain shutoff in order to delay the start of irrigation after a rain event (1 to 7 days).
- ◆ Manual rain switch (“Automatic Watering–No Watering”) provides a means of quickly turning off all irrigation programs without disturbing the stored program(s).
- ◆ Connectivity for any one of the following options: rain, moisture, or freeze sensor devices on a per program basis—when the sensor is “active,” irrigation will stop and the display will indicate that the sensor is active.

- The ability to select either “Odd” or “Even” day watering on a per program basis.
- Selectable cycle-and-soak irrigation programming or conventional programming on a per program basis.
- Programmable cycle run time, “Max Cycle Time,” and “Soak Time” on a per station basis.
- Automatic minimization of the water window by intelligently scheduling station starts when other stations are satisfying their “Soak Time.”
- The controllers provide the ability to display total program duration, real-time flow in gallons per minute (gpm), alarm information related to flow and station field wiring conditions, daily ET values, sensor status, and total water usage.

When connected to an optional Rain Master flow sensor, the Eagle and Eagle Plus controller will suspend irrigation in the event of a line break (leak), catastrophic main line failure, or unscheduled flow. Station limits may be automatically “learned” by the controller, and irrigation will be suspended for any station that fails its limit checks while it irrigates. The controller display shows real-time flow measured in gpm, as well as flow and station field wiring fault conditions.

The standard size RME Eagle controller dimensions are 13.1 by 10.4 by 4.4 inches, and the extended size cabinet is approximately 7 inches taller. The Eagle Plus enclosure is 15.5 by 10.75 by 6 inches. The enclosures are constructed of rolled steel with jet coat[®] or stainless steel and are suitable for outdoor installation. Various optional stainless steel pedestal enclosures are available. Eagle and Eagle Plus controllers are UL approved, Federal Communications Commission certified for emissions, include an internal 24-VAC transformer, and the current capacity is 1.0 (1.5 Eagle Plus) ampere per station and/or master valve circuit(s). The controllers have terminal screw connections and will accept 12-gauge wires. Optional heavy duty lightning and surge protection is available for the Eagle, and the Eagle Plus comes standard with lightning protection.

Rain Master’s products are available throughout the United States at all major irrigation distributors. A distributor search engine can be accessed at Rain Master’s Web site. The manufacturer’s suggested retail price (MSRP) for the standard RME Eagle 6-station controller starts at \$674. A 36-station price of \$4,039 includes a full year of online technical support, Internet service, and ZipET. Individual Internet service plans for wireless two-way communications range from \$9.95 to \$14.95 per month. The MSRP for the Weather Center EG is \$3,683. All Rain Master controllers come with a 5-year warranty. Nationwide

product support is available by a network of Rain Master sales representatives. Toll-free factory telephone support (800-777-1477) is available from 8:00 a.m. through 5:00 p.m. Pacific Standard Time.

Installation

Rain Master reports installation of the controller is straightforward. The AC power, however, has to be hard-wired and a contractor is recommended. Installation time and cost varies depending on site-specific conditions.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

Rain Master reports that thousands of Eagle controllers have been installed throughout the United States and that the Rain Master RME Eagle controller has been recognized and accepted by more than 40 water purveyors/agencies across the Nation. A list of water agencies that accept Rain Master's products in their water saving incentive programs can be accessed at Rain Master's Web site.

Although "formal" water savings data were not available for this report, Rain Master reports average water savings of 25 to 40%. Rain Master's reputation and the controller's 5-year warranty are significant factors when considering the reliability and overall performance of their products.

A SWAT test performance report for the RME Eagle is posted on the Irrigation Association SWAT Web site. Rain Master has also received WaterSense certification.

Signature Control Systems

Signature Control Systems, Inc. (Signature), was founded in 2000 and is headquartered in Irvine, California, with its manufacturing facility in Peoria, Illinois. Signature manufactures a range of residential, commercial, and golf course irrigation controllers. In 2013, the company launched a range of weather-based irrigation controllers for all market segments, including the EZ Connect 8250I Ethernet Based Residential Controller, which runs on Signature's SHARE central control platform.



The EZ Connect 8250I comes standard as a 12-zone indoor mount irrigation controller with two expansion ports for extended control outputs. It includes two data-ready sensor inputs for a combination of any two of the rain, flow, moisture or temperature sensors. The EZ Connect 8250I is an Internet-based controller with a contemporary design, incorporating cloud-based software making it a smart ET-based residential controller.

Operational Features

The EZ Connect 8250I is an Internet-based controller that makes use of a built-in Ethernet port to access Signature's SHARE central control platform. Internet access for remote locations can also be achieved via WiFi using third party Ethernet to WiFi or Ethernet over Power [EoP] technology. Connection and programming control can be done via any computer anywhere in the world with Internet connectivity, via the Signature SHARE Web site.

The EZ Connect 8250I can also be accessed via an iPhone or Android App, which allows for additional flexibility and functionality. The App is simply downloaded from the relevant App store and the controller registered via the SHARE centralized database. This allows access to the controller from anywhere, at any time, through the convenience of a smartphone.

Once the controller is registered with the central database and the "Intelligent Watering" option has been activated, a sequence of agronomic sensitive database entries, via user-friendly screen prompts, is used to enter the site-specific conditions to include such detail as:

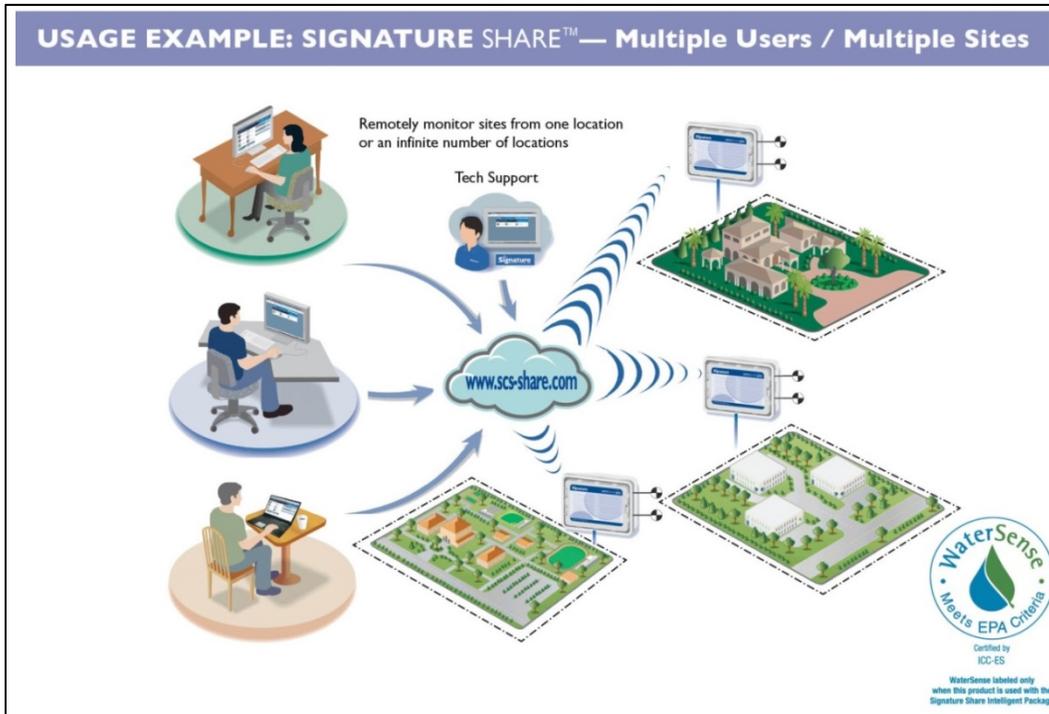
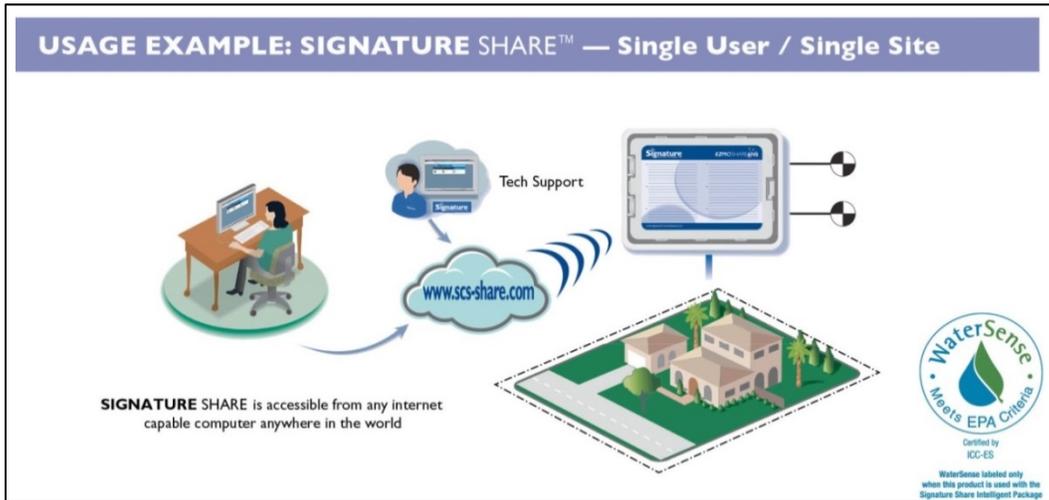
- ◆ Rotor type by zone
- ◆ Planting type by zone
- ◆ Specific conditions by zone (i.e., slope, sun/shade, and soil type)
- ◆ Zone precipitation rate, field capacity, and current depletion rate

A daily feed of proprietary weather data from Signature will then provide a daily ET value for the controller location. This ET value is calculated using wind, solar radiation, temperature, humidity, and rainfall and is automatically downloaded into the database for that controller. Shortly before the next scheduled irrigation, the central database will automatically contact the controller and download new run times or postpone irrigation if rainfall has exceeded the ET value.

The SHARE software will calculate run times and soak times based on the application rates and slope and soil conditions per zone and determine the most efficient run time sequence of zones. The controller will automatically start zones, while other zones are paused to maximize water infiltration and percolation rates and power consumption efficiencies.

Weather- and Soil Moisture-Based Landscape Scheduling Devices

The EZ Connect 8250I controller has no buttons or complex keypad. All programming inputs are done either via the Internet or the smartphone App, which has multiple languages. Signature reports their software is easy to maintain and keep up to date as all software resides in the SHARE platform and is updated automatically every time the controller is online.



Descriptions, Prices, and Warranty

The EZ Connect Share 8250 series controller comes in two versions, the 8250B for basic model and the 8250I that incorporates the Intelligent Irrigation package as discussed here. The controller is available in a plastic wall mount indoor configuration with outdoor options available from Signature. The indoor unit is 7 by 5.75 by 2 inches in size with an external transformer.

The standard station output configuration is 12 stations at 24-VAC per station, with a maximum loading per station of 0.50 ampere. Additional items may be required for operation if a LAN connection is not available and are sold separately (i.e., Ethernet to powerline adaptor or Ethernet to WiFi adaptor).

Each program has four start times and is exclusively programmable via the SHARE platform via smartphones, tablets, or PCs with Internet connectivity. Scheduling options are monthly, odd/even, or interval (1 to 31 days).

Diagnostic features include a 1.0 ampere self-resetting fuse for short circuit zone protection, a manual test button for maintenance without an Internet connection, and intelligent station current monitoring of the station wiring and solenoid valve.

Table 12.—SHARE/EZ Connect Controller Prices

Controller Description	Model No.	Retail List Price
SCS-Share™ Software Platform [Basic] With Region-Specific 8250 Irrigation Controller and Region-Specific Limited Data Package*	SHRPWIAAA8250BANE0	\$323.00
SCS-Share™ Software Platform [Smart Weather and WaterSense] With Region-Specific 8250 Irrigation Controller and Region-Specific Limited Data Package*	SHRPWIAAA8250IANE0	\$277.00
SCS-Share™ Access Complete With Region-Specific 8250 Controller, Smart Watering Software, and Limited Specific Data Bundle*	SHRPWIAAA8250DANE0	\$595.00

Installation

Signature reports that installation of the controller can be done by the typical homeowner provided the owner feels capable of doing so; otherwise, a qualified contractor is the best option. Free technical support is available directly from Signature at 866-474-4628, or directly through one of the Signature regional offices listed on its Web site at: www.signaturecontrolsyste.ms.com. Signature reports that setting up the controller on the SHARE platform can also be done by the homeowner by logging into <http://scs-share.com/>, clicking on “create a new account” and following the setup wizard. Once this is done, the user can login to their secured SCS Share account. After logging in, the user goes to “Site Functions” then “Add Controller” by using the device’s ID, which is printed on the control panel and in the user manual. Once this is done, the controller is fully

accessible by the registered user from anywhere in the world via a PC, tablet, smartphone, or any computer device connected to the Internet, via the user's secure user name and password.

Track Record, Water Savings, WaterSense Certification and SWAT Testing

Signature obtained WaterSense certification in June 2013.

Skydrop

Skydrop, Inc., is based in Lehi, Utah, and began business in early 2014, and its WiFi-based smart controller entered the market in September of 2014. The Skydrop smart sprinkler controller is a stand-



alone weather-based wireless irrigation controller that accesses weather data in real time via the user's WiFi Internet connection and automatically adjusts irrigation scheduling. The controller can be operated, adjusted, and monitored via WiFi using a Web browser, mobile device, or at the controller. Skydrop's "cloud" service interprets hyperlocal, real-time weather data to control and monitor an unlimited number of controllers.

Operational Features

The Skydrop can be installed as a new controller or one that replaces an existing clock-type controller. All irrigation activity is wirelessly communicated back from the controller to the WiFi-connected device.

The Skydrop controller is mounted to an interior wall and the valve wires are attached with button connectors. Once connected to the cloud, the user can access the Skydrop controller from a Web browser or mobile device via the Skydrop mobile App. In addition, it enables Skydrop to interpret hyperlocal, real-time weather data to schedule irrigation events. Once installed, controller setup includes start time, duration, plant type, soil type, slope, shade, and sprinkler type.

After the initial setup, minimal further user intervention should be required. Skydrop automatically checks weather conditions several times each day. Irrigation schedule adjustments are calculated based on temperature, wind, precipitation, solar radiation, and humidity and wirelessly transmitted to the controller. An optional rain sensor can also be easily attached.

Weather adjustments are transmitted automatically—the user does not need to be online nor does a computer need to be on. If the Internet is not available, the user can set up scheduling similar to older controllers. In the event the user has WiFi but then loses an Internet connection, the historical schedule is used to continue effectively watering.

The controller includes a cycle and soak feature to eliminate or reduce runoff when landscapes are sloped. Individual zones can be put on a temporary hold for a user-defined number of days. An antifreeze feature automatically suspends all watering when the temperature forecast approaches the freezing point. Skydrop maintains a log of all water usage and displays a variety of water usage and saving reports and graphs.

Users can manually turn on/off valves and check the system status via their WiFi-connected devices.

Description, Prices, and Warranty

The Skydrop controller operates 8 stations plus a master valve/pump, and is expandable to 16 stations with an expansion unit. If additional station capacity is needed, another controller can be installed and operated from the common WiFi-connected device.

The connectors accommodate wire sizes ranging from 16 to 24 gauge. The controller is constructed of precision formed stainless steel and engineered plastic that is suitable for indoor installation only. Its dimensions are 9.7 by 3.4 by 1.9 inches and it includes a 4.3-inch LED display panel. The power supply is from a 120/24-VAC external transformer (with a lithium backup battery). Station zone capacity is 500 milliamperes with recommended maximum capacity of 1 solenoid per zone. The controller has nonvolatile memory to retain programming during power outages and its clock is maintained during power outages with a lithium battery. Surge and lightning protection is provided by a metal oxide varistor.

The retail price for the Skydrop controller is \$299 and the price of the expansion unit is still being determined.

Skydrop has a 30-day “satisfaction or money back” guarantee, plus a 2-year limited manufacturer’s warranty. There are no monthly fees or additional charges for basic software functionality. Software updates and feature enhancements are free.

Installation

Skydrop reports its controller can be installed and set up by the typical homeowner in under 30 minutes. An installation video and guide are available at: <http://www.skydrop.com/installation>. In addition to its online support, toll-free telephone technical support is available at 844-SKYDROP.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

Skydrop is currently working to get WaterSense certified, but does not plan to pursue SWAT testing at this time. Skydrop reports estimated water savings of 20 to 50%.

Weathermatic

Weathermatic®, established in 1945, is a worldwide manufacturing company of a full line of irrigation products. The company, headquartered in Dallas, Texas, began developing water conserving products in the 1950s when it used soil moisture sensors, which were later followed by its innovation of the industry's first rain sensor shutoff device in the 1970s.



Weathermatic's SmartLine™ residential and commercial irrigation controllers operate based on weather conditions using onsite sensors.

