

RECLAMATION

Managing Water in the West

Weather- and Soil Moisture- Based Landscape Irrigation Scheduling Devices

Technical Review Report—6th Edition



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

August 2018

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Irrigation Scheduling Devices"**

Weather- and Soil Moisture- Based Landscape Irrigation Scheduling Devices

Technical Review Report—6th Edition

prepared by

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Lower Colorado Region
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and

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Technical Service Center
Denver, Colorado**



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August 2018

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Acronyms and Abbreviations

%	percent
°C	degree Celsius
°F	degree Fahrenheit
3G	third generation of wireless mobile telecommunications technology
4G	fourth generation of broadband cellular network technology
A	ampere/amperes
ABS	acrylonitrile butadiene styrene
AC	alternating current
AI	artificial intelligence
Android®	Google mobile operating system
ANSI	American National Standards Institute
app	application software
ASA	automatic seasonal adjustment
ASABE	American Society of Agricultural and Biological Engineers
ASCE	American Society of Civil Engineering
AWG	American Wire Gauge
CAD	computer-aided design
CIMIS	California Irrigation Management Information System
CIT	Center for Irrigation Technology at California State University, Fresno
DC	direct current
DIY	do-it-yourself
DVD	digital versatile disc
EPA	U.S. Environmental Protection Agency
ET	evapotranspiration
ET _o	reference evapotranspiration
FDR	frequency-domain reflectometry
ft	United States survey foot/feet [L]
GHz	gigahertz [T-1]
gpd	gallons per day [L ³ /T]
gpm	gallons per minute
Hz	hertz
HOA	homeowner association
IA	Irrigation Association
ICC	International Code Council
IFTTT	If This Then That
iOS®	Apple mobile operating system
IoT	Internet of Things
IP66	Ingress Protection Code 66

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

IRWD	Irvine Ranch Water District
LAN	local area network
lb/lbs	United States pound/pounds [M]
LCB	Licensed Certifying Body
LCD	liquid-crystal display
LED	light-emitting diode
LTE	Long-Term Evolution
mA	milliamperes
MHz	megahertz [T-1]
MSRP	manufacturer's suggested retail price
MWD	Metropolitan Water District of Southern California
MWDOC	Municipal Water District of Orange County
NOAA	National Oceanic and Atmospheric Administration
PC	personal computer
PDA	personal digital assistant
PLC	powerline communication
PVC	polyvinyl chloride
R3 Study	Residential Runoff Reduction Study
Reclamation	Bureau of Reclamation
SCADA	supervisory control and data acquisition
SWAT	Smart Water Application Technologies
TCM	Total Cycle Management
TDT	time-domain transmissometry
UL	Underwriters Laboratories, Inc. [®]
U.S.	United States
USB	universal serial bus
VAC	volts of alternating current
VDC	volts of direct current
WiFi	wireless networking technology

Acknowledgements

This report was prepared with the assistance of the Bureau of Reclamation (Reclamation), Technical Service Center staff and individuals from other government agencies and private industry. The Technical Service Center's Water Resources Engineering and Management Group (Water, Environmental, and Ecosystems Division) performed product research and coordinated report preparation. Staff from the U.S. Environmental Protection Agency (EPA), Metropolitan Water District of Southern California (MWD), Municipal Water District of Orange County (MWDOC), Irvine Ranch Water District (IRWD), Inland Empire Utilities Agency, Eastern Municipal Water District, and Western Municipal Water District also provided input.

The preparers of this report acknowledge the input provided by these agency and district staff and extend their appreciation to the following individuals: Stephanie Tanner and Julius Duncan, EPA; Joanna Kind, Eastern Research Group, Inc. (for EPA); and Brent Mecham, Irrigation Association® (IA).

Representatives of the reviewed product manufacturers provided product information and approval of their respective product discussion sections in this report. The preparers of this report appreciate each of these individuals' input. It is acknowledged that the report's level of detail could not have been achieved without the significant assistance provided by the product manufacturers' representatives.

Disclaimer

Nothing in this report constitutes endorsement by 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. 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 Brandon House at 303-445-3909 or bhouse@usbr.gov or to Reclamation's Southern California Area Office at 951-695-5310.

Introduction

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

In the late 1990s, IRWD, MWDOC, and MWD learned of an emerging irrigation management technology using weather-based irrigation scheduling devices. This technology removes the need to make manual irrigation scheduling adjustments because the device adjusts the schedule automatically as weather and evapotranspiration (ET) change. A water conservation evaluation of this technology was implemented at 40 sites selected from the top 23 percent (%) of water users in the IRWD service area. This evaluation identified an average single-family home conservation rate of 37 gallons per day (gpd) [Hunt et al., 2001].

In 2004, MWD and East Bay Municipal Utility District received grant funds from the California Department of Water Resources for installation of weather-based irrigation controllers. A post-project evaluation was conducted using data from just under 2,300 sites located in both northern and southern California [Mayer et al., 2009]. It found that, with 95% confidence, water use decreased by an average of 137.9 ± 71.8 thousand gallons per year. It should be noted, even though there was an overall average reduction in water use, 959 sites experienced a statistically significant *increase* in water use. This highlights the fact that smartcontrollers are not a water conservation panacea and high water users should be targeted to achieve a significant reduction. The evaluation found that if a smartcontroller is installed at a location where the landscape is being deficit irrigated, water use is likely to increase.

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 conservation of 42 gpd per single-family home from homes in Irvine, California [Diamond, 2003]. Conservation at nonresidential sites was 545 gpd. The R3 Study also quantified a reduction in runoff ranging from 64 to 71%. 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 conservation resulting from soil moisture-based smart systems are similar to those discussed previously for weather-based systems [DeOreo et al., n.d.; Allen, 1997; Cardenas-Lailhacar et al., 2005; Mecham, 2010].

Introduction

Water agencies throughout the country recognize smart irrigation control as a tool to achieve landscape water conservation and reduce nonpoint source pollution. When the first study began, the study team was aware of only a few smart technologies and manufacturers. Today, over 30 smart irrigation control manufacturers exist, and the technology continues to evolve at a rapid pace.

In 2003, MWDOC approached Reclamation's 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 developments in weather-based controllers and researched other smart irrigation scheduling products, including soil moisture sensor-based and small commercial products. The fifth edition of the Technical Review Report, *Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices*, was published in May 2015. Second, third, and fourth editions of the report were published in August 2007, September 2009, and July 2012, respectively.

This sixth edition of the report includes information on smart irrigation controller products from 24 companies. This information was current as of May 2018. Since the fifth edition, products from 11 companies have been added: Aeon Matrix[®], Inc.; Scotts Miracle-Gro[®]; GreenIQ, Ltd.; Hydro-Rain[®]; MC Smart Controls; Netro[®], Inc.; NxEco[®], Inc.; Orbit Irrigation[®]; Spruce Irrigation; Toro[®]; and Tucor, Inc. Ten companies have been removed due to the company's request, dissolution of business, and unresponsiveness to communication attempts. These include: Acclima, Accurate WeatherSet, Alex-Tronix, Brilliant Integrated Technologies, Cyber Rain[®], HydroPoint, Irrisoft, OnPoint EcoSystems, Rachio[®], and Raindrip. Reclamation is aware of two smartcontroller manufacturers that are not included in the report: Netafim[®] USA and Green Electronics, LLC. Efforts to contact these manufacturers or receive information for this report were ultimately unsuccessful.

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. In addition, some of the stand-alone controllers reviewed possess central control system-type features.

Smart Water Application Technologies® (SWAT) Initiative

In an effort to set an industry benchmark, 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. SWAT has developed performance testing protocols to assess how irrigation controllers perform under various soil and climate conditions. These protocols formed the basis from which EPA developed their WaterSense labeling specifications for weather-based irrigation controllers.



In response to public and water agency interests, SWAT has ceased testing of products and providing testing reports. SWAT found that most water agencies and consumers are more interested in WaterSense labeling conducted by EPA.