Operational Features

The Weathermatic SmartLine controller technology patent was filed in 1998 and granted in 2000. SmartLine controllers accept user inputs by zone for sprinkler type, plant type, soil type, slope, and a zone fine-tune adjustment factor. The units then incorporate a Zip code input (for solar radiation) and an onsite weather monitor (sensing temperature and rainfall) to calculate real-time ET estimates that are used with user inputs to calculate proper zone run times, including cycle/soak, at user-selected



start times and watering days. The SmartLine controller/weather sensor package operates stand-alone and does not require communication with remote servers to obtain weather data or irrigation schedules, and no ongoing service costs are associated with the unit. After 8 years of development, testing, and field trials, the SmartLine controller series entered the market in November of 2004. Next Generation firmware entered the market in 2011. The Next Generation firmware allows users to exempt selected zones from ET watering and from shutdown for rain and freeze conditions. This feature is important for users with potted plants under cover that do not receive natural rainfall. Next Generation firmware also allows the users to select a minimum deficit for ET watered zones. The SmartLine will save water by skipping set watering days until the minimum deficit is reached. Next Generation firmware also has an automatic change feature for Daylight Savings Time. The feature is user-resettable.

The Weathermatic controller platform is built around zone modules that allow expandability from 4 to 8 zones for their SL800 model and 4 to 16 zones for the SL1600 to accommodate various size residential and commercial landscapes. The SL1620 and SL1624 have fixed zone capacities of 20 and 24. A larger commercial model, the SL4800, provides module and wiring space for up to 48 zones. The SL1600, SL 1620, SL1624, and the SL4800 are all suitable for indoor or outdoor installation. The SL800 is an indoor model.

Descriptions, Prices, and Warranty

The SL800 is a fixed four-zone unit that can be expanded to six or eight zones with two-zone modules (SLM2). The SL1600 controller is shipped standard with a 4-zone module and can be expanded to 8, 12, or 16 zones with additional 4-zone modules (SLM4). The SL1620 and SL1624 controllers are fixed 20- and 24-zone units. The SL4800 is shipped with 12 zones included. SLM12 modules are added to accommodate 24, 36, or 48 zones. The controller housing dimensions are 7 by 7.8 by 1.8 inches for the SL800; 9.1 by 10.1 by 4 inches for the SL1600 series; and 15 by 16.5 by 5.8 inches for the SL4800. The SL800 has an external transformer power supply with a barrel connector that plugs into the side of the controller for fast installation. The SL1600 series controllers have internal transformers with a prewired plug-in cord that will accept 120 or 240 VAC. The SL4800 will also have a 120/240-VAC internal transformer, but without a prewired plug-in cord (professional installation required). For the SL800 controller, either a 120- or 240-VAC power supply with connectors for Europe or Australia can be specified when ordering. The controller output circuit capacities are 1.0 ampere for the SL800; the SL1600 series and the SL4800 is rated at 1.2 amperes. Weathermatic reports these capacities are adequate for running three-zone valves concurrently, including a master/pump valve for the SL800 and SL1600 series; and five valves concurrently, including a master/pump valve, for the SL4800. Accepted wire sizes range from 14 to 18 gauge.

The SmartLine controllers have advanced functions including zone-to-zone and master valve timing delays and a built-in valve locator, as well as a unique diagnostic function that displays the electrical current by zone for troubleshooting. Additionally, the user can omit specific calendar event dates, days of the week, and times of the day when no watering is allowed.

In late 2011, Weathermatic introduced SmartLink™ that allows SmartLine users to access any number of sites and controllers and perform any function that can be performed in front of the controller. SmartLink requires an Aircard that plugs into the SmartLine controller. With the SmartLink Wireless Landscape Network, you can manage all your sites from any computer or mobile device and a simple Internet connection. No software, long-term contracts, or expensive hardware is required. A flow version of the SmartLink Aircard is also available. Set flow limits by zone and detect leaks or broken heads. SmartLink is a major labor and water saver for property management companies, HOA managers, and other commercial users allowing immediate access with any smart device.

Weathermatic offers a two-wire option with the SL1600 series controllers. The SmartWire™ decoder module for two-wire systems (model SLM48DM) can be integrated into these controllers and is considered cost effective for 18 zones and larger systems. The SLM48DM includes connections for up to three different two-wire paths and includes an LED display and status lights for programming, operation status, and troubleshooting. The valve decoders used to decode the signals from the SLM48DM come in one-, two-, and four-valve capacity (models SLDEC-1, SLDEC-2, and SLDEC-4). Additional valve decoder features include: shock and freeze/heat resistant, 14-gauge wiring, surge protection, and functional distance up to 100 feet from the valve.

The onsite weather sensor includes a temperature sensor and rain sensor. The unit has a microprocessor to record and process measurements. The temperature-sensing unit is encased in a solar shield. The hygroscopic disc-type rain sensor can be set to trigger rain delay at rainfall depths from 0.125 to 1 inch. Weather sensor models available are the SLW1 wired unit and the SLW5 and SLW15 wireless units. The SLW15 has line-of-sight operation up to 600 feet. The SLW1 has no onboard power requirement (battery) to replace. Operation limit is 200-wired feet from the controller. The SLW15 requires onboard battery power.

SmartLine Solar is a solar-powered package available in 24- and 48-zone models for operating standard 24-VAC solenoids.

SmartLine controllers are distributed through Weathermatic's established wholesale suppliers (specialty irrigation suppliers) and installation professionals. The list prices for currently available and planned residential controllers and components are listed in table 13. The warranty is a "trade warranty," which means the warranty is extended to the landscape irrigation professional or installing contractor only. The warranty varies based on the product as follows:

- Ten Years—11000CR and 8200CR series valves and S24B solenoids
- Five Years—Rotors, spray equipment, nozzles, 21000 series valves, and S20P solenoids
- Three Years—SmartWire when used with SLWIRE
- Two Years—N-100 and 12000 series valves
- One Year—SmartWire when used without SLWIRE
- SmartLine[®] and Valcon controller products, and all other cataloged products not specifically listed, are under the 5- or 10-year extended warranties
- SmartLine controllers (SL800, SL1600 series, and SL4800) and SLW weather stations are covered under warranty for lightning damage

Table 13.—Weathermatic SmartLine Controllers and Component Prices

Description	Model	Availability	Price
4- to 8-zone indoor controller ¹ (with two zones included in base price)	SL800	Currently available	\$110.20
4- to 16-zone residential controller ¹ (with four zones included in base price)	SL1600	Currently available	\$209.95
20-zone commercial controller ¹	SL1620	Currently available	\$577.45
24-zone commercial controller ¹	SL1624	Currently available	\$682.45
48-zone commercial controller ¹ (with 12 zones included in base price)	SL4800	Currently available	\$524.95
2-zone module for SL800	SLM2	Currently available	\$36.70
4-zone module for SL1600	SLM4	Currently available	\$62.95
12-zone module for SL4800	SLM12	Currently available	\$209.95
Two-wire decoder module	SLM16DM	Currently available	\$313.95
Two-wire decoder module	SLM24DM	Currently available	\$418.95
Two-wire decoder module	SLM48DM	Currently available	\$786.45
Two-wire decoder for one valve	SLDEC1	Currently available	\$126.00
Two-wire decoder for two valves	SLDEC2	Currently available	\$252.00
Two-wire decoder for four valves	SLDEC4	Currently available	\$357.00
Economy Onsite Weather Sensor	SLW1	Currently available	\$157.45
Wireless Weather Sensor, 900 MHz	SLW5	Currently available	\$367.45
Wireless Onsite Weather Sensor	SLW15	Currently available	\$367.45
SmartLink Aircard for GSM Cellular Network	SL-AIRCARD-GSM	Currently available	\$499.95
SmartLink Aircard for CDMA Cellular Network	SL-AIRCARD-CDMA	Currently available	\$599.95
SmartLink Aircard With Flow for GSM Cellular Network	SL-AIRCARDFLOW-GSM	Currently available	\$599.60
SmartLink Aircard With Flow for CDMA Cellular Network	SL-AIRCARDFLOW-CDMA	Currently available	\$699.90

Programming of the “Auto Adjust” ET portion of the controller requires inputs by zone for sprinkler type, plant type, soil type, and slope. Sprinkler type can be entered on a basic level by the user by selecting the type of sprinkler in a zone—“Spray,” “Rotor,” or “Drip.” A more advanced user can scroll past these basic inputs with default precipitation rates and prescribe an exact numerical precipitation rate for the zone from 0.2 to 3.0 inches per hour. Users will select the standard setting (“STD”) for zones not included in ET Auto Adjust watering. Plant type works similarly to the sprinkler type input in that the user can simply select the type of plant life in the zone—“Cool Turf,” “Warm Turf,” “Annuals,” “Shrubs,” “Native,” or “Trees.” Again, a more advanced user can scroll past these basic inputs with default percentages and prescribe an exact numerical percentage for the zone from 10 to 300% based on the plant life in the zone and sun/shade consideration. The soil type (“Clay,” “Sand,” and “Loam”) and slope (numerical degree of slope 1 to 25+ degrees) are used to automatically calculate the cycle/soak function by zone.

In addition to these inputs by zone, the user programs the Zip code of the site or, primarily for locations outside the United States, the latitude of the site. This input and the calendar day of the year are used to determine the solar radiation at the site, which is a variable in ET calculation. These static inputs are combined with the dynamic onsite weather monitor inputs to perform the overall equation that determines proper zone run times.

The SmartLine user has the ability to fine-tune the zone run times by zone through a “More/Less” function. This allows the user to increase watering by zone up to 25% or decrease watering by up to 50%.

The controller’s irrigation schedule is based on the user-prescribed irrigation days, start times, and omit times (dates, days, and times of day) so as to conform to local watering restrictions and also accommodate site-specific hydraulic issues that vary by time of day. Once programmed, the controller calculates ET for the period beginning at the end of the last irrigation cycle, or measurable rainfall, and ending at the next prescribed irrigation day. Irrigation will occur if the calculated deficit exceeds the minimum deficit setting. If sufficient demand has not been reached, irrigation will not occur, and the controller will carry over the accumulated ET to the next prescribed irrigation day and time. This accumulation threshold, which prevents ineffective irrigation, is calculated based on a default accumulation factor. SWAT testing on SmartLine is available for viewing at: www.irrigation.org.

Installation

Installation and programming of SmartLine controllers are designed to be simple and intuitive for both the novice homeowner and the advanced professional who are familiar with the unit’s industry standard programming dial. Advanced user functions are located in an “Advanced Menu” position on the programming dial

so as to not complicate the setup for novice users. While programming the unit is simple, Weathermatic recommends installation by a professional who will give the site the highest rate of success, not only for controller programming but also for complete system operations with an emphasis on water conservation. Based on Weathermatic's solid reputation and well-established support network, it appears the SmartLine controllers' technical support system is outstanding. Installation and programming instructions are available on Weathermatic's Internet site (<http://www.weathermatic.com/>), and a programming video and DVD are available to supplement the standard user manual.

Track Record, Water Savings, WaterSense Certification, and SWAT Testing

Weathermatic tested its Hargreaves equation-based ET calculation algorithm and controller functionality extensively for 8 years. For comparing ET calculations, CIMIS weather station reference ET values were compared to those using the Weathermatic controller/weather monitor methodology at 10 geographically diverse sites over a 7-year period for 70 years of combined data. Weathermatic reports good correlation between the CIMIS and Weathermatic ET data at all sites. The graph shown in figure 8 is one example that is representative of the study.

In addition to comparing the ET calculation, the Weathermatic SmartLine controllers were included in a field study performed by a Rocky Mountain Region Water Conservancy District. This 3-year study analyzed the Weathermatic controller's accumulated water output in comparison to actual ET (as measured by lysimeter), reference ET (ET degree calculated with onsite weather station data), and net plant watering requirements (PWR). The study results sample graph in figure 9 shows the Weathermatic unit watered consistent with plant demand.

The Weathermatic SmartLine controllers were also part of a field pilot program conducted by the Marin Municipal Water District. In this study, 13 controllers were installed at 7 sites to compare water usage in 2002 and 2003 to the base year usage in 2001. Weathermatic reports that, in 2002, sites installed with the Weathermatic ET controller saved 26%. In 2003, the water savings climbed to 32%. Based on documentation from this program submitted by Weathermatic, it appears that the Weathermatic controller performs well and yields significant water savings.

Irrigation Association SWAT test reports are posted for Weathermatic's controllers and they have received EPA WaterSense certification.

Weather- and Soil Moisture-Based Landscape Scheduling Devices

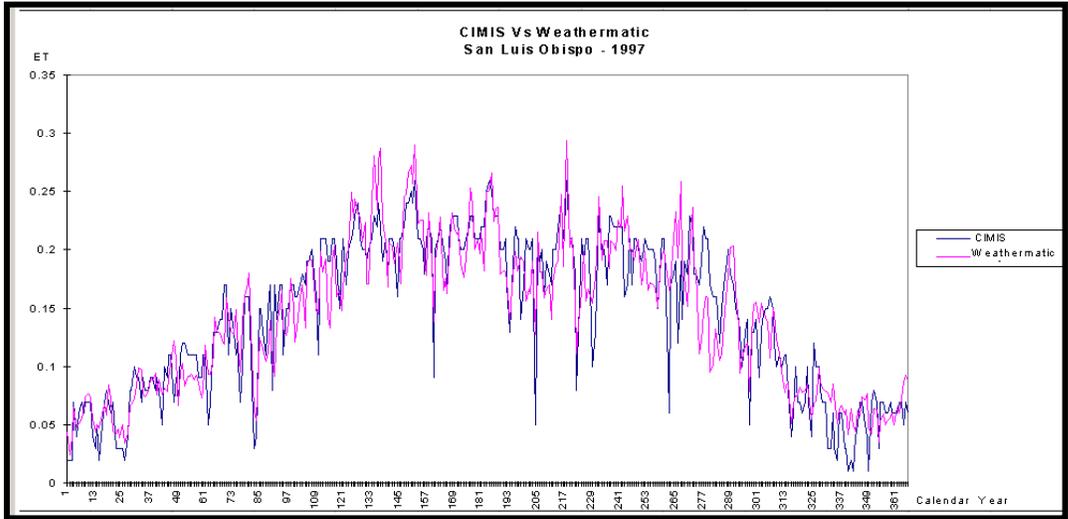


Figure 8.—Comparison of Weathermatic ET to CIMIS ET.

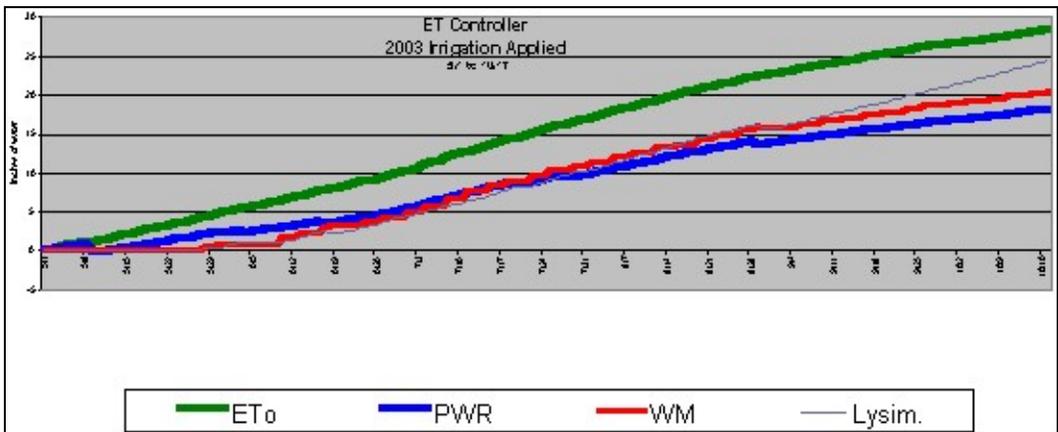


Figure 9.—Example of Weathermatic field study results.

Soil Moisture-Based Irrigation Control System Principles

All of the soil moisture-based products reviewed operate on the principal of scheduling irrigation as a function of soil moisture conditions measured onsite with one or more soil moisture sensors. The concept is for an appropriate amount of irrigation to occur when needed to maintain adequate soil moisture levels.

Landscape soil moisture conditions should be maintained such that root zone moisture levels are between field capacity and the wilting point. Field capacity conditions occur following irrigation or precipitation when the maximum amount of water is retained in the soil after seepage and surface drainage ceases. The wilting point occurs when soil moisture is depleted to the point at which plants wilt without recovery during the night. The soil moisture levels at which field capacity and wilting point occur are a function of soil characteristics.

Soil moisture is typically reported in terms of volumetric soil water content, or as soil tension. Soil moisture content is the ratio of the volume of water in the soil to the volume of void spaces between the soil particles, and is reported as a percentage value. Soil tension is a measure of the negative pore pressure that occurs in the void spaces (increasingly negative as the moisture level drops), and is reported as a negative pressure reading.

Most of the soil moisture-based products reviewed function such that a preset irrigation quantity is applied when the measured soil moisture level drops to a threshold point set by the user. Ideally, the irrigation quantity applied replenishes the soil moisture to field capacity with minimal surface runoff and seepage below the root zone (over-watering). Some of the products reviewed begin and end irrigation based on two preset thresholds; the first is set at a moisture level well above the wilting point and the second is set at near field capacity. One product adjusts run times based on soil moisture data. Most of the devices, however, do not automatically calculate total run times or cycle and soak times.