The convenience of only requiring WaterSense labeling for inclusion in a smartcontroller incentivization program, for instance, and not needing to review SWAT testing reports is understandably appealing. In light of this, SWAT will focus on developing draft testing

Smart Irrigation Technology Overview

protocols for irrigation equipment that aids in improved water use efficiency and conservation. SWAT and IA will work with the American Society of Agricultural and Biological Engineers (ASABE) to develop the draft protocols into standards that are accredited by the American National Standards Institute (ANSI) to become American National Standards. They are currently working on ANSI standards for weather-based controllers, soil moisture-based controllers, and rain sensors. When complete, it is expected that these standards will be used to inform and update existing codes, standards, and other voluntary programs such as EPA's WaterSense.

SWAT has also developed testing protocols for other water-efficient product categories for residential and light commercial landscape use. Testing protocols have been completed for rain sensors, flow sensors, check valves, and sprinkler heads. The organization has also maintained active involvement in state and Federal policy development on irrigation water conservation.

SWAT plans to continue to focus on and expand its public outreach initiative to water providers, consumers, and contractors. Through the IA website (www.irrigation.org), a wide array of online and in-person classes is available to consumers. Landscape contractor certifications for technicians, auditors, contractors, designers, and water managers are currently available. Contractor-specific classes are also available in both online and in-person formats. Water agencies are also able to sponsor these classes to be taught in their local area.

Testing results for weather-based controller products have been removed from the SWAT website and readers are encouraged to instead refer to the EPA WaterSense database. Results from soil moisture sensor-based products will remain on the website until EPA's WaterSense® Program begins testing and labeling these products.

Until the cessation of offered testing, manufacturers could voluntarily submit their products for testing, by a third-party, based on SWAT protocols. Testing protocols for climatologically/weather- and soil moisture-based irrigation controllers were released in April 2003. These have since undergone revisions with the current climatologically-based testing protocol (8th version), approved in September 2008, and the current soil moisture-based protocol (3rd version), approved in August 2011. The protocols can still be found on the SWAT website (www.irrigation.org/SWAT/).

The Center for Irrigation Technology at California State University, Fresno (CIT), had been conducting SWAT smartcontroller benchmark testing. Weather-based testing began in 2004. The testing was performed in a laboratory environment using a "virtual landscape" that was subjected to a representative climate based on weather station data. The purpose of the testing was to evaluate the ability of a device to adequately and efficiently irrigate the virtual landscape without over or underwatering. Although actual irrigation did not occur, the test calculated the irrigation quantities prescribed by the device for six different zones with varying site conditions (e.g., soil and plant types, ground slope, sun/shade, irrigation system, etc.). The test duration was for 30 consecutive days with a total minimum rainfall and ET of 0.4 inch and 2.5 inches, respectively. Testing results were summarized in performance reports (performance summaries and technical reports), which were posted on the SWAT website (www.irrigation.org/SWAT/) as

test results were released by manufacturers. The performance summaries included percentage scores in the categories of “Irrigation Adequacy” and “Irrigation Excess.” The technical reports also included details associated with these scores.

Soil moisture-based controller testing began in 2003, and was also conducted at CIT. Testing is in a laboratory environment to evaluate the sensors’ ability to provide a consistent calibration curve or setpoints between drying cycles and between individual sensors. The manufacturer provides 20 sensors, and 3 were 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. Certain samples also undergo numerous wet/dry and freeze/thaw cycles in the development of calibration curves. Regression and confidence level analysis results were also presented in the calibration reports.

Soil moisture sensor calibration reports for nine soil moisture sensors from seven manufacturers are available on the SWAT website (www.irrigation.org/SWAT/). 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. Testing per SWAT protocols and releasing test results are voluntary by manufacturers. A few manufacturers indicated concerns regarding the SWAT testing and reported they would not submit their products for testing unless certain protocol changes were made. SWAT testing results are only discussed in this report if they have been released by the manufacturer.

U.S. Environmental Protection Agency WaterSense® Program

In 2006, EPA introduced its voluntary public-private partnership “WaterSense®” (WaterSense) Program. The mission of WaterSense is to protect the future of the United States (U.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.



To receive the WaterSense label, all products must be certified in accordance with the WaterSense Product Certification System (currently, version 2.1 published January 31, 2016). The system requires that products be tested by an approved, third-party Licensed Certifying Body (LCB). Controllers can be tested at either an LCB facility or the product manufacturer’s facility with supervision by LCB personnel. LCBs also perform annual inspections of the manufacturer’s production facilities to ensure adequate quality control measures are in place. In addition, they are required to annually retest 15% of the controllers they evaluate with off-the-shelf acquired units to ensure continuing compliance with WaterSense controller requirements.

Smart Irrigation Technology Overview

On November 3, 2011, EPA published its specifications for testing and certifying weather-based irrigation controllers. Controllers must create or modify irrigation scheduling based on current ET conditions. EPA considered the existing SWAT protocols and worked closely with IA to develop the WaterSense specifications for smartcontrollers. The specifications apply to standalone 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 the “Standalone Controller Versus Add-On Device” section in this report). As of May 2018, over 800 irrigation controller products have received WaterSense certification. These products are listed on the WaterSense website (www.epa.gov/watersense/product-search).

In May 2013, EPA announced its intent to develop a specification for soil moisture-based smartcontrollers similar to the weather-based smartcontrollers. Despite efforts by EPA and ASABE, a satisfactory testing specification has not been found. Soil moisture measurements are sensitive to many environmental factors, which makes standardization difficult. For simplicity, EPA has chosen to focus efforts on developing a specification for bypass-type soil moisture controller add-on devices. These inhibit watering from occurring when soil moisture contents exceed a threshold. Further information on EPA’s efforts to develop a testing specification for bypass-type soil moisture controller add-on devices can be found on the WaterSense website (www.epa.gov/watersense/soil-moisture-based-control-technologies).

EPA has expanded the WaterSense certification of outdoor products to include spray sprinkler bodies with integrated pressure regulation. Spray sprinkler bodies connect an irrigation system to the sprinkler head and provide a consistent flow at the sprinkler head. Efficient sprinklers are an important part of water conservation, which can be realized by a smartcontroller. The specification for spray sprinkler bodies was released on September 21, 2017. The specification includes a test method based on the *ASABE/ICC 802-2014: Landscape Irrigation Sprinkler and Emitter Standard* and outlines requirements for verifying the product effectively regulates pressure to the sprinkler head. As of May 2018, 21 spray sprinkler body products from one manufacturer have received WaterSense certification.

The WaterSense website (www.epa.gov/watersense/outdoors) also offers a variety of other landscape irrigation water conservation tools and ideas. Ideas for selecting plants that consume less water are presented through state-specific plant databases and studies, to a photo gallery of water conservation landscape conversions. Landscape irrigation professionals can also receive a WaterSense certification through a series of courses and exams offered in conjunction with IA. A water budgeting tool, local ETo, and local rainfall estimator are also available. These are helpful for developing base irrigation schedules, which are required by certain smartcontrollers.

Texas A&M Smart Irrigation Controller Evaluation Program

In 2008, the Irrigation Technology Center at the Texas A&M AgriLife Extension in College Station, Texas, established the “Smart Irrigation Controller Testing Facility.” The facility was developed to evaluate what testing criteria should be considered when benchmarking the performance of a smartcontroller for Texas consumers. The facility also evaluates the

performance of smartcontroller technology as a whole. The facility has compiled multiple *Evaluation of Smart Irrigation Controllers* reports documenting their findings through continued testing of nine smartcontrollers from seven manufacturers. Reports are available on their website (itc.tamu.edu/smart.php).

Reported Water Conservation

Weather-based smartcontrollers attempt to supply an adequate amount of water to vegetation in order to replace ET losses. Water conservation is realized when a user was consistently or occasionally over-irrigating their landscape prior to installation of a smartcontroller. In cases where a user is initially deficit irrigating their landscape, installation of a smartcontroller is likely to increase water use. Under controlled, research conditions, water conservation of 40 to 70% can be concluded. However, when larger scale studies are conducted, conservation can be less than 10%. This discrepancy can likely be attributed to the larger scale smartcontroller installation programs not targeting high water users—likely over-irrigators [Dukes, 2012b].

It is important to note that water conservation, especially percent reduction, can be calculated by numerous methods and verification can be difficult. Regardless of a product's reported water conservation potential, actual conservation will vary significantly from user to user depending on pre-installation irrigation habits, irrigation system, and site conditions. It is imperative that weather conditions be considered when calculating water conservation. A properly installed irrigation system (e.g., piping, sprinkler heads, spray sprinkler bodies, etc.) with acceptable distribution uniformity is critical to realizing water conservation and maintaining a healthy landscape.

No Rating of Products

No attempt has been made in this report to rate the products relative to each other. Certain comparison criteria are discussed, but it is left up to the reader to research further and determine which products may suit their application.

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 ET, which is a function of weather conditions and plant type. ET is defined as the quantity of moisture that is both transpired by a 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 parameters are maximum and minimum air temperature, net solar radiation, average vapor pressure, and average wind speed [Allen et al., 2005]. 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 that 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 use 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 generate watering schedules automatically. Others require the user to enter a base daily irrigation schedule, and then the device determines the frequency (which days) irrigation occurs or adjusts run times. Some of these partially automated systems provide guidelines for establishing the base schedule while 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. Even some

Weather-Based Irrigation Control System Principles

weather station data may not be adequate for ET calculation. Specifically, some weather stations do not measure radiation directly but calculate it from other parameters, while some stations are not properly located for ET parameter 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 U.S.

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, study results were submitted by manufacturers showing accurate ET calculation and/or significant water conservation associated with their product as discussed under the product descriptions in this report. In addition to the SWAT testing previously discussed, 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].

Weather-Based Control Product Features and Comparison Criteria

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

Installation

Many manufacturers recommend professional installation and programming of their products, while several indicate installation and programming of their residential models can be done by “do-it-yourself” (DIY)-type homeowners. However, 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 on their respective websites. 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 rebate programs, water agencies should consider requiring professional installation or requiring users to attend workshops to receive training before performing self-installation. Several review studies have found that proper installation and programming of smart controllers is vital to the device supplying an adequate amount of water, which is how conservation can be realized [Mayer and DeOreo, 2010; Dukes, 2012a].

Standalone 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 standalone 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—EPA’s WaterSense defines these as plug-in devices.

Weather-Based Control Product Features and Comparison Criteria

A number of inexpensive, add-on type devices are available on the market, but do not qualify as a “smartcontroller add-on” as they fail to adjust irrigation scheduling. These essentially act as an irrigation switch by interrupting the common power wire from an existing controller to the solenoid valves when certain criteria are met. Criteria are based on local weather, and the user can also interrupt irrigation remotely via a companion smartphone application software (app). These types of devices cannot automatically initiate irrigation or adjust watering times, but disallow watering when, for example, rain is forecasted for the area. While these devices certainly have their merit, including ease of installation and price, they simply do not meet the criteria to be covered in this report.

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. This gives 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 (e.g., 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

Most standalone controllers provide multiple run and soak times to limit runoff (cycle/soak). Some calculate cycle/soak times 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, multiple cycle/soak cycles by zone is an advantageous feature.

Landscape Establishment/Fertilizer and Syringe Programs

Some standalone 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 can be used for installation and system testing purposes. The program provides a convenient means of executing a short run time for each station. Syringe cycles can also be used during hot periods of the day to prevent scorching damage to turf. No controllers in this report automatically schedule syringe cycles.

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\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 a 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

Weather-Based Control Product Features and Comparison Criteria

expands when wetted. Tipping bucket-type gauges are generally more accurate than 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

Most of the standalone 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 add-on scheduling devices operate on either 24 VAC or 9 volts of direct current (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. In addition, 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. This could lead to problems with cost, maintenance, and accessibility, among other factors. An option for a majority of smartcontrollers is the ability to use a two-wire system in lieu of the traditional, multiwire configuration. The two-wire system eliminates the need for separate wires at each valve and sensor, replacing the wires with a single two-wire path. A decoder is required at each connection to a valve or sensor. In some applications, the two-wire system could lead to a large savings in wiring costs, as well as simplifying installation—linear systems like highway corridors and greenbelts where large quantities of wiring would be required for traditional circuitry. This can allow for flexibility in the controller location, and the two-wire approach streamlines the process of adding zones to the irrigation system.

Another alternative to the traditional wiring circuitry is the emerging use of wireless valve control systems. Solenoids are signaled via a radio transmitter connected to the irrigation controller. If the radio signal is lost, outputs will go back to user-defined conditions until the signal is re-acquired. What sets the wireless systems apart from the other two options is the ease of installation and modular additions to the irrigation system, since no wires are required. The technology is still very new and has had limited use, unlike the traditional and two-wire systems.

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. Few of the controllers that receive a scheduling signal do not have clock mode capability. For those that do not, if the signal subscription is cancelled, the controller must be replaced.

Display and Data Review

It is likely advantageous for a device to have a large, easy-to-read display that shows 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. Several controllers have the ability to display this information remotely through either a web browser or companion smartphone app.

Batteries and Nonvolatile Memory

All of the products reviewed have nonvolatile memory to retain 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.

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 their respective product descriptions for input prior to being incorporated into this report.

Aeon Matrix, Inc.

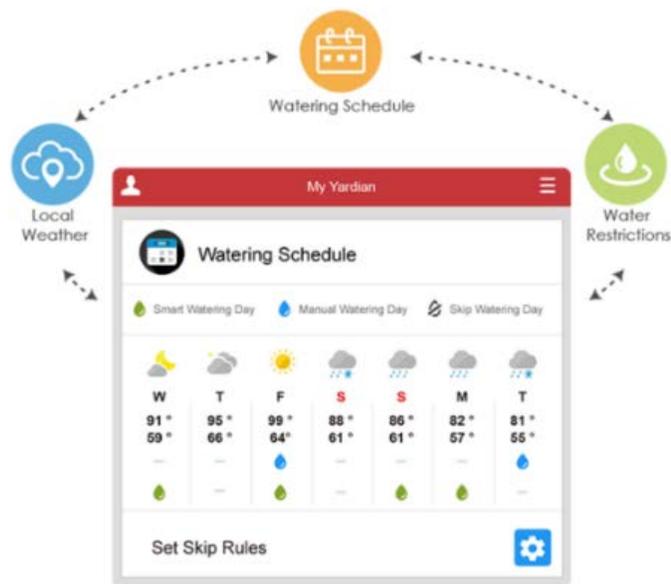
Aeon Matrix, Inc., was founded in 2014 with a mission to care for people and the world where they live, play, and work. They are the manufacturers of the Yardian® (Yardian) irrigation controller. The company is headquartered in Taipei City, Taiwan, with offices in Milpitas, California.

The Yardian is a standalone smartcontroller that is suitable for residential and light commercial applications in the U.S. and Canada. It creates an irrigation watering schedule informed by user-entered physical information by zone, local weather, and local watering restrictions. Manual programming is not necessary as the unit can automatically generate a watering schedule. If there is rain in the local weather forecast within the following 24 hours, the unit will suspend watering. An onsite rain sensor can also be connected to the unit, and the collected data can be shared between all Yardian controllers in the vicinity. The Yardian uses data from the rain sensor to interrupt/delay watering and adjust the irrigation schedule. Manual operation is also possible with an automatic adjustment for the time of year—updated on a monthly time step. A scheduling feature unique to the Yardian is its access to a proprietary database of local governmental water restrictions. It is programmed with the ability to split station run times into shorter durations to allow infiltration of applied water before application of additional water (cycle/soak). This is helpful in reducing irrigation water runoff. The Yardian comes equipped with WiFi and/or powerline communication (PLC) to collect the various sources of data from the internet used to adjust the irrigation schedule. If the internet connection is lost, the unit will use data backed up internally to continue making schedule adjustments. Once an internet connection is established, the Yardian can be interfaced with via a smartphone app. All setup and scheduling can be done through the app. The Yardian can also be accessed and controlled through a website interface.