As with the weather-based products, some of the soil moisture-based systems include a stand-alone controller and others include an add-on device that works with an existing clock-type controller. Regardless of stand-alone versus add-on controller type, some of the devices control the irrigation of all zones based on measurements from one soil moisture sensor. Others control individual zones or groups of zones based on measurements from multiple sensors placed in representative zones.

In general, all of the soil moisture-based systems' operate similarly and comparison is more straight-forward relative to that of the weather-based systems. Most of the products possess similar components and features. All of the systems reviewed provide potentially effective methods for scheduling irrigation based on soil moisture sensing, which should result in water savings.

Several different types of soil moisture sensors are used with the systems reviewed. In recent years, significant technological advances have been made in the field of soil moisture sensors. In general, the accuracy of all types of sensors has improved and costs have gone down significantly for some types of sensors. However, all types of soil moisture sensors possess one or more inherent deficiencies that should be considered. Several types of sensors function based on the dielectric properties of the soil, which vary depending on the soil type. Hence, calibration of these devices is soil specific to varying degrees depending on the specific type of device. Specifically, a factory-calibrated sensor may not function accurately for certain soil types and should be field calibrated. Salinity or fertilizer content, as well as temperature, affect the measurement accuracy of some sensors. Certain tensiometer type sensors will not tolerate freezing temperatures and or require maintenance anytime the soil becomes exceedingly dry.

Soil Moisture-Based Control Product Features and Comparison Criteria

Significant product components and features are discussed below. The discussion identifies different methods used to achieve similar results by the various products and associated advantages and disadvantages.

Soil Moisture Sensor Types

Soil moisture sensors have been used for laboratory and outdoor testing purposes and for agricultural applications for over 50 years. There are many types of sensors, but only those used in the present generation of landscape irrigation scheduling systems are discussed.

Electrical Resistance Granular Matrix

This type of sensor consists of two electrodes embedded in a reference matrix material, which is confined within a corrosion-proof and highly permeable case. The matrix material includes gypsum to buffer against the effects of salts and fertilizer, but these sensors do not dissolve like gypsum block sensors. Soil moisture is constantly absorbed or released from the sensor as the surrounding soil moisture conditions change. As the soil moisture changes, the sensor moisture reacts as reflected by the change in electrical resistance between the electrodes. Reaction time, however, is relatively slow compared to some other types of sensors. As the moisture level increases, conductivity increases, and the sensor is calibrated to output the moisture level in terms of soil tension. Calibration is temperature- and soil-type dependent. This type of sensor has been used in agricultural and landscape applications for approximately 20 years, and their performance is well documented. They are relatively inexpensive, and their manufacturer reports a minimum useable life of 5 to 7 years.

Electrical Conductivity Probes

This type of sensor measures soil moisture by how well a current of electricity is passed between two probes (electrodes) that are inserted directly into the soil. As the soil moisture changes, the sensor moisture reacts as reflected by the change in electrical resistance between the electrodes. Reaction time is relatively fast. As the moisture level increases, conductivity increases, and the sensor is calibrated to output the moisture level in terms of volumetric soil water content by percentage. Since the probes have direct contact with the soil, there is no buffer against salt and fertilizer effects on the measured conductivity. These devices are sensitive to the spacing of the probes as well as being influenced by soil type, salts, and

fertilizers. Specifically, bent probes and improper calibration for soil type can result in poor performance. Also, fluctuations in salt and fertilizer levels can affect measurement accuracy/consistency.

Time Domain Transmissometry (TDT)

This type of sensor measures the time required for an electromagnetic pulse to travel a finite distance along steel rods or length of wire (wave guide), and the travel time is dependent of the dielectric properties of the soil surrounding the wave guide. As moisture increases in the soil, the pulse travel time decreases and the sensor's time signal is converted into a volumetric soil water content measurement by percentage. This technology, which evolved from and is similar to time domain reflectometry, provides high accuracy that is independent of low and moderate salt and fertilizer levels in the soil. The original time domain reflectometry type sensors were expensive and difficult to use. The recently developed time domain transmission devices are less expensive and more suitable for landscape irrigation applications. The manner in which a TDT signal is processed is unique to its manufacturer, and at least one manufacturer has patented its digital signal analysis process. The significance of the signal processing method, with regard to accuracy and consistency, is beyond the scope of this review; and it is recommended the reader research this matter as warranted.

Frequency Domain Reflectometry (FDR or Capacitance)

This type of sensor contains a pair of electrodes (either an array of parallel spikes or circular metal rings) which form a capacitor with the soil acting as the dielectric in between. The electrodes are inserted into the soil or in an access tube in the soil. An oscillating frequency is applied to the electrodes, which results in a resonant frequency, the value of which depends upon the dielectric constant of the soil. The moisture content changes the dielectric constant of the soil, thereby changing the resonant frequency. The change in frequency then is converted to a soil moisture measurement. FDR sensors, which operate at high frequency (greater than 20 megahertz), are relatively independent of soil salt and fertilizer levels. This type of sensor is especially sensitive to undisturbed soil contact. (See discussion of undisturbed soil contact under the "Installation" heading below.)

Tensiometers

This type of sensor measures the soil moisture tension, or negative pore pressure, as it changes with soil moisture content. Tensiometers operate by allowing the soil solution to come to equilibrium with a reference pressure indicator through a permeable ceramic piece that is in contact with the soil. A vacuum gauge measures the soil moisture tension, and high tension reflects low soil moisture. Tensiometers accurately measure wet soil moisture levels independent of salt and fertilizer levels but are less accurate for dry soils. They can require maintenance to refill the tensiometer with liquid and maintain the integrity of the soil/ceramic

tip interface. (This typically occurs only when the soil dries beyond the wilting point.) Some tensiometers must be removed from the soil during winter months in northern climates where the soil freezes.

Installation

All of the soil moisture system manufacturers recommend professional installation and programming of their commercial products and report that installation and programming of their residential models can be done by a nonprofessional. Based on discussions with third-party individuals with experience installing most of the reviewed residential models, it appears homeowner installation may not be a realistic option with certain products. The degree of difficulty to install any of the products can vary significantly depending on site-specific conditions. A significant factor is the soil moisture sensor wiring configuration. Some sensors are connected to the existing nearby valve wiring, and some must be connected to the controller with potentially long runs of new wiring. Wiring the sensors to the irrigation valves should be easy in most cases, but the ease of connecting to the controller depends on site-specific conditions (distance, obstacles, etc.). It is difficult to determine what percentage of homeowners successfully install and program the various residential products. Installation and programming instructions are available for some of the products at their Web sites. All potential customers should review this information when shopping for a device regardless of whether they plan to do their own installation and programming.

Additional installation issues to be considered are associated with the placement of the soil moisture sensor(s) in the root zone. A soil moisture sensor should be in contact with relatively undisturbed soil that is representative of the irrigated landscape. Contact with disturbed soil with a higher void space ratio may result in soil moisture readings that are not representative of the landscape. Some sensor types are more sensitive to this than others. Therefore, the sensor shape and method of placing the sensor with regard to undisturbed soil contact should be considered when comparing systems. Installation of the sensor may also result in disturbance of the turf root system and affect the health of the turf for a period following installation. This may cause the soil moisture in the vicinity of the sensor to be higher than typical due to reduced ET by the disturbed turf until it “heals.”

Stand-Alone Versus Add-On Controller

The controller component for most of the soil moisture products reviewed is an add-on device that works with an existing clock type controller. The other products include a stand-alone controller with many of the features of typical

clock type controllers. In some cases, the cost of the add-on device is a significant attraction. Regardless of cost, the quality of an existing controller should be a factor when considering replacement with a stand-alone control device. If the existing controller is a high quality unit with adequate features, an add-on device may be an attractive alternative.

The primary stand-alone controller features which should be considered include: automatic scheduling, number of programs and start times, cycle and soak, master valve circuits, compatibility with other sensors (rain, flow, temperature, wind, etc.), remote control, and system testing capabilities.

Irrigation Schedules and Run Time Calculation and Adjustment

Most of the devices reviewed do not automatically calculate irrigation run times, although some adjust user-entered run times based on soil moisture measurement data or control run times with on and off soil moisture thresholds. None of the soil moisture sensor devices automatically calculate cycle and soak times. Some manufacturers (stand-alone and add-on) provide guidelines or computer programs to assist the user in calculating total run times and cycle and soak times. The product descriptions identify the manufacturers that provide guidelines or computer programs for determining appropriate run times and cycle and soak times.

Single Versus Multiple Soil Moisture Sensors

Most of the residential systems reviewed use one soil moisture sensor to control operation of the entire system, and varying zone conditions are accommodated for by adjusting run times. For complex residential landscapes and commercial systems, some systems have the capacity to use multiple sensors to control a single valve or groups of valves. For complex systems, the user should consider the sensor capacity of the controller. In some cases, multiple controllers with single sensor capacity can be used to build a multiple sensor system. Some of the multiple sensor controllers allow for bypassing the soil moisture control mode and running in clock mode by station. All of the products reviewed will allow for system-wide clock mode operation.

Soil Temperature and Conductivity Measurement and Display

Some of the sensors included with the products reviewed measure soil temperature and conductivity in addition to soil moisture. Soil temperature is necessary for calibration of the soil moisture measurement by certain types of

sensors. Some of the controllers allow for display of the temperature and conductivity measurements. Display of the conductivity measurements is a significant feature for users irrigating with wastewater effluent or water that contains high levels of salts in order to know when to flush the soil. When the user is informed that the salt levels in the soil have reached a critical point based on the conductivity readings, the landscape should be irrigated heavily to leach (flush) the salts to below the root zone.

Soil Moisture Sensor Accuracy and Calibration

As previously discussed, the measurement of soil moisture by some sensors is affected by soil type, temperature, and salinity. All of the sensor products reviewed are factory calibrated to measure moisture content for a spectrum of soil types. The manufacturers typically report a level of accuracy that is good for a range of soil types. In some cases, the accuracy may vary significantly for the different soil types. Also, the accuracy may be inconsistent for different moisture, temperature and salinity levels.

For the purpose of landscape irrigation scheduling, the consistency of a sensor is as important as, or more so than, its accuracy. For practical purposes, the user of a sensor-based landscape irrigation control system typically performs a quasi-calibration of the sensor during setup. This is accomplished when the user observes the moisture level reading that occurs with the soil at field capacity. Regardless of the accuracy of the reading, the user typically sets the irrigation trigger moisture level as a percentage of the field capacity reading. If the sensor does not read consistently, the percentage relationship between field capacity and the irrigation trigger will be affected. As an example, if a sensor reads 36% at field capacity and the user wants to set the irrigation trigger at 50% of field capacity, the controller would be set to irrigate at a reading of 18% if the sensor reads consistently. If the sensor does not read consistently, the controller would need to be set to irrigate at a reading higher or lower than 18%.

Power Supply and Surge and Lightning Protection

Most of the controllers and devices operate on 24 VAC, and few are battery powered. The stand-alone devices typically include a power transformer that converts 110-120 VAC to 24 VAC. The transformers are either hardwired inside the controller cabinet (internal) or plugged into a power outlet (external). The add-on scheduling devices that operate on 24 VAC either receive power from the existing clock/controller or from an external transformer. Most of the transformer devices include some type of current overload protection such as a fuse or breaker switch. Some of the controllers include lightning and/or surge protection or offer

these as an optional feature. Surge and lightning protection limits damage to the controller's circuitry from transient voltage and current from the power source (surge) and from the valve circuits (lightning).

Station Circuit Rating, Wiring, and Terminal Wire Sizes

The compatibility of the existing electrical circuits (wiring from the controller to the station valves) should be considered in selecting a stand-alone controller. If the station wire terminals on the controller will not accept the existing wire, adapters must be used. Also, the circuit current capacity required for an existing system should be checked prior to installing a new unit. Installation problems associated with insufficient circuit capacity to operate some irrigation valves with high circuit resistance are a possibility.

The traditional wiring system (circuitry) used for most controllers consists of a common and a dedicated wire from the controller to each valve and sensor. Some controllers utilize "two-wire" circuitry that consists of a single pair of wires connected to all of the valves and sensors in the system. These systems require the installation of a decoder device for each valve and sensor. Applications include large systems and linear systems (e.g., highway corridors) with large quantities of wiring required for traditional circuitry.

Warranties and Reliability

All of the products reviewed include a warranty. Warranty details are discussed in the product descriptions section. In some cases, the manufacturers' warranty periods vary for its different products. Although the warranty periods may or may not be indicative of the life expectancy of the products, some cases there appears to be a correlation between the cost and overall quality of the product to the warranty period. It is assumed the cost of a product somewhat reflects the quality of the construction materials and electronic components. Hence, the less expensive residential devices should not be expected to last as long and function as reliably as the more expensive residential and commercial products. Since most of the devices are relatively new products, it is difficult to speculate on how long they should last.

Soil Moisture-Based Product Descriptions

The following product descriptions address operational characteristics and features and include discussions of available information from demonstration and pilot studies relative to documented water savings and operation. Each of the manufacturers was provided copies of the product descriptions for input prior to being incorporated into this report.

Acclima

Acclima, Inc. (Acclima), of Meridian, Idaho, manufactures soil moisture sensor-based landscape irrigation control systems and soil moisture sensor based research equipment. Acclima began developing its landscape irrigation system components in 1997, and these products entered the market in 2003. Acclima's sensor technology is sold throughout the United States, Europe, South Africa, Asia, and Australia.



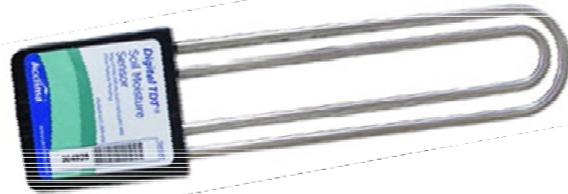
Acclima Closed Loop Irrigation[®] systems are governed by real-time root zone soil moisture content as measured by its patented Digital TDT[®] absolute soil moisture sensor. The Acclima sensor is the industry's only digital process time domain transmissometry soil moisture sensor. Acclima reports its digital process sensors measure the absolute soil moisture content regardless of changing soil types, electrical conductivity, and temperature. All systems accommodate one or more soil moisture sensors and either an add-on or stand-alone controller. Controllers suitable for all residential and commercial applications are available.

Sensor Description and Operation

The heart of all Acclima irrigation systems is the sensor. The sensor dimensions are 8 by 2 by 0.5 inches and is constructed of Type 304 stainless steel rods and electronic components embedded in moisture-resistant epoxy resin, molded in heavy duty plastic. Sensor rods are electrically isolated from the circuit board to prevent galvanic corrosion, and each sensor includes lightning protection. Sensors are buried in the soil among the active rootlets of turf, trees, and shrubs. The sensor reports the moisture content to the controller via the same wiring used

for valve control in resolution of tenths of 1%. A typical residential installation employs one sensor. Commercial systems typically use multiple sensors—one for each microclimate or landscape vegetation type. Various zones may be programmed to track any sensor.

Acclima reports that its patented Digital TDT sensor is unique because it provides *absolute* percentage volumetric water content whereas other sensors provide only *relative* moisture data. The sensor generates a



unique high frequency pulse along the sensor rods with a sampling interval of 5 picoseconds—the time required for light to travel 1.5 millimeters. This high-speed sampling minimizes the dielectric relaxation properties found in clay soils. Acclima reports this characteristic, combined with its patented digital analysis process, produces superior stability and accuracy in all soil types. The Acclima sensor can detect the addition of 0.002 inch of water to 4 inches of soil, yielding maximum water savings. Upon installation, the soil surrounding the sensor is doused to saturation and then allowed to percolate to field capacity. A sensor reading is taken at this time to determine the unique field capacity of the microclimate, and the irrigation threshold is calculated.

All Acclima irrigation controllers use the Digital TDT sensor as a “closed loop” feedback mechanism in controlling the irrigation process. The controller polls the sensor for accurate soil moisture readings; if the sensor returns a reading below the irrigation threshold, the system will intelligently replace only the amount of moisture lost through ET since the last irrigation cycle. Thus, root zone moisture levels are perpetually maintained at user-specified levels, resulting in optimized economy and healthier landscapes.

Controller Description, Prices, and Warranty

Acclima offers a variety of control devices suitable for any application. All stand-alone Acclima controllers allow multiple sensors with highly flexible programming. On all models, volumetric soil moisture content is displayed from 0 to 100%. Soil temperature is displayed in degrees Fahrenheit or Celsius, and soil conductivity in dS/m (10^{-1} siemens per meter).

Acclima’s Suspended Cycle[®] systems are programmed just as a standard irrigation clock. When the programmed time arrives, the system polls the sensor to see if irrigation is allowed. If not, the cycle is suspended; if water is required, irrigation takes place. Acclima’s Water on Demand[®] systems require no programming whatsoever. The user enters the irrigation threshold, specifies times when irrigation is *not* allowed, and the system irrigates only as needed without any programming.

Weather- and Soil Moisture-Based Landscape Scheduling Devices

The Acclima SC24 and SC36 controllers are stand-alone suspended cycle control units for between 24 and 36 zones.

The Acclima SC24/36 controller uses traditional valve wiring with four available programs and six start times. Each controller accommodates as many sensors as it has zones, and each sensor adds a new program to the controller. For multiple sensor setup, each sensor is connected to the valve for each reference zone, and sensor readings are transmitted to the controller via the valve wiring. Zones without sensors are assigned to a reference zone, and irrigation occurs based on the soil moisture measured in the reference zone. Unique soil moisture thresholds may be programmed for each reference zone.

The controller may be operated in automatic soil moisture based timer, or manual modes. Up to four zones, plus a master valve circuit, may run concurrently, dependent on system water volume capacity. Multizone watering may be configured per zone based on the water usage of that zone versus available water. This may be done automatically when a flowmeter is attached to the system, or the configuration can be adjusted manually at any time. These controllers support rain, wind, and freeze sensor inputs to shut off the water when weather does not permit irrigation. Flowmeter support checks for broken pipes and valves. Connection of a flowmeter requires an interface device manufactured by Acclima.

The controller's calendar/clock automatically compensates for leap years. The clock can be maintained for up to 2 months without power using two AA alkaline batteries. The nonvolatile program memory maintains configuration information even if the power fails and the batteries are dead. Watering day schedules include "Custom," "Every Day," "Odd Day," "Even Day," "Every nth Day" watering (where "n" may range from 3 to 31). Zone stacking ensures that all zones will eventually be watered even though program start times may overlap. Other features include soak/cycle, valve circuit test, programmable pause, rain delay (0 to 14 days) and water budget adjustment (5 to 500%). Remote control is available with optional hand-held radio and interface devices.

The controller cabinet measures 12.3 by 10 by 5.9 inches and is weather-resistant extruded ABS plastic, suitable for outdoor installation. The internal power transformer includes an over-under detector that automatically detects loads exceeding 2.1 amperes and an overload backup fuse (slow-blow, self-healing fuse: 2.5 A). Station circuit capacity is 0.6 ampere. The controllers possess surge and lighting protection consisting of the following:

Input:	Transient voltage suppressor (TVS)
Common Wires, Signal Ground:	5,000-ampere gas discharge tube to earth ground
Each Terminal:	Metal oxide varistor (MOV)
Earth Ground Terminal:	Up to #6 copper wire to divert surges to ground

The Acclima CS 3500 controller is a Water on Demand device, operating over a two-wire communications line, saving copper, and allowing flexibility for system modification. Up to 60 sensors may be used with this 64-zone system. The controller operates without programming. The user identifies blocks of time when irrigation is restricted and sets an upper and lower irrigation threshold. Water is applied when the sensor reports moisture below the lower threshold and will irrigate until the upper threshold is reported.

The two-wire circuit requires valve adapters (decoders) to establish the two-wire communications bus to valve interface. These adapters contain electronic switches that apply power to the solenoid valves upon command from the controller. Acclima sensors also contain a single electronic switch so there is no need for a valve adapter when a sensor is installed in the valve circuit.

The CS3500 offers features similar to the Acclima SC Series and has central control capabilities using the Acclima Irrigation Manager™ software and advanced communications capabilities through serial cable, dial-in modem, cellular phone, or radio communications. The clock can be maintained for up to 10 years without 24-volt power using a CR2032 battery. The CS3500 cabinet is the same size and material as the SC24/36 and is suitable for exterior mount. Surge and lightning protection are also similar to the SC24/36.

Prices for selected Acclima products are summarized in table 14. Acclima products may be purchased through distribution by referring to the Acclima Web site at: www.acclima.com. Acclima products carry a 2-year warranty.

Table 14.—Acclima Product Prices

Description	Model No.	Price
SC24 Commercial Controller	ACC-SYS-SC24	\$1,097
SC36 Commercial Controller	ACC-SYS-SC36	\$1,497
CS 3500 Commercial Controller	ACC-SYS-WD64	\$2,997
Digital TDT Soil Moisture Sensor	ACC-SEN-TDT	\$197
Flowmeter Interface	ACC-FPM-015	\$600

Acclima also offers products for soil scientists and researchers including an SDI-12 format TDT sensor which connect to Acclima’s DataSnap portable data logger or to any other data logger that works in the SDI-12 protocol.

Installation

Detailed installation instructions, manuals, and videos are available on the Acclima Web site at: www.acclima.com. Acclima recommends professional installation of the SC24, SC36, and CS3500 control systems.

Track Record, Water Savings, and SWAT Testing

The accuracy of Acclima's Digital TDT soil moisture sensor is well documented by independent laboratories, and their patented irrigation systems have been tested and researched by numerous academic institutions. Acclima's sensor technology was first evaluated by the Center for Irrigation Technology in 2003. Since then, dozens of independent university studies have validated unprecedented savings of water and fertilizer. Acclima reports average water savings are approximately 30 to 40% in arid climates; savings increases with higher annual rainfall. Acclima submitted their technology for independent verification before placing their products on the market. Testing entities include the following:

- ◆ University of Arkansas
- ◆ Oregon State University
- ◆ University of Florida
- ◆ Utah State University
- ◆ New Mexico State University
- ◆ University of Tennessee
- ◆ Brigham Young University
- ◆ California State University, Fresno

Information on the above testing and research and certain study report documents are available on Acclima's Web site.

SWAT calibration test reports for Acclima's Digital TDT and ACC-SEN-TDT sensors were posted in 2008 and 2009, respectively.

Baseline

Baseline, LLC (Baseline), located in Boise, Idaho, designs and manufactures soil moisture sensor-based landscape irrigation control systems. Baseline began business in 1998, and its first soil moisture sensing products entered the market in 2002. Its systems include add-on and stand-alone controllers, as well as centralized control systems. Baseline reports its products are easy to use and require minimal administration time.



Baseline's biSensor™ soil moisture sensors actually measure the moisture level in the soil, and the Baseline controllers use this information to manage the frequency of irrigation. Irrigation is allowed after the soil dries to a pre-determined moisture threshold. A regular irrigation schedule is programmed into the controller and, when the soil moisture measurement read by the sensor drops below the moisture threshold, the controller runs the irrigation program.

Sensor Description and Operation

The biSensor™ comes in two models: a 6-inch rigid sensor used with the WaterTec S100 soil moisture monitor and a 14.95-inch rigid sensor used with the other Baseline controllers. The biSensor measures the volumetric soil moisture content in the root zone and transmits soil moisture and temperature information to the controller via the same wiring used for valve control. A single sensor can control multiple irrigation zones. A typical residential system includes just one sensor. A commercial system may use numerous sensors associated with various microclimates or landscape types. Baseline recommends installation in a V-shaped trench to minimize soil disturbance where contact is made to the sensor. The biSensor is constructed of corrosion-resistant fiberglass and is expected to last 25 years in the soil, regardless of climate.

Baseline's soil moisture sensors work by sending a high frequency pulse of electricity down an embedded wire path. The high frequency of the pulse causes the sphere of influence of the pulse to move outside the sensor blade and into the soil around it. When the pulse travels through moisture, it slows down. The sensor measures the speed, and then converts this measurement to a moisture content reading. The biSensor can reliably track less than 1/10th of a percent of change volumetrically. Baseline's biSensor readings are not affected by salts and temperature changes. All sensor-related electrical components are insulated from the soil, including the actual sensing elements.



Baseline's stand-alone controllers can be linked to a computer network through a variety of wired and wireless communications. Baseline's BaseManager 2.0 central control allows users to manage an unlimited number of controllers remotely over the Internet from a computer, iPad, or even a telephone. BaseManager users can do everything they would normally have to do at the controller from the convenience of their Internet-connected device.

Controller Descriptions, Prices, and Warranty

Baseline's controllers include one add-on model and two stand-alone models. The stand-alone controllers use two-wire valve control wiring, conventional valve wiring, or a combination of two-wire and conventional wire. The add-on unit has a single biSensor and works with just about any existing irrigation timer. Multiple biSensors can be connected to Baseline's stand-alone controllers. The soil moisture reading for all controllers is displayed as volumetric water content from 0 to 100%. The biSensor monitors the soil moisture and, when the configured threshold is met, the system can be set to either turn on the irrigation at the next scheduled start time or shut off the irrigation. Baseline's stand-alone controllers can use either the lower threshold or the upper threshold sensor-based watering strategies. The WaterTec S100 uses the lower threshold watering strategy. When using the lower threshold watering strategy, the sensor only allows irrigation when the soil has dried out to a level at, or below, the threshold. With upper threshold, you can choose which day and what time of day to start watering and the sensor will shut off watering when soil moisture reaches the upper threshold.

The Baseline WaterTec™ S100 soil moisture monitor is an add-on device for use with an existing clock/controller and a single biSensor. The S100 monitor is constructed of heavy-duty water-resistant plastic and is appropriate for exterior installation. Its dimensions are 4.6 by 2.6 by 1.5 inches, and it has a three-character, one-line LCD display and touchpad-type controls. The S100 comes with a 6-inch biSensor soil moisture sensor.



Guidelines for performing a site audit and determining appropriate total run times and soak and cycle times are included with the WaterTec S100.

The BaseStation 3200 V12 is a stand-alone commercial controller supporting up to 200 zones in any combination of two-wire and conventional wire. Up to 25 biSensor moisture sensors per controller can be connected directly to existing valve lines for existing (or new) sites. Conventional wire boards can be added to the BaseStation 3200 V12 in order to expand the conventional wire capacity. The BaseStation 3200 V12 supports up to 99 separate programs with up to 8 start times per program. For sensor-based watering, the user selects the watering strategy and programs the schedule. The total run times are adjusted by the controller based on its evaluation of soil moisture data. (Guidelines are provided for determining an appropriate base schedule.) Other features include day interval calendar, event scheduling, self-test diagnostics, and adjustable soak cycles.

Users can manage the BaseStation 3200 V12 controller remotely with BaseManager 2.0. The BaseStation 1000 control panel has a high contrast 3.5-inch color LCD screen, an option selection dial, and programming buttons.

The BaseStation 1000 is a stand-alone commercial controller supporting up to 100 zones in any combination of two-wire and conventional wire. Up to 20 biSensor moisture sensors per controller can be connected directly to existing valve lines for existing (or new) sites. Conventional wire boards can be added to the BaseStation 1000 in order to expand the conventional wire capacity. The BaseStation 1000 supports up to 40 separate programs with up to 8 start times per program. For sensor-based watering, the user selects the watering strategy and programs the schedule. The total run times are adjusted by the controller based on its evaluation of soil moisture data. (Guidelines are provided for determining an appropriate base schedule.) Other features include day interval calendar, event scheduling, self-test diagnostics, and adjustable soak cycles. Users can manage the BaseStation 1000 controller remotely with BaseManager 2.0. Memory expansion modules are required to support maximum device and program totals and to fully support BaseManager 2.0 features. The BaseStation 1000 control panel has a high contrast 3.25-inch backlit mono LCD screen, option selection buttons, and programming buttons.

The BaseStation 3200 V12 and BaseStation 1000 are available in indoor/outdoor wall mount cabinets or an outdoor pedestal. The small wall mount cabinet is constructed of powder-coated steel, and its dimensions are 12 by 10 by 4.75 inches. The large wall mount cabinet is constructed of either powder-coated steel or stainless steel, and its dimensions are 15.5 by 12 by 6 inches. The pedestal is constructed of stainless steel and its dimensions are 36 by 17 by 12.6 inches.

Current suggested retail prices for Baseline products are summarized in table 15. Baseline products are available from its distributors, and a distributor list is available at the Baseline Web site at: www.baselinesystems.com. All Baseline products have a 5-year warranty.

**Weather- and Soil Moisture-Based
Landscape Scheduling Devices**

Table 15.—Baseline Product Suggested Retail Prices

Description	Model No.	Price
WaterTec Add-On Soil Moisture Monitor	S100	\$149*
200-Zone Stand-Alone Controller in a Small Wall Mount Cabinet	3200C	\$2,300
200-Zone Stand-Alone Controller in a Large Wall Mount Cabinet	3200X	\$2,400
200-Zone Stand-Alone Controller in a Pedestal	3200P	\$4,400
200-Zone Controller With 12-Station Conventional Wire Board in a Small Wall Mount Cabinet	3200C-R12	\$2,575
200-Zone Controller With 24-Station Conventional Wire Board in a Small Wall Mount Cabinet	3200C-R24	\$2,850
200-Zone Controller With 36-Station Conventional Wire Board in a Large Wall Mount Cabinet	3200X-R36	\$3,225
200-Zone Controller With 48-Station Conventional Wire Board in a Large Wall Mount Cabinet	3200X-R48	\$3,500
200-Zone Controller With 12-Station Conventional Wire Board in a Pedestal	3200P-R12	\$4,675
200-Zone Controller With 24-Station Conventional Wire Board in a Pedestal	3200P-R24	\$4,950
200-Zone Controller With 36-Station Conventional Wire Board in a Pedestal	3200P-R36	\$5,225
200-Zone Controller With 48-Station Conventional Wire Board in a Pedestal	3200P-R48	\$5,500
50-Zone Stand-Alone Controller in a Small Wall Mount Cabinet	1000C	\$1,150
50-Zone Stand-Alone Controller in a Large Wall Mount Cabinet	1000X	\$1,250
50-Zone Stand-Alone Controller in a Pedestal	1000P	\$3,250
50-Zone Controller With 12-Station Conventional Wire Board in a Small Wall Mount Cabinet	1000C-R12	\$1,425
50-Zone Controller With 24-Station Conventional Wire Board in a Small Wall Mount Cabinet	1000C-R24	\$1,700
50-Zone Controller With 12-Station Conventional Wire Board in a Large Wall Mount Cabinet	1000X-R12	\$1,525
50-Zone Controller With 24-Station Conventional Wire Board in a Large Wall Mount Cabinet	1000X-R24	\$1,800
50-Zone Controller With 36-Station Conventional Wire Board in a Large Wall Mount Cabinet	1000X-R36	\$2,075
50-Zone Controller With 48-Station Conventional Wire Board in a Large Wall Mount Cabinet	1000X-R48	\$2,350
50-Zone Controller With 12-Station Conventional Wire Board in a Pedestal	1000P-R12	\$3,525
50-Zone Controller With 24-Station Conventional Wire Board in a Pedestal	1000P-R24	\$3,800
50-Zone Controller With 36-Station Conventional Wire Board in a Pedestal	1000P-R36	\$4,075
50-Zone Controller With 48-Station Conventional Wire Board in a Pedestal	1000P-R48	\$4,350

Description	Model No.	Price
BaseStation1000 Expansion Module (expands to support +25 zones, +10 programs, +5 soil moisture sensors, +1 MV/flow sensor/pump, +1 pause device)	1000-MEXP-25	\$275
BaseStation1000 Expansion Module (expands to support +50 zones, +20 programs, +10 soil moisture sensors, +2 MV/flow sensor/pump, +2 pause devices)	1000-MEXP-50	\$525
BaseStation1000 Expansion Module (expands to support full BaseManager 2.0 functionality)	1000-MEXP-BM	\$350
biSensor Soil Moisture Sensor (1.5-foot)	5315B	\$249
biCoder Two-Wire Valve Adapter (single zone)	5201	\$144.38
biCoder Two-Wire Valve Adapter (two-zone)	5202	\$202.13
biCoder Two-Wire Valve Adapter (four-zone)	5204	\$283.50

*Price includes biSensor.

Installation

Although Baseline recommends installation by a landscape professional, it reports that the WaterTec S100 can be installed by most homeowners. The reported average homeowner installation time is about an hour. Even though the BaseStation 3200 V12 and BaseStation 1000 are reported to be less labor intensive to install than the majority of industry smart controllers, Baseline recommends that these systems be installed by a landscape professional.

Track Record, Water Savings, and SWAT Testing

The Portland Water Bureau implemented a 3-year Soil Moisture Sensor Pilot Study to investigate the ability of soil moisture sensor-based irrigation controllers to decrease the amount of water used for irrigation at landscape sites in Portland, Oregon. The study was also designed to determine whether soil moisture sensor-based irrigation works as well as weather-based controllers that require third-party communication.

The Portland Water Bureau selected Baseline's soil moisture sensors (biSensors) and BaseStation 3200 irrigation controllers to enable soil moisture sensor-based irrigation. At one small study site, a Baseline WaterTec S100 was installed to connect a biSensor to an existing irrigation controller. Baseline equipment was selected for use in this study due to its ability to work with the existing field wiring irrigation, its accuracy, reliability, and advanced features like remote communication and flow monitoring.

In their Project Summary of the Soil Moisture Pilot Program, the Portland Water Bureau states,

“This study concluded that this particular soil moisture sensor-based irrigation product is more efficient than traditional automated methods. The less expensive WaterTec S100 system still provided substantial water savings, and it would be cost effective for many small to medium commercial landscape sites.”

SWAT calibration test reports for Baseline’s S-100 and BL-5315B sensors were posted in 2010.

Calsense

As discussed in the “Weather-Based Product Descriptions” section of this report, Calsense® manufactures water management systems for large commercial customers. The Calsense Model 1000-S soil moisture sensor measures and transmits soil moisture readings to a Calsense ET2000e irrigation controller to provide efficient landscape irrigation. The ET2000e will automatically suspend irrigation when the soil moisture level is above the threshold set by the user. A full description of the ET2000e and its features are included in the Calsense discussion in the “Weather-Based Product Descriptions” section of this report.