Weather-Based Product Descriptions

The Yardian comes standard with a 720-pixel high-definition security camera with a 130-degree field of view, night vision, and light sensor. Live feed from the camera can be viewed anywhere via the companion smartphone app. For privacy, live streaming is transmitted encrypted directly to the user's smartphone and does not get stored on a remote server accessible through the internet (the cloud). The Yardian can also be set to notify the user when any motion is detected and collect a video clip. Aeon Matrix, Inc., has plans to extend these capabilities to include time-lapse videos for quick review of how the Yardian's field of view has changed over days, months, seasons, or years. One-day cloud storage for motion-activated videos is stored for free by Aeon Matrix, Inc.—additional storage can be purchased. Stored videos can be viewed and downloaded via the smartphone app. Aeon Matrix, Inc., also offers a weatherproof junction box (Tbox) that allows the sprinkler wiring to be located up to 3.6 feet (ft) away from the Yardian, providing versatility as to where the unit can be located.



The Yardian receives firmware updates, new software, configuration settings, and security enhancements automatically through its internet connection. It can also be controlled with a third-party, home-integration web-service *If This Then That* (IFTTT). This provides a framework that allows the user to write custom applications or actions for the controller. The Yardian also integrates with Amazon's Alexa® AI assistant. Aeon Matrix, Inc., suggests that these capabilities will allow the Yardian to persist through technological advancement in the future and prevent it from becoming obsolete. The Yardian is also certified for use with Apple, Inc.'s MFi® Program.

Operational Features

The Yardian comes standard in a weatherproof box suitable for outdoor installation. The controller comes in 8- and 12-zone capacity models. Both units can be connected to a master valve and any normally open/closed rain sensor. The controller is self-surge protected and can automatically detect faulty, short-circuited valves. The unit can be powered with 100 to 240 VAC, 50/60 hertz (Hz), and comes with a 6-ft power cord. The unit outputs 24 VAC, 750 milliamperes (mA) to the system. Internet connectivity can be established by either a 2.4-gigahertz (GHz) 802.11 b/g/n wireless standard WiFi, 2T2R router, or PLC (on select models). The companion app can be used on smartphone and tablet devices running Apple, Inc.'s iOS 9.0+ or Google's Android 4.1+ mobile operating systems.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Physically, the unit measures 7.875 inches long by 7.875 inches high by 2.75 inches wide and weighs in at 2.2 pounds (lbs). The unit is intended to be wall-mounted and will accept 14 to 22 American Wire Gauge (AWG) wire.

Descriptions, Prices, and Warranty

The Yardian comes standard with WiFi and has a manufacturer's suggested retail price (MSRP) \$200 for the 8-zone and \$225 for the 12-zone capacity models. The option is available to add PLC connectivity for \$50. All models can be connected to a master valve and rain sensor. All updates are free and no subscription fees are charged. Cloud storage of security camera footage is free for 1 day's worth of video. Additional storage is available for a fee.

Each Yardian comes with a 2-year, transferable limited warranty and a 30-day money-back satisfaction guaranty.

Installation

According to Aeon Matrix, Inc., professional installation and setup are not necessary if the user has some basic electrical knowledge. Approximately 30 to 60 minutes are needed. Setup is done through a companion smartphone application. Users are prompted to enter physical information about each zone including: plant type, soil type, sun exposure, sprinkler head type, and topographic slope. Using this information, local weather, and local water restrictions, the Yardian generates a watering schedule automatically for each zone. An instructional video and tutorial are available on the company's website (<https://us.yardian.com>). Once the app is set up, zones can be cycled immediately, which can be useful for watering system checking and configuration.

WaterSense Certification, Track Record, and Awards

The Yardian received EPA WaterSense Certification in 2017. Aeon Matrix, Inc., received the "2017 Top of Innovation Award" at the SMAhome International Exhibition and Conference for the Yardian.

Calsense

Calsense was founded in 1986 in Carlsbad, California. The company engineers water conservation and resource management technology specific to the large residential and light commercial sector of the irrigation industry. The company's target customers are parks, schools, large residences, and homeowner associations (HOAs). Calsense controllers can interface with various sensors such as flow, moisture, wind, rain, soil moisture, and ET. Controllers can be monitored and controlled remotely anytime, from anywhere using the Calsense Command Center Online central control software backed up to the cloud. Since 1986, Calsense has remained dedicated to water efficiency through not just weather-based irrigation, but also flow monitoring, soil moisture sensing, and managing water budgets.

Weather-Based Product Descriptions

Operational Features

The CS3000 is Calsense's irrigation controller that can be set up to operate as a weather-based irrigation controller. It automatically calculates station run times based on landscape details such as plant material, head type, and sun exposure. The CS3000's options are modular, which means stations, lights, communication modems, points of connections, and weather options can be added or removed in the field. The wall mount box is made of 16 AWG stainless steel and a transient protection board is included, which protects the controller and attached options against high voltages—such as lightning strikes.



The CS3000 provides a wide range of programming flexibility, including:

- ◆ Unlimited programs that can water individual stations or be interspersed to maximize system capacity and reduce watering time
- ◆ Ability to assign landscape details such as plant material, head type, and sun exposure to groups of stations to simplify programming stations with similar characteristics
- ◆ Support for managing flow on up to 4 mainlines and 12 points of connection simultaneously when sharing flow with multiple controllers
- ◆ Automatic cycle and soak scheduling to water each station for a fixed cycle time and allow the water to soak in between cycles, maximizing infiltration and minimizing runoff
- ◆ Ability to accommodate multiple types of irrigation schedules including irrigating even days, odd days, prescribed days of the week, and interval scheduling ranging from every other day up to every 4 weeks
- ◆ Predictive water budget feature that aids in conservation during drought conditions by automatically deciding where to take water from when bumping into the budget while maintaining guidelines
- ◆ Manual programs that allow the user to schedule stations to run for a preset time, up to six times per day, for hydroseeding and new planting
- ◆ Electrical alerts, such as short circuits and no currents, to help the user troubleshoot field wiring and solenoid problems
- ◆ Permanent memory that stores all controller programming and setup data, including date and time, in non-erasable memory

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

- ◆ Availability in multiple station counts including 8, 16, 24, 32, 40, or 48 stations. If initially less than 48 stations are purchased, additional stations can be added at any time in the field.
- ◆ Support for up to 128 stations when using 2-Wire. This can either be 128 2-Wire stations, or when combined with conventional-wired stations, up to 80 2-Wire stations and up to 48 conventional wires.

The CS3000 works with the Calsense Flow Meter (model FM) and third-party hydrometers to continuously monitor real-time flow through the irrigation mainline. This feature detects and alerts the user to mainline breaks, high flows caused by broken risers and pipes on each individual station, and low flows due to malfunctioning or shutdown valves. Since the CS3000 can use real-time flow measuring, it is able to maintain a record of water usage. Scheduled irrigation usage can be recorded on a mainline, point of connection, and station-by-station basis. Unscheduled water usage, along with non-controller water usage, is recorded and shown using built-in reports.

The CS3000 includes a wide range of water reports available directly from the controller, including:

- ◆ A summary of all usage for each irrigation mainline
- ◆ Usage of each point of connection connected to the mainline
- ◆ Station-by-station usage
- ◆ A complete station-by-station history that includes the date and start time of each cycle, programmed minutes, programmed in, number of cycles, actual flow rate, expected flow rate, and any alerts that occurred during irrigation

Calsense's FLOWSENSE® (model CS3-FL)(FLOWSENSE) allows multiple controllers to share an internet-connected central communication option, master valves, flowmeters, and pumps, as well as real-time weather data from devices such as an ET gauge, tipping rain bucket, and/or third-party rain and freeze sensors. This sharing is accomplished through a two-way communication link between the controllers in the field using the Hardwire (models CS3-M and CS3-MSSE) or Spread Spectrum Radio (model CS3-SR) options.