Sensor Description and Operation

The 1000-S is a solid-state tensiometer-type soil moisture sensor that provides consistent long-term soil moisture readings to the Calsense irrigation controller. The moisture sensor electronics are encased in epoxy, and the sensor is constructed of heavy-duty plastic. There is no maintenance or calibration required for the life of the sensor. The 1000-S readings are unaffected by temperature, salinity, or changes in soil pH. The sensor’s dimensions are 6.4 by 1.9 by 1.6 inches.

The 1000-S is installed in the root zone and is connected to the valve that controls the area where the sensor is located. Soil moisture data are transmitted to the irrigation controller via the valve control wiring, so special wire runs between the irrigation controller and the sensor are not necessary. The only additional wiring required is between the valve and the 1000-S sensor. The total combined maximum wire run between the moisture sensor and the irrigation controller is

3,000 feet. Calsense reports that maintenance of the 1000-S is only required when the soil becomes extremely dry, requiring the device be removed and soaked and then placed into moist soil. If the soil freezes, removal is not required.



The Calsense ET2000e controller, using the sensor to measure available water in the pore space of the soil, makes a decision before the start of each cycle/soak run whether or not to apply water. This decision is based on the actual moisture reading compared to the user-input moisture set point. Total run times and cycle and soak times are included in the base program entered by the user, based on field knowledge and soil moisture content for the time of year.

A 1000-S is connected to a representative station for each different climatic and plant material zone, which is defined as a primary station. Secondary stations are stations without sensors and are assigned to a primary station that shares similar water requirements. The user chooses groups of stations controlled by the same sensor during initial setup. Stations can be easily changed or moved from one sensor to another through user-friendly programming. Calsense recommends a general guideline of one moisture sensor per four active valves to cover varying moisture needs. Up to one soil moisture sensor per every valve may be connected using the ET2000e controller.

Controller Description, Prices, and Warranty

The 2000e features are discussed in more detail under the Calsense portion of the “Weather-Based Product Descriptions” section of this report.

Calsense products are available from many distributors located throughout the United States. A list of these distributors is available from Calsense upon request (800-572-8608 or www.calsense.com). The current retail price for the 1000-S is \$210. It has a 5-year warranty. The price range for the various ET2000e models is from \$1,050 to \$3,925, as detailed in the Calsense discussion in the “Weather-Based Product Description” section of this report. Calsense provides technical support at no charge to assist in the proper installation of the moisture sensors for the most efficient system.

Installation

Calsense recommends professional installation of the ET2000e, and installation time varies significantly depending on site conditions.

Track Record, Water Savings, and SWAT Testing

Although Calsense has not participated in any outside studies or demonstration projects, its track record speaks for itself. During Calsense's 23 years of existence, they have developed a large database on its products' performance and customer success.

Dynamax

Dynamax, Inc. (Dynamax), manufactures a wide variety of products used for plant science research, including sap flow systems for measuring real-time plant water use. Dynamax's focus is on new technologies and applications for plant science research, including water balances, irrigation scheduling, crop management, plant stress, water use efficiency, remediation, or environmental science. If interested in plant-water relations, Dynamax can supply all equipment needs and help manage your plants more efficiently. Dynamax is located in Houston, Texas, and has been in business for 25 years. Distribution of its soil moisture-based landscape irrigation control systems began in 1999.



Dynamax offers the GP-1 and GP-2 Data Logger/Irrigation Monitors. Both devices offer numerous applications, including use as stand-alone or add-on landscape irrigation scheduling devices.

Sensor Description and Operation

The SM150 is a frequency domain reflectometry (FDR)-type of dielectric sensor that measures volumetric soil moisture content from 0 to 60 with a Dynamax reported 3% accuracy. The SM150 soil moisture sensor consists of a waterproof housing that contains the electronics and two sharpened stainless steel rods that are inserted into the soil to minimize disturbance. Each SM150 is adjusted during manufacturing to provide a consistent output when measuring media of known dielectric constant, making them readily



interchangeable without any system recalibration. Specifically, Dynamax reports soil temperature effects and low-to-moderate salt and fertilizer effects are negligible. The overall length of the sensor is 5.4 inches with the rods being 2.5 inches. The SM150 can be inserted with little force into soils or artificial substrates and preserves the soil structure around the measurement rods for accurate representative readings.

The ML3 Theta Probe is Dynamax's newest and most durable sensor out there on the market. Regarded as Dynamax's gold standard performance sensor, it is also the most reliable with an accuracy of 1 to 2% for soil moisture and for temperature, 0.5%. With the addition of a thermistor sensor, it allows for the possibility of logging soil temperature with soil moisture simultaneously. The cabling system makes it simple to extend or replace cables and the white body allows for the reduction of radiative heating effects. With improvements to the sensor calibrations, the ML3 now has a wider salinity range by 25%, which makes it the ideal moisture sensor for any application.



Controller Descriptions, Prices, and Warranty

As a stand-alone controller, the GP1 can be programmed to initiate continuous irrigation at a prescribed soil moisture level and then discontinue irrigation at a second soil moisture level. This is best suited for precision irrigation applications and/or drip irrigation systems. As an add-on device, irrigation frequency and total run times are controlled automatically by utilizing the two soil moisture level set points. When the soil moisture drops to the first trigger, irrigation run and soak cycles are initiated. The cycles are discontinued when the second soil moisture level is measured. With the GP1 connected to a clock controller, it will control and regulate all valves with one SM150 sensor or two



groups of valves with two to four sensors. Up to 10 valves may operate simultaneously, and multiple GP1 units can be used to control individual valves or groups of valves as with the other devices.

One to four SM150 or ML3 Theta probe soil moisture sensors may be connected to the GP-1, and it has terminals for up to two temperature sensors, a flow sensor, and a rain gauge. It also has a terminal for connection of an external alarm mechanism. The GP1 has several unique features, including two soil moisture level thresholds for irrigation on and off.

The GP1 is constructed of polycarbonate and ABS plastics and is suitable for outdoor installation. Its dimensions are 5.5 by 4.1 by 1.8 inches. The GP1 operates on 11- to 24-VDC power from batteries (alkaline or lithium) or an external transformer. Approximately 6 feet of minimum 12-gauge wire is required to connect the GP-1 to the existing controller. The GP-1 is programmed using a personal computer or a personal digital assistant (PDA) device. Programming software is included with the GP-1, and an optional PDA and PDA kit is available.

The GP2 is Dynamax's newest data logger that was just recently introduced to the market with the storage capacity of 2.5 million readings. This powerful and rugged data logger is compatible with all of Dynamax's sensors and has 12 differential (or 24 single-ended) channels, making it ideal for demanding research applications and field work. One to twelve SM150 soil moisture sensors may be connected to it, or up to six ML3's as the terminal capacity allows for six different temperature sensors and four pulse counters. A new addition to this data logger is that it can control six different irrigation zones. It can log most sensor types and accepts voltages, resistance, current, potentiometer, bridge, counter, frequency, and digital state inputs. The analog outputs can be fully customized with each channel having its own input type and recording parameter. The software now includes a "Script Editor," which provides exceptional flexibility in defining control conditions ranging from simple thresholds to sophisticated calculations. The GP2 also comes with a unique "Program Simulator" function that allows logging programs to be tested before real world activation. The dimensions are 8.9 by 7.3 by 3 inches.

Current retail prices for Dynamax soil moisture sensor based irrigation control products are summarized in table 16. Dynamax products may be ordered directly by contacting the sales department through their Web site (www.dynamax.com) or toll-free telephone (800-896-7108) and through its distributors and irrigation design consultants. A distributor search engine is also available at its Web site. Dynamax provides a 1-year warranty with its soil moisture sensor control systems.

Table 16.—Dynamax Products Retail Prices

Description	Model No.	Price
GP1 Data Logger ¹	GP1	\$760
GP2 Data Logger ¹	GP2	\$2,195
Soil Moisture Sensor	SM150	\$235
Theta Soil Moisture and Temperature Sensor	ML3	\$460
Portable Theta Soil Moisture Meter	TH2O	\$1,225
Soil Temperature Probe	ST3	\$102

¹Price includes one soil moisture sensor, 82-feet of cable, and owner's manual.

Installation

Dynamax data loggers and soil moisture sensors are easy to install and maintain. Both the GP1 and GP2 data loggers are self-contained and have their own integral enclosures and power supplies. Batteries typically last up to 9 months, but external batteries and solar panels may also be used. Optional mounting brackets are supplied so the loggers can be wall mounted or on a 1.5-inch-diameter pipe.

The SM150, SM300, and ML3 Theta soil moisture probes have connectors such that cables up to 100 meters (300 feet) long can be attached. The sensors are waterproof and can be submerged or buried at almost any depth.

For greenhouse applications, the sensors are usually inserted in the soil at the top of the pots, or partially buried to reach the middle of the pot. The cable and connectors can be buried as well, and no further protection is needed.

Track Record, Water Savings, and SWAT Testing

The ML2 and ML3 Theta probe and the SM200, SM300, and SM150 soil moisture sensors have been tested extensively in irrigation trials over the last several years. Results show that these sensors have advantages in dry conditions and when soil type may be highly variable. They work well in a wide variety of soil types and artificial medias as well, with little or no temperature or salinity effects. When used with the GP1 or GP2 data loggers, where soil moisture set points can be used to schedule irrigation, these sensors have been shown to save water and increase irrigation efficiency. References and publications are available on the Dynamax Web site.

A SWAT calibration test report for the Delta-T SM200 sensor was posted in 2010.

Hunter Industries

Hunter Industries (Hunter®) was established in 1982 and is headquartered in San Marcos, California. Hunter manufactures and distributes a full line of landscape irrigation products worldwide. Hunter offers a new soil moisture sensor-based interrupt accessory for standard 24-VAC controllers called Soil-Clik™.



Sensor Description and Operation

Soil-Clik uses a proven granular matrix style moisture sensor to obtain a relative moisture level reading, and interrupts irrigation when a user-programmable level of moisture is detected in the soil. The sensor connects to the outdoor-grade Soil-Clik module with two 18-AWG direct burial wires, and displays the current moisture level in an LCD display.

Simple controls allow the user to set the level of moisture at which irrigation will be stopped. Soil-Clik never initiates irrigation, and does not determine run times or application amounts. Soil-Clik simply halts preprogrammed irrigation when it is not needed.

Hunter recommends combining Soil-Clik with the Solar Sync sensor for a complete, environmentally aware control solution. This combination provides ET-adjusted run times (application amounts), rain and freeze shutdown, and automatic interrupt if soil is still wet.

The Soil-Clik module displays the current measured moisture level (in centibars), and allows the user to raise and lower the desired moisture level with simple plus-and-minus button adjustments.

The module also provides a one-button update of the current soil moisture level, which updates the LCD display immediately with current information.

The module also provides a one-button override, which cancels the moisture sensor interrupt for special situations when more watering is desirable.

Wiring is color-coded for low voltage power, sensor probe connection, and the output, which can either be used with smart sensor inputs or as a simple common interrupt.

When the desired soil moisture level is reached, a simple solid-state relay opens the output, either as the input to a normally-closed sensor or to open the field wiring common wire. The display indicates when irrigation has been inhibited by the module.

Controller Descriptions, Prices, and Warranty

The Soil-Clik module is housed in a weatherproof plastic enclosure and its dimensions are 4½ by 3½ by 1¼ inches. The Soil-Clik probe is a direct burial sensor, 3¼ inches tall and 7/8 inch in diameter, with 32-inch-long wire leads. The Soil-Clik module operates on 24 VAC (less than 100 mA) connected to the controller’s internal 24-VAC power terminals. The module provides power and signal to the soil moisture probe.

Soil-Clik is available from Hunter distributors worldwide, and further information can be accessed at Hunter’s Web site. The retail price for the Soil-Clik is \$149.00. The price range for compatible Hunter controllers is from \$150 to \$2,250. Soil-Clik comes with a 5-year warranty.

Table 17.—Hunter Products Price Summary

Description	Model	Price
Soil-Clik Module and Probe	SOILCLIK	\$149

Installation

Installation and programming of the Soil-Clik can be performed by the user or irrigation professional. The Soil-Clik module can be wall mounted near the controller, and the sensor is installed in the field.

The Soil-Clik sensor wiring may be extended up to 1,000 feet from the module. The sensor should be placed in the sunniest, driest area of the landscape. The sensor should be placed within the last (highest numbered) zone or station to irrigate, and the controller wiring may be adjusted to make the driest station last. The sensor is placed in the last zone to prevent normal irrigation from interrupting a program before it has finished, or to prevent the entire program from starting when soil is already wet.

The Soil-Clik probe is placed in full contact with the surrounding soil in a vertical, or near vertical position, with the wiring positioned at the top. Before installing, it is recommended to soak the lower 2/3 of the probe in a bucket for approximately 30 minutes to speed acclimatization to the soil. It is also recommended to mix and pour a slurry of native soil and water into the sensor hole, to complete contact with the surrounding earth. The Soil-Clik owner’s manual is available at Hunter’s Web site (www.hunterindustries.com) and contains detailed installation and programming information.

Track Record, Water Savings, and SWAT Testing

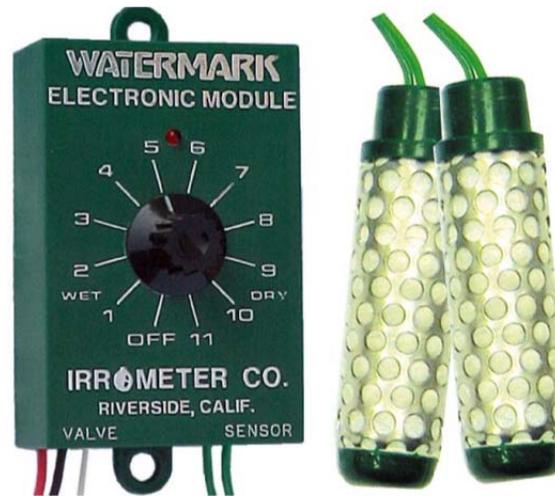
The Soil-Clik probe is a proven design with a long history in agricultural and landscape irrigation.

The Hunter Soil-Clik will function as complementary component in an EPA WaterSense approved application with Hunter Solar Sync and compatible controllers, but has no rating of its own at this time.

Hunter has had 10 to 15 years' experience with ET-based irrigation. The Soil-Clik is positioned as either a stand-alone water-savings solution, or as a premium accessory for the Solar Sync sensor.

IRROMETER

The IRROMETER Co., Inc. (IRROMETER), located in Riverside, California, has been in business since 1951. IRROMETER manufactures irrigation optimization equipment including soil moisture sensors and control devices, soil solution access tubes for nutrition management, and pressure gauges. Their original tensiometer-type soil moisture sensing products have been on the market since 1951. The WATERMARK resistance-type sensor was introduced in 1985.



IRROMETER offers four different add-on control devices for soil moisture-based residential and commercial landscape irrigation control. The controllers use one or more of the WATERMARK soil moisture sensors to interrupt the existing clock/controller schedule until the soil moisture reaches the user-prescribed level. Included with the purchase of an IRROMETER control system is its WaterPerfect turf and landscape irrigation scheduling and water management software. This software program aids the user in the proper scheduling of irrigation utilizing WATERMARK soil moisture sensors, including calculation of total run times and cycle and soak times based on site conditions.

Sensor Description and Operation

The WATERMARK is a solid-state electrical resistance-type sensor, which IRROMETER reports provides accurate readings from 0 to 200 centibars. This covers the entire soil moisture range required in irrigated landscapes, including heavy clay soils. The sensor is installed by placing it into a hole made with a 7/8-

inch-diameter rod to the desired sensor depth. If a larger diameter hole is made, then a “grout” of the soil and water is poured into the hole. The sensor consists of two concentric electrodes embedded in a reference matrix material, which is surrounded by a synthetic membrane for protection against deterioration. The exterior surface is of ABS plastic and a stainless steel mesh. The internal matrix includes gypsum, which provides some buffering for the effects of salinity levels normally found in irrigated landscapes. The sensor is 7/8 inch in diameter by 3 inches long. The original WATERMARK (model 200) was improved in 1993 to the current model 200SS, which has improved its soil moisture response characteristics. The sensors are maintenance free and are not damaged by freezing. The reported minimum life span for a WATERMARK sensor is 5 to 7 years.

IRROMETER’s soil moisture sensor-based control devices include the WaterSwitch (WS1), WATERMARK Electronic Module (WEM), Battery WEM (WEM-B), and WATERMARK Multiple Hydrozone System (MHS). As mentioned above, all of these devices use the WATERMARK sensors and interrupt the common power supply to the clock/controller or interface with the controller’s sensor circuit, and the WEM may be used to control individual valves. The sensor wiring is connected directly to the control module, which is connected to either the clock/controller or the valve(s). The maximum run between the sensor and controller is 1,000 feet using 18-gauge wire. Larger wire sizes can be used for longer distances.

Controller Descriptions, Prices, and Warranty

The WATERMARK Electronic Module is IRROMETER’s flagship controller. It is a versatile device that can be used in multiple connection scenarios. The WEM can be used to control an individual valve, a group of valves watering areas of similar water demand, or all the valves on any clock/controller. In a typical residential application, a pair of WATERMARK sensors is connected to the WEM; and the wiring configuration for the connection to the clock/controller provides for interruption of the power supply common connection. Alternatively, a pair of sensors and a WEM may be installed and connected to a single valve at the valve box. When a new system is being installed for a large landscape with a need for multiple sensor pairs, multiple common wires can be installed to provide for use of multiple WEMs and sensors. For retrofit of an existing system where multiple sensors are needed, a Multiple Hydrozone System device (wired or wireless) should be used rather than installing the needed additional common wiring.

The WEM’s cabinet is constructed of heavy-duty plastic and it can be installed indoors or outdoors. It may be installed at the controller or at the valve. The WEM’s dimensions are 3 by 2 by 1.5 inches. The WEM is adjustable from 10 to 120 centibars by a simple dial that has an “OFF” position to allow for overriding the sensors. The WEM’s indicator light comes on when the clock/controller is

powering a valve controlled by the WEM, and the soil moisture conditions are drier than the selected setting indicating irrigation is allowed. It is powered by a 24-VAC supply from the clock/controller.

The WaterSwitch and the Battery WEM are designed for use with clock/controllers that possess switch terminals (rain, freeze, flow, etc.). This provides for a simple wiring configuration and easy installation. Both function similar to the WEM and possess the same features. The WaterSwitch is constructed of heavy-duty plastic and is suitable for indoor or outdoor installation. Its cabinet dimensions are 2 by 2 by 1.25 inches that make it small enough to mount inside many controller cabinets. The WaterSwitch is powered by the 24-VAC supply from the clock/controller.



The Battery WEM is designed for use with a DC-powered clock/ controller. It is constructed of heavy-duty plastic and is suitable for outdoor installation. Its cabinet dimensions are 2.5 by 1.5 by 2 inches. The Battery WEM is powered by a 9-volt battery housed inside its waterproof battery compartment.



The most advanced of IRRMETER Company's Landscape Automation Products is the Multiple Hydrozone System. Where the WaterSwitch and the WEM are designed to manage a single valve or hydrozone (area of specific plant type or irrigation need, such as turf, shrubs, trees, etc.), the Multiple Hydrozone System is designed to manage many different plant types, generally in a larger or commercial application. Both the MHS (wired) and W-MHS (wireless) Multiple Hydrozone Systems work with an existing AC irrigation controller to eliminate programmed irrigations when plants have adequate soil moisture. The system makes decisions to open or close the valve common wire or signals the controller, based on the plant's demand, controlling up to 48 stations in as many as 8 hydrozones. Valves are grouped together into hydrozones based on that location's specific irrigation needs. The system is digitally programmable and can report and download data for maximum irrigation management and analysis. It will show the last allowed watering, report watering history, and will display the percentage of water saved. A manual override feature is also included.

The wired MHS requires a base unit and a pair of WATERMARK sensors for each hydrozone. The wireless W-MHS requires the base unit and a wireless transmitter for every two hydrozones. Two pair of WATERMARK sensors are included with each transmitter. Both the MHS and the W-MHS are factory-wired and mounted and come in a rainproof stainless steel locking enclosure measuring 9.5 by 12.25 by 5 inches with a dead-front door for access to all wiring connections. A basic system will accommodate up to 16 valves initially and is expandable to 48 valves with the addition of optional Expansion Boards.



Current retail prices for IRROMETER soil moisture sensor-based irrigation control products are summarized in table 18. IRROMETER products are available through irrigation equipment distributors, some of which are listed at its Web site at: www.irrometer.com.

IRROMETER provides a 1-year warranty with its soil moisture sensor control systems.

Table 18.—IRROMETER Product Retail Prices

Description	Model No.	Price
WaterSwitch Add-On Controller	WS1	\$100 ¹
WEM Add-On Controller	WEM	\$200 ²
Battery WEM Add-On Controller	WEM-B	\$200 ²
MHS Wired Base Unit	MHS - _ - _	\$1,200
W-MHS Wireless Base Unit	W-MHS - _ - _	\$2,000 ³
W-MHS Wireless Transmitter	MHS-T	\$990 ⁴
MHS Expansion Board (additional 16-station capacity)	MHS-XB	\$98
MHS Base Receiver Connection Cable (optional 50-foot)	MHS-C	\$123
WATERMARK Soil Moisture Sensor Pair (5-foot lead wire)	200SS-5PR	\$70

¹Price includes one WATERMARK soil moisture sensor.

²Price includes two WATERMARK soil moisture sensors.

³Price includes 15-foot connection cable.

⁴Price includes four WATERMARK soil moisture sensors.

Installation

IRROMETER recommends professional installation, but it reports a typical residential system can be installed by some homeowners in approximately 2 to 4 hours.

Track Record, Water Savings, and SWAT Testing

IRROMETER's WATERMARK sensors have been used in soil science research by universities, as well as in production agriculture and landscape applications, worldwide for over 20 years. Their use in landscape applications has been documented for the longest period of time by a study that originated in 1993 for the city of Boulder, Colorado. The consulting firm conducting the study, Aquacraft, Inc., published numerous papers from 1995 to 2001 for the Irrigation Association, the American Society of Agricultural Engineers, the American Water Resources Journal, and the American Water Works Association. Both the graph shown in figure 10 and the following excerpt is from one of these published papers:

“The results of this study were quite encouraging from the standpoint of both irrigation efficiency and cost effectiveness. On a seasonal basis, the systems limited applications to an average of 76% of theoretical requirement when all sites are combined.”

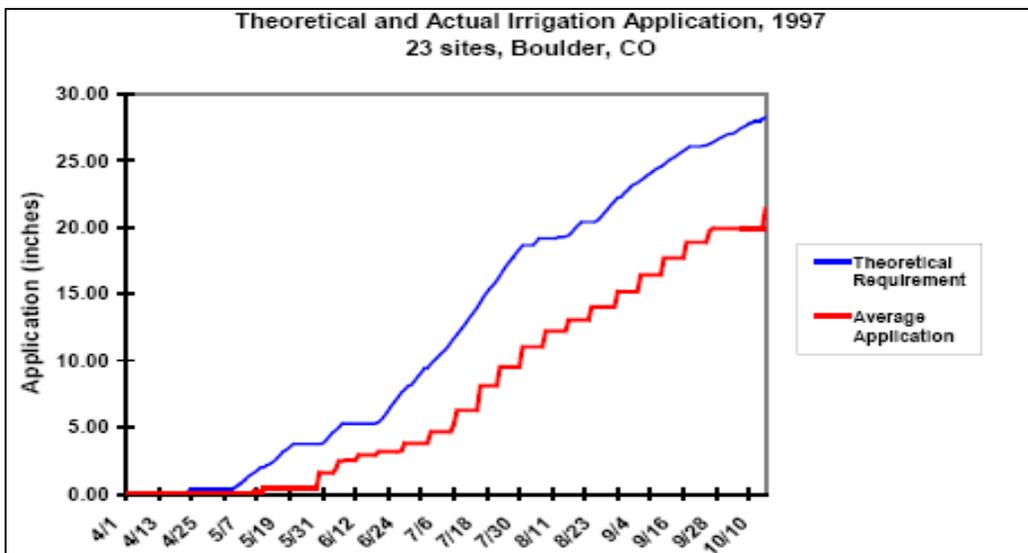


Figure 10.—Watermark performance compared to turf water requirement.

IRROMETER's WATERMARK control products have also received the *Smart Approved WaterMark* designation, Australia's water saving labeling program for products to reduce outdoor water use.

A SWAT calibration test report for IRROMETER'S WATERMARK sensor was posted in 2008.

MorpH₂O

MorpH₂O Water Management LLC (MorpH₂O), located in Ogden, Utah, since 2006, is a manufacturer of soil moisture based landscape and agricultural irrigation products and other agricultural irrigation and microclimate monitoring instruments.

MorpH₂O's AguaMiser™ landscape irrigation system includes add-on control devices utilizing ECH2O soil moisture sensors.

The AguaMiser interrupts programmed irrigation events when soil moisture is at or above an adjustable level or “trigger point.” The trigger point is determined using an easy-to-follow procedure that calculates field capacity of the soil, to then set a lower soil moisture limit. AguaMiser technology interprets sensor readings and adjusts the state of the relays that will accommodate “N/O” (normally open) or “N/C” (normally closed) circuits.

This allows the user to adapt to a multitude of situations; such as, using this technology to start fertigation systems or even control SCATA and other protocol-type switches.

AguaMiser MZ (multi zone) units can control and monitor up to 64 wireless transmitters and soil sensors, with Web-based data collection and reporting available in the spring of 2015.



AguaMiser™
Transmitter and Sensor

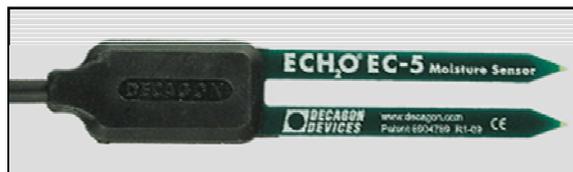
AguaMiser™ Single zone



AguaMiser™ Multi-zone

Sensor Description and Operation

The AguaMiser uses the Decagon Devices ECH2O EC-5 soil moisture sensor. The EC-5 is a capacitance/frequency domain-type sensor that calculates volumetric water content by measuring the dielectric constant of the soil. The EC-5 incorporates a high frequency oscillation, which reportedly allows the sensor to measure soil moisture in any soil with minimal salinity and textural effects. Its reported accuracy is $\pm 3\%$ for most soils and



its functional temperature range is -40 to +50 °C. The dimensions of the EC-5 are approximately 3.5 by 0.7 inches. It comes with a 16-foot cable that can be extended up to 250 feet with an extension kit.

Controller Description, Prices, and Warranty

The AguaMiser's cabinets are suitable for indoor and outdoor installation.

The AguaMiser can be purchased online at www.morph2o.com or from the local distributors provided on the Web site. Prices for AguaMiser systems range from a single probe-wired controller including sensor for \$250.00 to basic wireless models with probes start at \$300.00. A sensor wiring extension kit is \$0.75 per foot, plus \$4.00 per splice kit.

The MorpH₂O warranty on the AguaMiser and EC-5 is 2 years and includes replacement or repair to correct material or workmanship defects.

Installation

MorpH₂O recommends professional installation, but reports most homeowners can perform installation using the installation guide included on its Web site. The installation guide includes brief instructions on wiring, calibration, sensor placement, troubleshooting, and setting appropriate run times.

Track Record, Water Savings, and SWAT Testing

MorpH₂O has conducted multiple tests at sites in Utah, Nevada, and California. Published test results are available at www.morph2o.com. Tests at an Ogden Utah school experienced return on investment in a 2-week period. The Magna City, Utah, test showed an average savings of as much as 68% from normal water use. A test was performed at Brigham Young University in Utah that showed an average savings of 40% on a previously calibrated existing system.

A SWAT calibration test report for the ECH2O EC-5 soil moisture sensor was posted in November 2008.

Rain Bird

As discussed in the “Weather-Based Product Descriptions” section of this report, Rain Bird Corporation (Rain Bird®), based in Glendora, California, is an international supplier of irrigation products that began business in 1933. The SMRT-Y Soil Moisture Sensor Kit from Rain Bird, introduced in 2009, is an add-on irrigation controller and soil moisture sensor that controls irrigation events based on the absolute moisture requirements of a site’s vegetation.



The SMRT-Y sensor measures the moisture level in the soil. When the soil is dry, the SMRT-Y allows the irrigation controller to water as scheduled. When the soil moisture level is sufficiently high, the SMRT-Y will disable all zones from irrigating. The SMRT-Y acts as a switch, opening and closing the zone common wire depending on the soil moisture level. When the zone common wire is open, the irrigation system valves will not operate. The moisture threshold—the level of moisture where the SMRT-Y switches on or off—is set by the user and can be adjusted up or down as needed.

By locating the sensor in the driest or worst case zone and correctly programming the irrigation controller to accommodate the zone specific characteristics (plant type, sun versus shade, etc.), the SMRT-Y’s single sensor can manage irrigation of the entire system. One or two zones can be isolated from the influence of the SMRT-Y by using the optional bypass wires attached to the SMRT-Y controller interface unit.

Sensor Description and Operation

The SMRT-Y TDT-type sensor’s stainless steel rods act as wave guides and not electrodes. The rods allow an electromagnetic pulse to travel along their surface. As the moisture content increases, the speed of the pulse is slowed. The speed of the electromagnetic pulse is inversely proportional to the moisture level of the soil near the rods. Rain Bird’s patented sensor uses an additional feature called “digital signal processing” to more accurately measure this pulse delay.

The stainless steel alloy used for the rods on the SMRT-Y sensor was chosen because of its ability to resist corrosion in environments characterized by high salinity. In addition, the SMRT-Y rods are isolated from the electronics inside the body of the sensor to avoid galvanic reaction. The SMRT-Y sensor also includes

electrical surge protection within the sensor to protect against lightning strikes. The sensor dimensions are 8 by 2 by 0.5 inches.

The SMRT-Y sensor is factory calibrated and never needs re-calibration. The SMRT-Y is designed to be accurate with changing conditions including soil type, soil temperature, and soil salinity.

Checking soil conditions every 10 minutes, the SMRT-Y displays moisture content, electrical conductivity, and temperature of the soil, all at the touch of a button. The sensor is buried in the soil at a depth of about 3 to 5 inches and connected to an existing valve. It communicates with the SMRT-Y controller via the existing valve wiring.



If feasible, a separate common wire can be used to supply power to only those zones targeted for control by the SMRT-Y sensor. Using this technique, the SMRT-Y sensor can be used to control from one to any subset of the irrigation controller's zones. If only one or two zones are to be isolated from the influence of the SMRT-Y sensor, the optional bypass wires may be used.

Controller Description, Prices, and Warranty

The SMRT-Y controller is constructed of heavy duty plastic and it can be installed indoors or outdoors. Its dimensions are 3 by 3 by 0.75 inches and it operates on 25 VAC at 12-watt current supplied by the existing timer/controller. Its operating temperature range is -4 to 158 °F (-20 to 70 °C).

The controller has a 1- by 2-inch LED display that shows status (watering allowed or suspended) and watering history for the last seven irrigation cycles.

The SMRT-Y kit (controller, sensor, mounting hardware, and manual) retails for \$209. It can be purchased online through Rain Bird's Web site at: <http://www.rainbird.com/landscape/products/accessories/smrt-y.htm> or at selected irrigation supply retailers. The SMRT-Y controller and sensor come with a 1-year warranty.

Installation

Although installation by a Rain Bird trained professional is recommended, Rain Bird reports installation may be performed by some homeowners. A comprehensive online tutorial for the ESP-SMTe series is available at www.rainbird.com/ESP-SMTe. Installation and programming instructions in English and Spanish are provided with the controller.

Track Record, Water Savings, and SWAT Testing

Rain Bird reports that water savings of 40% or more are typical. A study by the University of Florida resulted in savings of 73%. In addition to saving water, Rain Bird reports the SMRT-Y can prevent over watering, which can cause fungus and root damage due to rotting. A SWAT calibration test report for the SMART-Y sensor was posted in September 2010.

UgMO Technologies

UgMO™ Technologies' (UgMO) corporate headquarters is located in King Of Prussia, Pennsylvania. The company has developed a wireless soil sensor system designed to control and/or monitor large and small landscape irrigation systems. The UgMO system is designed to save water and money, while protecting and enhancing the health of turf and landscapes. The two systems (PH100 and UG1000) utilize the UgMO wireless soil sensors to ensure that only the amount of water needed by a landscape is applied.

The system's underlying network architecture, called SenLink™, consists of battery-powered sensors with built-in radio modules. These sensors are installed completely belowground and are capable of radio communication to aboveground repeaters, control units that may act on the data, or data bridges that port the data onto the Internet.



Sensor Description and Operation

The UgMo ProHome PH100WS wireless TDR-type sensor measures soil moisture, temperature, and salinity at the root level of the plant in real-time, up to six times an hour, 24-hours a day. This wireless sensor data are transmitted to the UgMO Irrigation Controller or Base Station, both of which utilize its patented watering algorithms to deliver only the water the landscaping needs, zone-by-zone.

With two AA lithium batteries, sensors will operate for 5 to 7 years without replacement or other maintenance. The sensor dimensions are 3.9 by 1.2 by 1.6 inches. It is fully waterproof and corrosion resistant.

Belowground to aboveground communication is a challenging problem and UgMO has developed extensive intellectual property and expertise in making this feasible. Varying soil conditions (mainly moisture content), sensor depth, and antenna design complicate below to aboveground radio communication.

Repeaters receive sensor communication from the belowground sensors at 433 MHz and forward them over a frequency hopping link that operates in the US ISM band between 902 and 928 MHz. Currently, the system is configured for a minimum of a 2,000-foot range aboveground with direct line of site at an antenna height of 5 feet with an integrated internal antenna. Other ranges are possible with different antenna and transmit power level configurations. UgMO repeaters are powered by connection to a hard-wired power source or photovoltaic cells. By using a number of repeaters, effective sensor transmission can be extended to several kilometers.