The FLOWSENSE technology is designed to allow the user to set up and operate this feature directly in the field with the Calsense CS3000 controller. No other software is required.

Benefits of FLOWSENSE include:

- ◆ Ability to share a single internet-connected central communication device
- ◆ Synchronizes programming across controllers so any controller on the chain can be programmed from any other controller in that chain

Weather-Based Product Descriptions

- Eliminates the need for additional relays when sharing pumps or master valves with several controllers
- Manages the number of valves that can be turned on at a time based on mainline flow capacities
- Eliminates scheduling conflicts with multiple controllers
- Provides water management capabilities with or without a flowmeter

With FLOWSENSE, the user can control the number of valves turned on based on the flow capacities of each mainline. This minimizes the water window; thus, the allowable mainline flow rate is never exceeded, ensuring pumps operate at their capacity and each irrigation mainline functions at maximum efficiency.

The CS3000 also has the capability of managing flow on up to four mainlines simultaneously, all controlled in the field by the CS3000. Additionally, turning on stations by using the manual feature or any internet-connected device, including smartphones, ensures that the maximum capacity of each mainline is not exceeded even during programmed irrigation.

Programming the CS3000 is performed at the controller, or from a computer or smartphone via WiFi.

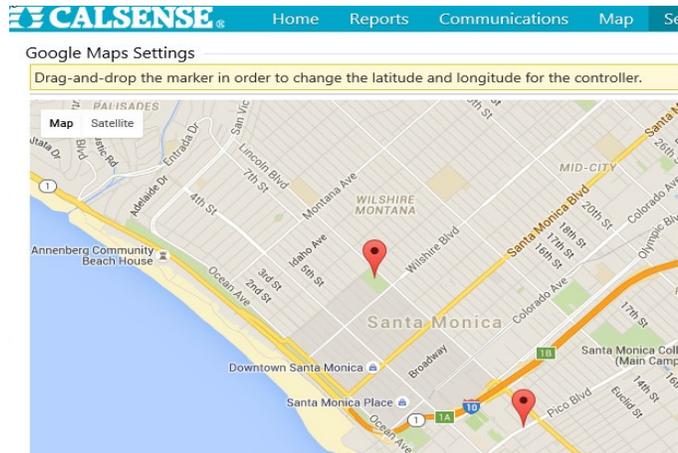


Calsense's computer interface dashboard.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

WEATHERSENSE is a free service provided with the Calsense Cloud-based Command Center Online central control software. It provides users with real-time ET and rain data without the need for an onsite ET or rain gauge. Information is automatically distributed daily to controllers in the field.

The service provides real-time ET and rain estimates to any location within the U.S. using aggregated data from more than 25,000 weather stations combined with computer-modeled near-surface weather conditions. The high-resolution modeled data are meant to ensure current conditions are accurate even in areas with localized microclimates. The controller location is input into the Command Center Online map, and then ET and rain estimates are provided for each controller's latitude and longitude.



At the start of an irrigation day (typically 8:00 p.m.) the previous day's ET value is stored for historical purposes. The controller then uses the new daily ET value to calculate each station's irrigation time based on the total ET for all days since the last irrigation. By using the onsite physical conditions such as plant material, head type, and exposure, the controller automatically determines how long to run each cycle for and soak between cycles to minimize runoff. Using a station adjust factor, each station can be adjusted by the user to compensate for further considerations such as soil conditions.

The Calsense CS3-RR offers a rugged, waterproof Android® 4.4 Kit Kat® smartphone for radio remote capabilities with the Calsense CS3000 controller. Turning valves "ON" and "OFF" while at a project site provides an easy way to troubleshoot problem valves and landscape areas. Stations can be selected and viewed with their landscape description and corresponding flow rate, along with a countdown dial with the minutes remaining in the manual operation. Included with the CS3-RR is a 1-year prepaid data plan and a 3-year comprehensive warranty.

Calsense Command Center Online is a cloud-based package designed to provide complete irrigation control. It is specifically designed for easy operation and requires no prior computer experience. Flow and electrical issues in the field are pinpointed in a "Daily Alerts" report that lists the causes and locations of problems.



Weather-Based Product Descriptions

Each customer's service is unique and password protected, for data security. User accounts are issued and managed by an administrator account so that only authorized users can access controller information. Programming changes can be made to the irrigation system without having to go to the field. Daily weather information can be shared automatically to adjust station run times. Decisions made and actions taken are based on real-time conditions of the landscape through the reporting capabilities of the system. 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 occurred at the controller. System administrators have management reports listing sites and users for their company.

Calsense provides several flexible options for communication between the central computer and field units. The primary ways to communicate with Calsense CS3000 controllers are cellular, WiFi, and Ethernet. Each of these options can also be shared by a chain of controllers with FLOWSENSE.

Descriptions, Prices, and Warranty

The CS3000 is available in 8-, 16-, 24-, 32-, 40-, and 48-station, conventionally-wired models. It can also be ordered as a 2-wire controller with a capacity of up to 128 stations anywhere along a 7,000-ft cable run with the use of the Calsense CS-2W-ST decoder. Calsense also offers the flexibility of a hybrid controller, both as a conventional and 2-wire controller up to 128 stations. If a CS3-48-WM controller is installed to handle 48 existing conventional wires, the model CS3-2W-OPT (2-wire option) can be plugged into the controller in the field, providing up to an additional 80 valves (using 2-wire) for new phases of construction or retrofits to any landscape project.

The CS3000 has an unlimited number of regular programs that can be created based on similar hydrozones. Drop-down menus offer a way to select plant type, head type, application rate, soil type and soil holding capacity, exposure, slope, and crop coefficients for each station group. A maximum number of start times or repeats per station is determined by station total minutes (programmed or ET-calculated) and by calculated cycle and soak minutes based on soil type, slope, and application rates and distribution uniformity.

The user can select a 7-day watering schedule (or every other day; every third day; or every 2-, 3-, or 4-weeks) to accommodate any type of water restrictions or guideline. No water days can also be designated for each station group for so many calendar days. Irrigation is resumed automatically after the days have elapsed. Programs can operate simultaneously based on the system capacity of the mainline and pump efficiency. The CS3000 is typically installed by a landscape contractor, and then Calsense provides programming assistance and troubleshooting service at no charge to the user following the landscape establishment period.

The CS3000's front panel includes an ergonomic key layout and has a 5.7-inch backlit, ¼ Video Graphics Array, sunlight-readable, liquid-crystal display (LCD) where information can be viewed on the same screen, and with a scrolling side menu design that makes programming intuitive and easy to follow.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

The controller has nonvolatile memory, and the clock maintains time during power outages, powered through an internal transformer, without the need for a backup battery. The controller will accept up to 14 AWG wire, and the station current capacity is 1.5 amperes (A). Optional alternating current (AC) powerline overload protection consists of a sealed unit suitable for outdoor installation and carries full Underwriters Laboratories, Inc.[®] (UL), approval. The CS3000 will detect, alert, and identify open and shorted circuits in field wires and solenoids. The affected station is skipped until repaired.

The CS3000 has several enclosure options that include single- and double-wide units, preassembled at the Calsense factory for turnkey installations. The enclosures are constructed of heavy-duty stainless steel (12 AWG for the flip-top and 14 AWG for the body) for weather- and vandal-resistance. The units come complete with transient and lightning protection, factory-labeled terminals, a ground-fault circuit interrupter outlet, and a keyed switch.

The CS3000 with station cards and mounting accessories, and the stainless steel enclosure with transient protection boards are made and assembled in the U.S.

Warranty

Calsense warrants its manufactured products against defects in material and workmanship for a period of 10 years from the date of original purchase by the original purchaser. Manufactured products include all Calsense irrigation controllers, transient protection boards, modular cards and terminals, and Calsense enclosures.

All peripheral, accessory, and communication devices; radio frequency equipment; and ancillary items such as (but not limited to) ET gauges, flow meters, and rain buckets, used in conjunction with Calsense irrigation controllers, have distinct warranties of their own and should be noted separately from this warranty. Calsense warrants 2-wire decoders and moisture sensors for a period of 5 years from the date of original purchase by the consumer.