Controller Descriptions, Prices, and Warranty

The UG1000 system breaks the traditional watering schedule paradigm. There are no scheduled cycle times to set and no complex site variables to enter. The 36-zone stand-alone controller is fully software upgradeable to incorporate future features. Its dimensions are 12.75 by 9.13 by 4.38 inches and it accepts wire sizes up to 14 gauge. The UG1000



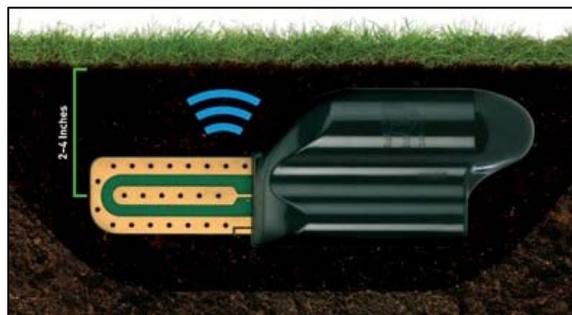
can be combined with the advanced UgMO Knows Web-based software platform for sophisticated agronomic analytics and environmental monitoring, along with leak detection and remote configuration.

The 6-zone PH100, also a stand-alone unit, uses the same wireless sensor technology as the UG1000, but is designed for smaller residential and commercial properties. Its dimensions are 7.5 inches in diameter by 2.25 inches deep. The PH100 has a wire harness that splices with existing wire, so there are no wire size restrictions.

The sensors broadcast moisture and temperature data to the UgMO base station (controller), which serves as an interrupter that will adjust the scheduled irrigation run times to deliver only the required amount of water that is needed by the landscape.

With UgMO sensors buried in each irrigation zone, soil moisture conditions are monitored and water is applied, zone-by-zone, according to the plant needs. In order to keep soil moisture at the optimum level, the required run times for each zone can vary greatly depending on numerous factors, including the following: plant type (such as turf, shrubs, or trees); soil types; exposure; and the rate of water application in a zone, which depends upon water pressure, sprinkler type and density of sprinkler heads. In essence, UgMO operates like a thermostat that maintains temperature levels with the goal of maintaining optimal moisture levels to ensure plant health. Because the typical irrigation timer overwaters, maintaining the optimal moisture zone means using significantly less water. Most importantly, this “thermostat” is set zone-by-zone to reflect the irrigation system, soil types, plant types, and different microclimates.

Controllers receive sensor data, either directly from the sensor or through the repeater network, and act upon the information. Incoming soil moisture and temperature data are used to efficiently apply irrigation water to meet the plant needs while avoiding wasteful water usage by directly controlling irrigation valves. The controller can implement sophisticated adaptive learning protocols and can act, if desired, autonomously. Remotely upgradeable, new features and functions can be added after installation.



A key feature of UgMO is that while the system applies water, it also monitors changes in soil moisture as a result of irrigation. Thus, the UgMO data act as a full “soil laboratory” where the controller learns autonomously and without human setting, all the required parameters for efficient irrigation management. For example, UgMO is performing a constant vigil determining how much each irrigation cycle affects the soil moisture while also calculating dry down as well. In time, field capacities of the soil in each zone are learned and run times can be based achieving a target moisture level that is 70% of field capacity, a level that has been shown to be ideal for plant health and efficient water use. This allows UgMO to operate effectively in systems with different sprinkler types and coverage densities. These adaptive learning processes avoid human error and estimation as to the key parameters of soil type and sprinkler application rate.

The combination of these features produces effective, “as needed” irrigation management designed to yield water savings with little need for human monitoring or adjustment. In addition, because soil temperature is monitored, the system automatically suspends irrigation when soil temperatures fall to levels where plants go dormant. Finally, by creating an Internet-enabled local network, the system performance can be monitored, adjusted/configured, and updated remotely.

While UgMo is currently focused on measuring soil moisture, temperature, and salinity, the sensor platform is capable of implementing sensors with a variety of capabilities. In addition, while the current system architecture is a wireless network, depending on the application, there is a wide range of potential novel sensing/communication strategies that can be implemented. Although the initial application of the SenLink technology is for improving irrigation efficiency, the system has been designed with a flexible modular architecture in order to serve a variety of environmental control/monitoring applications.

UgMO Knows is a Web-based data visualization server accessible from any computer with Internet access and a Web browser. It is password protected and offers various level of user accounts from full privileges to modify and configure the system, to view only accounts. UgMO Knows allows for data charting and alarms to be generated (emails, telephone messages, etc.) when sensor data exceed user set limits. In addition, the platform supports advanced analytics and “data mining.”

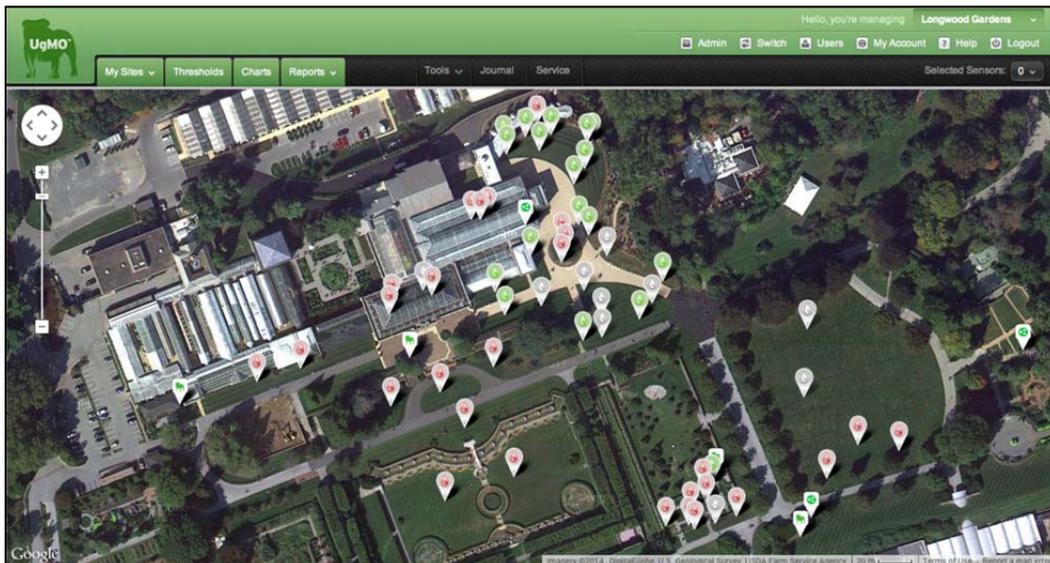


Figure 11.—Example of UgMO Knows, which incorporates Google map technology to provide users with real-time views of current conditions.

With the addition of a flow sensor attached to the irrigation pipes, the UG1000 can monitor waterflow isolated to the irrigation system and provide leak detection and system flow irregularities to the Internet. When combined with actual irrigation event data, the system can send system alerts to responsible parties by email, text, or a smartphone application.



Figure 12.—Example of UgMO Knows waterflow monitoring.

UgMO has a variety of pricing options including a savings share and lease model, where there is no out-of-pocket capital expense for the customer. Installation, warranty and maintenance are included in these programs for the life of the contract. UgMO reports “\$700/controlled irrigation zone as a pricing structure” for direct purchase of either controller. A 1-year parts warranty is included with direct purchase.

Installation

UgMo reports the PH100 can be installed by the typically homeowner, and the UG1000 is typically installed by an irrigation specialist. There is an installation support page at its Web site (www.UgMo.com) and a toll-free telephone support line.

Track Record, Water Savings, and SWAT Testing

UgMO reports its system has been optimized for improving the efficiency and performance of residential and commercial irrigation systems spanning areas from less than an acre to large facilities such as golf courses and college campuses. A SWAT calibration test report was posted for the UgMo ProHome PH100WS in August 2012.

References Cited

- Allen, Richard G. 1997. Demonstration of Potential for Residential Water Savings Using a Soil Moisture Controlled Irrigation Monitor. Retrieved April 29, 2015, from the World Wide Web at http://www.kimberly.uidaho.edu/water/swm/cons96p_rp_full.pdf.
- Allen, Richard G., Ivan A. Walter, Ronald L. Elliot, and Terry A. Howell. 2005. The ASCE Standardized Reference Evapotranspiration Equation. American Society of Civil Engineers.
- Cardenas-Lailhacar, Bernard, Michael K. Dukes, and Grady L. Miller. 2005. Sensor-Based Control of Irrigation in Bermuda Grass. Proceedings of the 2005 American Society of Agricultural Engineers Annual International Meeting.
- DeOreo, William B. et al. No date. Soil Moisture Sensors: Are They a Neglected Tool. Retrieved April 29, 2015, from the World Wide Web at https://www.cuwcc.org/Portals/0/Document%20Library/Resources/Water%20Efficient%20Product%20Information/Research%20and%20Savings%20Studies/Soil%20Moisture%20Sensors_%20Are%20They%20a%20Neglected%20Tool_.pdf.
- Irvine Ranch Water District (IRWD). 2001. Residential Weather-Based Irrigation Scheduling: Evidence from the Irvine “ET Controller” Study. Retrieved April 29, 2015, from the World Wide Web at <http://www.hydropoint.com/documents/2013/09/evidence-from-the-irvine-et-controller-study.pdf>.
- Irvine Ranch Water District (IRWD). 2003. Residential Runoff Reduction (R3) Study. Retrieved April 29, 2015, from the World Wide Web at https://www.irrigation.org/SWAT/Case_Studies/Case_Studies.aspx.
- Mecham, Brent Q. No date. A Practical Guide to Using Soil Moisture Sensors to Control Landscape Irrigation. Retrieved April 29, 2015, from the World Wide Web at https://watergreat.com/reference/Practical_overview_2010.pdf.
- Pittenger, Dennis R. et al. 2004. Evaluation of Weather-Sensing Landscape Irrigation Controllers. Retrieved April 29, 2015, from the World Wide Web at <http://ucanr.edu/sites/UrbanHort/files/131533.pdf>.

Attachments

**Weather-Based Irrigation Technologies—Summary of
Product Information and Features**

**Weather-Based Irrigation Technologies—Summary of
Product Information and Features (continued)**

**Soil Moisture-Based Irrigation Technologies—
Summary of Product Information and Features**

Weather-Based Irrigation Technologies—Summary of Product Information and Features

Company Name	Accurate WeatherSet	Alex-Tronix	Brilliant Integrated Tech.	Calsense	Cyber Rain	ETwater Systems	Hunter Ind. (ET System)	Hunter Ind. (Solar Sync)	HydroPoint WeatherTRAK	Irrisoft Weather Reach
Telephone	(818) 993-1449	(888) 224-7630	(866) 803-3443	(800) 572-8608	(818) 585-7178	(415) 945-9383 ext. 208	(760) 591-7344	(760) 591-7344	(800) 362-8774	(435) 755-0400
Contact Person	Andrew Davis	George Alexanian	Martin O'Loughlin	Rick Capitanio	Reza Pourzia	Katherine Wing	Dave Shoup	Dave Shoup	Tracey Bradley	Steven Moore
Website	www.weatheraset.com	www.alex-tronix.com	www.bit-usa.com	www.calsense.com	www.cyber-rain.com	www.etwater.com	www.hunterindustries.com	www.hunterindustries.com	www.hydropoint.com	www.irrisoft.net
Number of Residential Model Types	2	2	3	0	2	2	1	4	1	1
Number of Commercial Model Types	1	2	2+	1	1	3	1		1	1
Date Product(s) Entered Market	1994	2005	2014	1993	2007	2005	2006	2009	1997	2002
Method of Operation and Water Savings										
Basis for Schedule	Historical Data		•	Backup	•	Back-up		•	Back-up	Back-up
	On-site Sensor(s)	•	•	•	• ¹	•	• ¹	•	• ¹	• ¹
	Remote Weather Station(s)/Sensors			•					•	•
	Weather Forecasts					•				•
Weather Data Source	On-site solar and rain sensors	On-site temperature sensor and solar radiation estimated based on geographic location	Public & private weather stations data managed by centralized computer server	Historic ET data, evaporative atmometer type ET sensor, weather station or CIMIS data	Weather forecasts automatically from Internet and historic weather data	Public and ETWS weather stations and/or optional on-site weather station	On-site weather station with full set of sensors	On-site temp, solar, & rain sensors	Public and private weather stations managed by central computer and wireless delivery	Public & private weather stations data managed by centralized computer server
Manufacturer Reported Water Savings (Percent)	25	10 to 30	30-76 (note 2)	20 to 40 ²	30 to 40	20 to 50	30	30	16 to 58 ²	20 to 70
Product Features										
Stand-alone Controller or Add-on to Existing	Stand-alone	Stand-alone and Add-on	Stand-alone	Stand-alone	Stand-alone	Stand-alone & add-on	Add-on	Add-on	Stand-alone	Add-on
Station or Zone Capacity	8-48	4-24	16 - 32	8-48	8-24, unlimited	8-48	1-48	Not Applicable	6-48	Not Applicable
Master Valve or Pump Circuit(s)	1	1	1	2	1	2	Not Applicable	Not Applicable	1	
Internal Power Transformer	Outdoor Models Only	Not Applicable	•	•	•	•	Not Applicable	Not Applicable	•	
Battery Powered - DC		•					Not Applicable	Not Applicable		
Station Circuit Current Rating (Amperes)	0.75 and 1.5	5.0 (DC pulse)	1.5	1.5	1.0	1.1	Not Applicable	Not Applicable	0.375 and 0.5	4
Terminal Wire Size Range (Gauge)	12-20	12-18	24-Dec	14	max 14 solid & 16 stranded	12 and smaller	Not Applicable	Not Applicable	12-20	14 to 26
Outdoor Installation	•	•	•	•	•	•	•	•	•	•
On-site Rain Gauge or Sensor w/ Rain Shutoff/Delay	Hygroscopic Rain Sensor	Hygroscopic Rain Sensor ¹	Hygroscopic Rain Sensor ¹	Tipping Bucket Rain Gauge ¹	Hygroscopic Rain Sensor ¹	Rain Sensor or Gauge ¹	Electronic Rain Sensor	Electronic Rain Sensor	Hygroscopic Rain Sensor ¹	Tipping Bucket Rain Gauge ¹
Rain Shutoff/Delay by Remote Sensor or Rain Forecast	•		•	•	•	•			•	•
Rainfall Irrigation Schedule Compensation	•		•	•	•	•	•	•	•	•
On-site Wind Gauge w/ High Wind Shut-off				• ¹	• ¹	• ¹	• ¹	• ¹	• ¹	• ¹
High Wind Shut-off by Remote Sensor							• ¹	• ¹	• ¹	•
On-site Temperature Sensor w/ Freeze Shut-off		•						•	• ¹	•
On-site Temperature Sensor w/ High Temp On or Off							• ¹	•	• ¹	
Freeze or High Temp Shut-off by Remote Sensor							• ¹		•	•
On-site Evaporative Atmometer Type "ET Sensor"				• ¹			• ¹		•	•
On-site Solar Radiation Sensor	•			• ¹			•	•		
On-site Humidity Sensor				• ¹			•			
Flow Sensor(s) Connectivity	5 models		•	•	•	•	•		• ¹	•
Additional Sensor Terminals			•	•	•	•	•		•	
Internet or Computer Interface			•	•	•	•	•		• ¹	• ⁶
Remote Control Device(s) for Controller			•	• ¹	•	•	• ¹		• ¹	
Two-way Communication between Server and Receiver			•	•	•	•	Not Applicable	Not Applicable	Commercial Model	•
Station Circuit Testing	5 models	•	•	•	•	•	Not Applicable	Not Applicable	•	
Surge and/or Lightning Protection	5 models	•	•	•	• ¹	•	•	•	•	•
SWAT Test Performance Report Available		•	•	•	•	•	•	•	•	•
EPA WaterSense Certification		•	•	•	•	•	•	•	•	•
Scheduling Features										
Fully Automatic Schedule (No Base Schedule Required)		•	•	•	•	•	•	•	•	• ³
Base Irrigation Schedule Required	•	•	•	•	•	•	•	•	•	•
User May Define Non-Irrigation Days	•	•	•	•	•	•	•	•	•	•
Operable in Manual Clock Mode	•	•	•	•	•	•	•	•	•	•
Manual Operation by Station or Program	•	•	•	•	•	•	•	•	•	•
Variable Total Run Times	•	•	•	•	•	•	•	•	•	•
Irrigation Schedule Period(s)	Weekday or daily to 40 days	Week or up to 99 Day	Customizable	7, 14, 21 or 28 Day	Week	Unlimited Days	Weekday, 1-31 day, odd/even	Not Applicable	8 Weeks, Odd/Even & Weekday	Custom, Cyclical, Odd/Even, Restricted
Available Start Times	10	4 per program	Choice of Start or End Time	6 per manual program	4	9			8 starts with 20 repeat cycles	
Cycle/Soak Manual Input	•	•	•	•	•	•	•	•	Optional	
Cycle/Soak Periods Automatically Calculated			•	•	•	•	•	•	•	
Runs Concurrent Stations	•	•	•	•	•	•	•	•	•	•
Number of Programs	5	4	Unlimited	7	4	Unlimited	Not Applicable	Not Applicable	Unlimited	4
Percent Irrigation Adjust Feature		•	•	% of ET Adjust per station			•	•	•	
Station Distribution Uniformity/Efficiency Setting			•	•	•	•	•	•	•	•
Syringe Cycle or Program	•			•	•	•	•	•	•	•
New Landscape Establishment/Fertilizer Program			•	•	•	•	•	•	•	•
Review of Weather Information			•	•	•	•	•	•	•	•
Review of Irrigation or Water Use Information	•	•	•	•	•	•	•	•	•	•
English and Spanish Languages Display			•	•	•	•	•	•	•	•
Product Support and Warranty										
Warranty	3 Years	2 Years	3	10 Years	3 (Res) and 5 (Comm) years	3 Years	2 Years	2 Years	3 (Res) and 5 (Comm) years	1 Year
Support	On-site Service Technicians	In Southern California	•	•	•	•	•	•	•	•
	Telephone Technicians	•	•	•	•	•	•	•	•	•
	Local Distributors	In Southern California	•	•	•	Selected areas	•	•	•	•
Installation and Maintenance Requirements										
Professional Installation & Programming Recommended		Recommended for 2 models		•		•	•	•	•	•
Ongoing Maintenance Required				Clean Sensors			Clean Sensors	Clean Sensors		
Battery Replacement Required		•				•	•	•		
Cost										
Suggested Retail Price	\$222 - \$1,440	\$249 - \$2,112	\$899	\$1,075 - \$3,950	\$850 - \$2,100	\$850 - \$3,000	\$475	\$110 - \$235	\$398 - \$4,299	\$420 - \$595
Annual Service Cost	0	0	\$132	0	0	\$75 - \$199	\$0	\$0	\$48 - \$225	0 - \$250