The standard warranty will be extended to cover lightning damage if the controllers and/or 2-wire decoders are in accordance with the manufacturer's installation instructions for each item installed, the National Electrical Code, and the grounding instructions.

Calsense provides ongoing customer education, support, and service. Customers, in turn, provide feedback and continue to help Calsense improve and enhance their product line, communicating directly through field service back to engineering.

Weather-Based Product Descriptions

Calsense Product Pricing Summary

Description	Model	MSRP
Wall Mount Controllers		
8-Station CS3000 Controller	CS3-8-WM	\$2,099
16-Station CS3000 Controller	CS3-16-WM	\$2,624
24-Station CS3000 Controller	CS3-24-WM	\$3,149
32-Station CS3000 Controller	CS3-32-WM	\$3,674
40-Station CS3000 Controller	CS3-40-WM	\$4,199
48-Station CS3000 Controller	CS3-48-WM	\$4,724
2-Wire CS3000 Controller	CS3-2W-WM	\$2,199
Additional Components		
2-Station Decoder	CS-2W-ST	\$210
POC Decoder for a Flow Sensor and Master Valve	CS-2W-POC	\$375
Soil Moisture Sensor Decoder With 1-Station Output	CS-2W-MOIST	\$775
2-Wire Terminal to Add to Conventional Controller	CS3-2WIRE-OPT	\$525
AC Line Protection	TP-110	\$205
Flow Sensors		
1-Inch Brass Tee-Mounted Flow Meter	FM-1B	\$595
1¼-Inch Brass Tee-Mounted Flow Meter	FM-1.25B	\$645
1½-Inch PVC Sch 80 Tee-Mounted Flow Meter	FM-1.5	\$510
2-Inch PVC Sch 80 Tee-Mounted Flow Meter	FM-2	\$530
Communication Options for Web Software		
4G LTE Cellular Modem	CS3-GR	\$1,595
1-Year Prepaid Data Plan for 1 to 2 Controllers	COMM-1YR	\$175
5-Year Prepaid Data Plan for 1 to 2 Controllers	COMM-5YR	\$750
WiFi Device for an Existing WiFi Network	CS3-WEN	\$1,250
Ethernet Device for CAT 5 or 6 Network Cable	CS3-EN	\$625

Calsense products are available from many distributors located throughout the U.S. A list of Calsense authorized distributors is available on the website (www.calsense.com).

Installation

Calsense recommends professional installation of the CS3000, and installation time varies significantly depending on site conditions. Typical installation cost for the wall mount controller is \$275 to \$325 for all materials and labor.

WaterSense Certification, Track Record, and Awards

Calsense is a partner in the EPA WaterSense Program. The CS3000 was certified with the EPA WaterSense label in March 2016, as a weather-based irrigation controller. As a WaterSense partner, Calsense shares in EPA's vision to protect and preserve the Nation's water supply by ensuring they meet Federal standards of efficiency.

Calsense has participated in demonstration projects by offering prospective customers their Demo Program, and its track record speaks for itself. During the company's 30-plus years of existence, they have developed a large database on their products' performance and customer reviews.

Calsense provides potential customers with a reference list of past and current users so they can learn of their personal and professional experience with the company.

GreenIQ

GreenIQ manufactures the Smart Garden Hub irrigation controller and is headquartered in Israel. The Smart Garden Hub controller entered the market in 2013. There are three Smart Garden Hub controller models (WiFi, 3G, and LTE-M), and all of them can be controlled from anywhere through an Android® or iOS® app, tablet, or personal computer (PC).



Operational Features

The Smart Garden Hub can be installed as a new standalone controller or one that replaces an existing clock-type controller. GreenIQ states that the controllers are easy to install and set up. In addition to instantaneous control, the Smart Garden Hub controllers can be set to automatically adjust irrigation schedules. They can program irrigation scheduling based on current and forecasted weather using public or private weather stations.

GreenIQ developed an IoT platform for efficient landscape irrigation and the Smart Garden Hub is the endpoint of the system. It can be controlled using the GreenIQ dashboard or third-party software using GreenIQ's application program interface. GreenIQ's IoT platform enables connectivity to multiple sensors to enhance irrigation and to a flowmeter that provides leaks and pipe break alerts.

The Smart Garden Hub automatically check weather forecasts using public weather stations via Weather Underground® or DarkSky®, and schedules irrigations based on ET and precipitation data to match soil moisture depletion. Alternatively, the controller can receive data from onsite weather stations, such as Davis Instruments or Netatmo. Weather and schedule adjustments are

Weather-Based Product Descriptions

updated automatically; the user does not need to be online nor does a computer need to be on. The GreenIQ Cloud-based software communicates with each Smart Garden Hub on a daily basis via WiFi or cellular connection to send any required watering adjustments.

The Smart Garden Hub can accommodate schedule constraints, 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 and photo for recognition (e.g., “Front Lawn”), adjust the total station run times by a percentage factor, and initiate manual irrigations by zone.



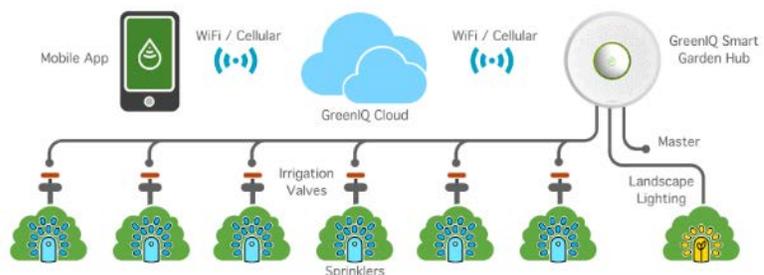
GreenIQ’s irrigation scheduling algorithms are based on real-time local weather data and weather forecasts combined with landscape information to estimate soil moisture depletion. The Smart Garden Hub can be configured with cycle/soak irrigation events to eliminate or reduce runoff, or to allow multiple watering cycles per day, per zone. The Smart Garden Hub uses rain data and will suspend irrigation events if rain is forecasted within the next 24 hours. In colder weather, the Smart Garden Hub automatically suspends irrigation events when the temperature forecast approaches the freezing point.

To enter landscape information, users go to the smartphone app and log into their account using their email address and password. Options include plant/vegetation type, irrigation emitter type, and cycle/soak configuration. After the initial setup and schedule confirmation, no further user intervention should be required.

The Smart Garden Hub connects to a wide variety of smart devices and sensors. This includes connection to outdoor lighting systems or fertilizer for automatic control. The controllers are also compatible with several home automation systems including Amazon Echo®, Google Home®, Nest®, Apple Watch®, Conrad Connect, Crestron®, and Control4®.

Descriptions, Prices and Warranty

The Smart Garden Hub controllers are available in 8- and 16-station models. In addition to the regular station circuits, the controllers provide a master valve/pump start



Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

circuit. The Smart Garden Hub is designed for indoor installation, but an outdoor IP55 waterproof box is approved for outdoor use. The dimensions for both models are 6.3 inches in diameter and 1.06 inches in depth.

Up to three soil moisture sensors, a weather station, and rain gauge/sensor can be connected to the controllers to maximize performance. A flowmeter can be connected and control of outdoor lighting fixtures is available with the addition of a lighting control relay (purchased separately). There is also an output port for a fertilizer pump channel.

GreenIQ controllers are powered via a 24-VAC external transformer and works with all 24-VAC irrigation systems. The Smart Garden Hub 8 and 16 controllers' connection terminal will accept existing wire sizes typical for irrigation systems (26 AWG to 14 AWG) and the circuit current rating is 1 A.



The Smart Garden Hub 8 is \$200 and the 16 is \$250. Flowmeter prices range from \$20 to \$40 and the lighting control relay price is \$35. Both controller units, flowmeters, and lighting control relays can be purchased online at GreenIQ's website (www.greeniq.com) or online from numerous "big box" retailers.

A manufacturer's warranty covers the Smart Garden Hub against defects in materials and workmanship for a period of 2 years from the date of purchase. There are no subscription fees for use or access to GreenIQ's Cloud-based apps. Software and firmware updates are free and automatically pushed to all Smart Garden Hubs.

Installation

GreenIQ states typical homeowner installation and programming time is under 30 minutes. During installation, the Smart Garden Hub automatically detects each connected sprinkler valve by performing a circuit test to validate the wiring for each zone. An installation video can be found on YouTube® (<https://youtu.be/Cmv2bEKN0p0>).

Technical support is available by toll-free telephone (800-972-5612) and via the company's website (www.greeniq.com).

WaterSense Certification, Track Record, and Awards

GreenIQ states the Smart Garden Hub controllers have all been tested to the highest industry standards, are EPA WaterSense-certified, and SWAT tested. The controllers qualify for rebates, up to the cost of the controller, in some water districts and utilities in the U.S.

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 line of WiFi standalone controllers which, when used in conjunction with the company’s Hydrowise™ (Hydrowise) software, are weather-based controllers. They also offer an add-on device for use with Hunter’s other controllers (Solar Sync™ [Solar Sync]). Hydrowise controllers make irrigation scheduling adjustments based on the local weather forecast, which it receives over the internet. The Solar Sync is an onsite weather sensor array that adjusts irrigation scheduling for many of Hunter’s other irrigation controllers. It is compatible with most Hunter irrigation controllers equipped with Solar Sync technology. Solar Sync is not compatible with other brands of controllers. Depending on the controller, Solar Sync is suitable for residential and commercial applications. Hunter also offers a soil moisture sensor-based product, which is covered in the “Soil Moisture-Based Product Descriptions” section in this report.

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 on Hunter controllers. Similar to Hunter’s 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 the Hunter X-Core, Pro-C®, PCC, ICC2, I-Core®, ACC, and ACC2 controllers, which all have Solar Sync logic and Seasonal Adjustment built in as standard features.



Operational Features

Hunter’s Hydrowise-ready controllers include the HC, HPC Face Panel, and Pro-HC. The HPC Face Panel can be used to upgrade Hunter Pro-C® controllers to be Hydrowise-ready. Hunter offers a free version of the Hydrowise software for both homeowners and contractors. Subscriptions are also available that have more features and functions. Hunter’s homeowner pay subscription service (Enthusiast Level) uses data from over 100,000 weather stations and the irrigation



Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

schedule is updated hourly. If a user opts for the free subscription service, weather stations from nearby airports are used (approximately 10,000 stations) and irrigation scheduling adjustments are updated daily. Hunter also offers a series of Contractor Level subscription services, some of which include free Enthusiast Level plans. This could be an attractive option for districts considering using Hydrowise controllers.

Hydrawise creates irrigation schedule adjustments based on forecasted temperature, rainfall, humidity, and wind speed. In addition to weather forecast data, Hydrowise controllers can also be connected to onsite sensors including a flowmeter (HC Flow Meter), rain sensor (Rain-Clik[®]), and freezing temperature sensor (Freeze-Clik[®]). Flowmeter data are used to notify the user of potential breaks and track water usage. They can be purchased for 0.75-, 1-, 1.5-, and 2-inch pipe and are accurate to $\pm 2\%$. Hydrowise controllers can also be integrated with common smart home products (e.g., Amazon's Alexa[®] AI assistant). All Hydrowise controllers come standard with a full-color, 2.7-inch touchscreen.

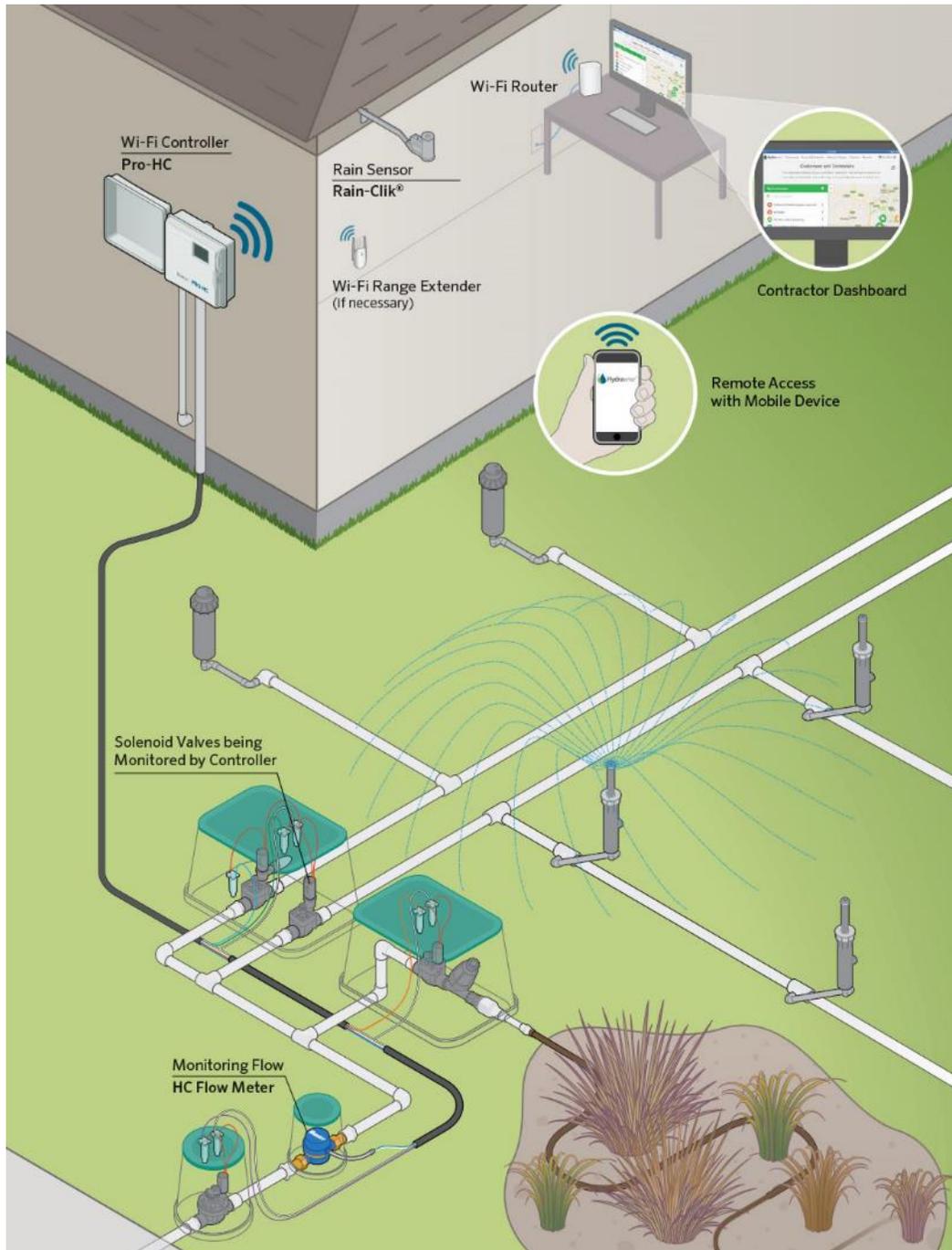
Hydrawise controllers can generate watering schedule automatically based on zone-by-zone parameters entered by the user. Hydrowise controller setup can be completed entirely on the companion smartphone app or web browser-based interface. All Hydrowise controllers have built-in solenoid circuit testing. If an error is detected, a notification can be automatically sent to the user. Irrigation can also be initiated manually from the unit. A wide variety of tools designed for landscape contractors is also available through the Hydrowise website, including the ability to manage over 200 controllers (www.hydrawise.com).

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 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 Soil-Clik[™] to maximize its products' environmentally responsive controls. Details for the Soil-Clik can be found in the "Soil Moisture-Based Product Descriptions" section in this report.