1 - Optional add-on feature not included in controller price(s) shown
 2 - Reported water savings documentation is published or publically available
 3 - Scheduling guidelines or assistance provided with purchase

4 - Complete pricing information was not available for this report
 5 - Controller back-up schedule based on recent ET good for 21 days without network connectivity which can be modified by user
 6 - Includes remote monitoring of irrigation operation and tracks meter usage for savings reports

Weather-Based Irrigation Technologies—Summary of Product Information and Features (continued)

Company Name	Irritrol	OnPoint EcoSystems	Rachio	Raindrip	Rain Bird (ETMi & ETC)	Rain Bird (ESP-SMT)	Rain Master	Signature Control Systems	Skydrop	Weathermatic
Telephone	(951) 785-3512	(650) 924-1326	(844) 472-2446	(559) 431-2003 x3014	(800) 724-6247	(800) 724-6247	(951) 785-3573	(267) 879-7869	(801) 692-1583	(972) 278-6131
Contact Person	Keith Shepersky	Kathleen Palmer	Emil Motycka	Dan Nourian	Sean Azad	Sean Azad	Bill Wolfe	Curt Schaubel	Ryan Fawson	Brodie Bruner
Website	www.irritrol.com	www.onpoint.com	www.rach.io	www.raindrip.com	www.rainbird.com/etmanager	www.rainbird.com/ESP-SMT	www.rainmaster.com	www.signaturecontrolsystems.com	www.skydrop.com	www.smartline.com
Number of Residential Model Types	1	2	2	2	2	3	0	2	1	2
Number of Commercial Model Types	1	2	2	0	2	0	2	2	1	1
Date Product(s) Entered Market	2011	2014	2014	2009	2006	June 2009	2002	2013	2014	2004
Method of Operation and Water Savings										
Basis for Schedule	Historical Data	•	•	•	•	Back-up	•	•		
	On-site Sensor(s)	•	• ¹	• ¹	•	• ¹	•	• ¹		•
	Remote Weather Station(s)/Sensors		•	• ¹		•		• ¹	•	
	Weather Forecasts			•				•		
Weather Data Source	On-site temp, solar and rain sensors and historic weather data	Public and private weather stations and spatial grid points	weather data pulled from based on public & private forecasts	On-site temp and rain (tipping bucket) and historic weather data	Public & private weather stations data managed by centralized computer server	solar + solar radiation, humidity & solar -- historic wind & humidity data	Automatic, historic or manually entered ET or with optional on-site weather station	Proprietary	Public and private weather stations	On-site temp & rain sensor and solar radiation estimated based on date & location
Manufacturer Reported Water Savings (Percent)	Not Available	20 - 50	20 - 50	up to 30	30-80	20-50	25 to 50	Not Available	20 to 50	20 to 50
Product Features										
Stand-alone Controller or Add-on to Existing	Add-on	Stand-alone	Stand-alone	Stand-alone	Add-on	Stand-alone	Stand-alone	Stand-alone	Stand-alone	Stand-alone
Station or Zone Capacity	Not Applicable	8 - 16	8 and 16	6	Not Applicable	13	6-200	12	8 - 16	4-48
Master Valve or Pump Circuit(s)			•		Not Applicable	•	40,910	•	•	1
Internal Power Transformer	Controller powers receiver			•		•	•			Some Models
Battery Powered - DC	DC powered sensor									
Station Circuit Current Rating (Amperes)	Not Applicable	0.35 - 0.4	1.3	0.45	1.0 (ETC)	1.0	1.0	0.5	0.5	1.5
Terminal Wire Size Range (Gauge)	Not Applicable	14 to 20	14 to 18	16 to 24	14 to 26	14 to 20	12-14		16 - 24	14-18
Outdoor Installation	•	• ¹	• ¹		• (ETC)	•		• ¹	• ¹	•
On-site Rain Gauge or Sensor w/ Rain Shutoff/Delay	Hygroscopic Rain Sensor	Electronic Rain Sensor ¹	• ¹	Tipping Bucket Rain Gauge	Tipping Bucket Rain Gauge ¹	Tipping Bucket Rain Gauge	Tipping Bucket Rain Gauge ¹	• ¹	• ¹	•
Rain Shutoff/Delay by Remote Sensor	•		Integration		•		•	•	•	
Rainfall Irrigation Schedule Compensation	•	•	• ¹		•	•	• ¹	•	•	•
On-site Wind Gauge w/ High Wind Shut-off		• ¹	• ¹				• ¹	• ¹		
High Wind Shut-off by Remote Sensor			•		•	•	• ¹	•		
On-site Temperature Sensor w/ Freeze Shut-off	•	• ¹	• ¹	•			• ¹	• ¹		•
On-site Temperature Sensor w/ High Temp On or Off		• ¹	• ¹				• ¹	• ¹		
Freeze or High Temp Shut-off by Remote Sensor			•		•		• ¹	• ¹	•	
On-site Evaporative Atmometer Type "ET Sensor"			• ¹				• ¹	• ¹		
On-site Solar Radiation Sensor	•		• ¹				• ¹	• ¹		
On-site Humidity Sensor			• ¹				• ¹	• ¹		
Flow Sensor(s) Connectivity		• ¹			• (ETC)		•	•		
Additional Sensor Terminals					• (ETC)		•	•		•
Internet or Computer Interface		•	•				• ¹	•	•	
Remote Control Device(s) for Controller	• ¹	• (phone, tablet, computer)	• (phone, tablet, computer)		• (ETC)	Planned for 2010	• ¹	•	•	Planned for 2010
Two-way Communication between Server and Receiver		•	•				• ¹	•	•	
Station Circuit Testing		•	•	•	• (ETC)	•	•	•	•	•
Surge and/or Lightning Protection		•	•			•	• ¹	•	•	•
SWAT Test Performance Report Available	•		•	•	•	•	•			•
EPA WaterSense Certification	•	•	•		•	•		•	Submitted	•
Scheduling Features										
Fully Automatic Schedule (No Base Schedule Required)		•	•			•	• ¹	•	•	•
Base Irrigation Schedule Required	•		•	•	• ³		•	•		
User May Define Non-Irrigation Days	•	•	•	•	•	•	•	•	•	•
Operable in Manual Clock Mode	•	•	•	•	•	•	•	•	•	•
Manual Operation by Station or Program	•	•	•	•	• (ETC)	•	•	•	•	•
Variable Total Run Times	•	•	•	•	• (ETC)	•	•	•	•	•
Irrigation Schedule Period(s)	Not Applicable	Weekday, Odd, Even, Interval	Interva 1 to every 21 days	Wk, Odd/Even, Interval		Days of Wk, Odd/Even, Cyclical	7 or 30 Day	Up to 31 Days & Odd/Even	Up to 31 Days & Odd/Even	Up to 31 Days & Odd/Even
Available Start Times	•	per program, unlimited cycle	•	4	8 (ETC)	2 Watering Windows	5-8	4		8
Cycle/Soak Manual Input		•	Planned for Summer 2015	•	• (ETC)		•	•	•	•
Cycle/Soak Periods Automatically Calculated	•	•	•			•	•	•	•	•
Runs Concurrent Stations	•				• (ETC)	•	•	•	•	•
Number of Programs	Determined by controller	4	Unlimited		4 (ETC)	Up to 13	4-16	12		4
Percent Irrigation Adjust Feature	•	•	•	•	• (ETC)	•	•	•		•
Station Distribution Uniformity/Efficiency Setting		•	•			•	•			
Syringe Cycle or Program		•	•		• (ETC)	•	•			
New Landscape Establishment/Fertilizer Program		•	•		• (ETC)	•	•			•
Review of Weather Information	•	•	•	•	•	•	•	•	•	•
Review of Irrigation or Water Use Information	•	•	•	•	•	•	•	•	•	•
English and Spanish Languages Display		•			• (ETC)	•	•	•		Planned for 2010
Product Support and Warranty										
Warranty	5 years	2 years	2 Year	1 Year	3 Years	3 Years	5 Years	2 Years	2 Years	2 Years
Support	On-site Service Technicians	Selected areas - third party	Selected areas - third party				•	•	•	•
	Telephone Technicians	•	•	•	•	•	•	•	•	•
	Local Distributors	•	Selected areas	•	•	•	•	•	•	•
Installation and Maintenance Requirements										
Professional Installation & Programming Recommended	•				•	•	•			•
Ongoing Maintenance Required	Clean Solar Sensor		Clean Sensors (If Applicable)				Clean Sensors (If Applicable)			
Battery Replacement Required	•			•					•	•
Cost										
Suggested Retail Price	\$229	\$550 - \$1,150	\$249 and \$299	\$69-\$109	\$658 - \$845	\$325 - \$450	\$684 - \$4,040	\$277 - \$595	\$299	\$255 - \$900
Annual Service Cost	0	0	0	0	0 - \$350	0	\$120 - \$180	0	0	0

1 - Optional add-on feature not included in controller price(s) show
 2 - Reported water savings documentation is published or publically available
 3 - Scheduling guidelines or assistance provided with purchase

Soil Moisture-Based Irrigation Technologies—Summary of Product Information and Features

Company Name	Acclima	Baseline	Calsense	Dynamax	IRROMETER	Morph20	Rain Bird	UgMo
Telephone	(866) 887-1470	(208) 323-1634	(951) 352-3891	(800) 896-7108	(951) 689-1701	(801) 388-9111	(800) 724-6247	(484) 690-0570
Contact Person	Brad Nuffer	Nick Toyn	Rick Capitanio	Gary Woods	Tom Penning	Scott Martin	Don Clark	Brian Dalmass
Web Page	www.acclima.com	www.baselinesystems.com	www.calsense.com	www.dynamax.com	www.irrometer.com	www.morph20.com	www.rainbird.com	ugmo.com
Number of Residential Model Types	2	1	0	1	1	1	1	2
Number of Commercial Model Types	2	3	1	2	3	1	1	1
Date Product(s) Entered Market	2003	2002	1986	2006	1985	2008	2009	2009
Method of Operation and Water Savings								
Interrupts Operation of All Stations	•	•		•	Residential Models			•
Interrupts Operation of Individual or Groups of Stations	•	•	•	Requires Multiple Controllers	Commercial Models	•	•	•
Manufacturer Reported Water Savings (Percent)	30 to 40 ¹	30 to 50	20 to 40 ¹	Not Available	24 to 60 ¹			40 to 80
Product Features								
Stand-alone Controller or Add-on to Existing	Stand-alone	Both	Stand-alone	Both	Add-on		Add-on	Both
Type of Soil Moisture Sensor(s)	Digital Time Domain Transmission	Time Domain Transmission	Tensiometer	Frequency Domain Reflectometry	Electrical Resistance	Frequency Domain Reflectometry	Time Domain Transmission	Frequency Domain Capacitance
Multiple Soil Moisture Sensors May Be Used	•	Commercial Models	•	Requires Multiple Controllers	Commercial Models			•
Soil Moisture Sensor Capacity	1-36	6 & 25	48	1 or 2	1 to 16	1	1	255
Sensor(s) or Controller Connects to Existing Valve Wiring	•	•	•		Commercial Models	•	•	•
Number of Soil Moisture Settings	1,000	Unlimited	Unlimited	51 and 0-60%	4, 9 and 11		Not Applicable	10
Measures and Adjusts for Soil Conductivity	•		•		"Internally Compensated"		•	•
Controller Displays Soil Conductivity	•							
Measures and Adjusts for Soil Temperature	•	•					•	•
Controller Displays Soil Temperature	•	Commercial Models						•
Controller Station Capacity	6, 12, 24, 36 & 64	12-200	8-48	Unlimited	Unlimited	4	Not Applicable	36
Master Valve or Pump Circuit(s)	Commercial Models	Commercial Models	2		Not Applicable		Not Applicable	•
Internal Power Transformer	Commercial Models	Commercial Models	•		Not Applicable	Not Applicable	Not Applicable	•
Battery Powered - DC	Commercial Models			Option Available	1 Model			
Station Circuit Current Rating (Amperes)	0.7	Not Reported	1.5	3 & 10	Not Applicable	Not Applicable	2.5	•
Outdoor Installation	•	• ²	•	• ²	All Models, Commercial option	•	•	•
Rain Gauge or Sensor Compatible w/ Rain Shutoff/Delay	•	•	•		•		•	•
Flow Sensor Compatible	Commercial Models	Commercial Models	•	•	•			•
Additional Sensor Terminals	•	Commercial Models	•	•	•			•
Remote Control Device for Controller	Commercial Models ²	Commercial Models	• ³	•				
System Testing and Diagnostics	•	•	•					•
Surge and/or Lightning Protection	•	•	• ³		•		•	•
SWAT Test Performance Report Available	•	•			•	•	•	•
Scheduling Features								
Fully Automatic Schedule (No Base Schedule Required)	Commercial Models	Commercial Models		Commercial Models			Not Applicable	•
Variable Total Run Times	•	Commercial Models	•	Commercial Models			Not Applicable	•
User May Define Non-Irrigation Days	•	Commercial Models	•		Not Applicable	Not Applicable	Not Applicable	•
Operable in Manual Clock Mode	•	•	•		Not Applicable	Not Applicable	Not Applicable	•
Manual Operation by Station or Program	•	Commercial Models	•		Not Applicable	Not Applicable	Not Applicable	•
Irrigation Schedule Period(s)	Odd/Even, Nth Day & Custom	All options available	7, 14, 21 or 28 day		Not Applicable	Not Applicable	Not Applicable	•
Cycle/Soak Manual Input	•	•	•		Not Applicable	Not Applicable	Not Applicable	•
Cycle/Soak Periods Automatically Calculated					Not Applicable	Not Applicable	Not Applicable	•
Available Start Times	Up to 6 or On Demand	8	6		Not Applicable	Not Applicable	Not Applicable	6
Irrigation Pause/Resume	•	Commercial Models	•		Not Applicable	Not Applicable	Not Applicable	•
Runs Concurrent Stations	•	Commercial Models	•	•	Not Applicable	Not Applicable	Not Applicable	3
Number of Programs	Up to 40	Up to 10	7	2	Not Applicable	Not Applicable	Not Applicable	6
Syringe Cycle or Program	•	Commercial Models	•		Not Applicable	Not Applicable	Not Applicable	•
Review of Recent Irrigation Information	•	Commercial Models	•					•
English and Spanish Languages Display	Commercial Models		•					
Product Support and Warranty								
Warranty	2 Years	5 Years	10 Years	1 Year	1 Year	2 Years	1 Year	For life of contract
Support	On-site Service Technicians	Some Locations	•	Some Locations	Some locations			•
	Telephone or Internet Technicians	•	•	•	•	•	•	•
	Local Distributors	•	•	Some Locations	•		•	•
Installation and Maintenance Requirements								
Professional Installation & Programming Recommended	Commercial Models	Commercial Models	•	Commercial Models	Commercial Models		•	•
Battery Replacement Required	5 to 10 years			Optional		•		No
Cost								
Suggested Retail Prices ³	\$277 - \$2,997	\$149 - \$4,560	\$1,285 - \$4,160	\$525 - \$1,045	\$100 - \$3,146	\$250 and up	\$209	\$0

1 - Reported water savings documentation is published or publically available

2 - Optional add-on feature not included in controller price(s) shown

3 - Prices include controller and soil moisture sensor(s)

**For copies of this report contact
Reclamation's Southern California Area Office in the
Lower Colorado Region at 951-695-5310 or download at:
<http://www.usbr.gov/waterconservation/docs/SmartController.pdf>.**