Weather-Based Product Descriptions



Descriptions, Prices, and Warranty

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

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Solar Sync is also available in a license-free wireless version for line-of-sight distances up to 800 ft, when it is not practical to run wiring from the controller to the optimum mounting location. The wireless Solar Sync 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.

Solar Sync is available from Hunter distributors worldwide and further information can be found on Hunter’s website (<https://www.hunterindustries.com/>). Retail price for the Solar Sync sensor are \$120, or \$225 for the wireless version. The price for compatible Hunter controllers range from \$115 to \$2,250. Solar Sync comes with a 5-year workmanship warranty from the manufacturing date. The wireless model also includes a 10-year battery warranty.

Hydrawise controllers will accept station wiring ranging from 14 to 20 AWG. The HPC-FP and Pro-HC models can be ordered in a lockable cabinet suitable for outdoor installation. The HC model can accommodate 6 to 36 zones with the addition of 12-zone modules. The unit measures 6 by 7 by 1.3 inches. The HPC-FP model offers 4 to 16 zones and measures 8.25 by 9.5 by 3.75 inches. The Pro-HC is available in 6-, 12-, and 24-zone models. The indoor unit measures 8.25 by 9.5 by 3.5 inches and the outdoor unit measures 9 by 10 by 4 inches. All controllers are available in either 120 or 230 VAC. Hydrawise controllers come with a 2-year workmanship warranty from the date of manufacture.

Pay subscription plans are not required to use a Hydrawise controller, but are designed to improve performance and functionality. Two plans are available for homeowners which are either free or \$60 per year. Contractor plans range from free to \$59 per month—some of which include free upgraded homeowner plans.

Hunter Product Pricing Summary

Description	Model	MSRP
Solar Sync	SOLARSYNCSSEN	\$120
Wireless Solar Sync	WSS-SEN	\$225

Installation

All Hydrawise controllers are intended to be wall-mounted. Professional installation is recommended. Installation instructions are available through the Hunter or Hydrawise websites.

Installing and programming the Solar Sync can be performed by the user or irrigation professional—professional installation is not required. Detailed installation and setup instructions are available through the Hunter website, including computer-aided design (CAD) drawings of their products. 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 ft of wire, which can be extended to a maximum of 200 ft. The wireless Solar Sync includes an integrated antenna with up to an 800-ft range, to a small receiver mounted at the controller. The Solar Sync owner’s manual is also available through the Hunter website.

Weather-Based Product Descriptions

WaterSense Certification, Track Record, and Awards

All Hydrowise controllers have received EPA WaterSense Certification. Solar Sync has completed SWAT testing, and performance reports were posted on the IA website (www.irrigation.org/SWAT). The Solar Sync sensor has also been tested and has received EPA WaterSense Certification, along with the X-Core, Pro-C, ICC2, I-Core, ACC, and ACC2 controllers.

Hydro-Rain

Since 1986, Hydro-Rain® (Hydro-Rain) has been producing contractor-grade landscape irrigation and low-voltage lighting products for the professional market. They are part of Orbit Irrigation Products, Inc. (Orbit®), located in Bountiful, Utah. Orbit manufactures and distributes over 2,000 products to 40 countries on 5 continents.

Hydro-Rain's B-hyve® (B-hyve) Pro (model HRC 400 WiFi), introduced in 2017, is a WiFi irrigation controller that can be controlled through a web-based dashboard and/or an Android® or iOS® app (see the "Orbit" section in this report for B-hyve homeowner models).



Operational Features

The B-hyve Pro can be installed as a new controller or one that replaces an existing clock-type controller. It allows the user to remotely monitor, manage, and optimize their landscape. During controller setup, a signal is sent to the B-hyve Pro from a remote device (computer, smartphone, etc.) connecting it to the internet through a WiFi network. With an internet connection, the user can control their irrigation system with the B-hyve Pro app on their smartphone, tablet, or the web dashboard from anywhere in the world. Users can also control the B-hyve Pro with the manual controls on the timer, or by using their voice with Amazon's Alexa® AI assistant-compatible devices.

In addition to customizable and quick control, users can enable the smart watering feature so that the B-hyve Pro will automatically adjust their irrigation schedule based on seasonality and weather events. Using WeatherSense® (WeatherSense) technology, the B-hyve automatically checks the weather forecast and issues adjustments based on ET and precipitation data to replenish soil moisture depletion; users do not need to be online nor does the computer need to be on. The B-hyve's irrigation scheduling algorithms are based on industry-standard practices to estimate soil moisture depletion.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

The WeatherSense software communicates with each B-hyve Pro controller on a daily basis via WiFi to send any required watering adjustments. The B-hyve Pro can accommodate schedules of a wide variety of duration and frequency, including schedules that require watering on an infrequent basis (e.g., every 21 days) and/or restricted watering schedules. After the initial setup and schedule confirmation, no further user intervention should be required for smart watering. If needed, the B-hyve Pro has a “plus/minus ET tuning” feature to adjust for over or underwatering.

There is also a “next water event” feature that can be accessed on the controller screen or remote control device in addition to irrigation history. B-hyve Pro controllers can operate independently if communication to the WeatherSense server 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.

The B-hyve Pro also considers soil type, sprinkler type, slope, and sun exposure. The B-hyve Pro controller can also be programmed to automatically schedule cycle/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.

The B-hyve Pro will also suspend irrigation events if rain is forecasted within the next 24 hours. Similarly, the controller will automatically suspend irrigation events when the temperature forecast approaches the freezing point. Onsite rain and freeze sensors can be installed (not included) to cause circuit interruption and suspend irrigations when significant rainfall or freezing temperatures occur. The B-hyve Pro controller will accommodate popular brands of rain and temperature sensors. The B-hyve Pro maintains a log of water usage and displays a variety of water usage and conservation reports.

Descriptions, Prices, and Warranty

B-hyve Pro controllers are available in 8-zone (model HRC 400 WIFI 8) and 16-zone (model HRC 400 WIFI 16) models. Suggested list prices are \$185 for the 8-zone model and \$225 for the 16-zone models.

In addition to the regular station circuits, the B-hyve Pro controllers provide a master valve/pump start circuit. If additional zones are needed, another controller can be installed and operated under the same account. The B-hyve Pro is designed for indoor or outdoor installation and both models’ dimensions are 3.75 by 9.375 by 8.625 inches.

The B-hyve Pro will accept wire sizes ranging from 14 to 22 AWG and the station circuit rating is 0.4 A. It is powered via an internal transformer rated for 1 A and works with the majority of 24-VAC irrigation systems. Remote control is via 2.4 GHz WiFi or Bluetooth 4.1 and mobile devices with iOS® 7.1+ or Android® 4.3+. The B-hyve Pro includes a backup battery, nonvolatile memory, and UL 1951-approved primary and secondary surge protection.

Weather-Based Product Descriptions

Hydro-Rain Product Pricing Summary

Description	Number of Stations	Model	MSRP
HRC 400	8	04080	\$185
HRC 400	16	04082	\$225

Installation

When users are selecting a location for their controller, they should choose one near an electrical outlet where there is a good WiFi signal, placed out of direct sunlight, and is easily accessible to the sprinkler wires from the valves. Users should also ensure operating temperatures are not below 32° or above 158 degree Fahrenheit (°F) (below 0° or above 70°C). Controllers come with pre-installed batteries. Installation involves mounting the controller, attaching sprinkler wires, plugging in the pigtail, and then pairing the controller with the smartphone app. B-hyve Pro controllers do not require professional installation, although the company recommends that a professional or irrigation contractor install their controller products.

Installation and technical support is available at customerservice@hydrorain.com or by calling 888-493-7672. Additional information and details are included in the installation and programming manual, which is available for download from the B-hyve website (<http://bhyve.hydrorain.com>).

WaterSense Certification, Track Record, and Awards

The B-hyve Pro has received EPA WaterSense labeling. B-hyve Pro also won the “Best New Product” at the 2016 *Irrigation Show* hosted by IA.

The B-hyve Pro app offers water audit features including their award-winning catch cup process. This feature allows a homeowner, contractor, or irrigation auditor to quickly and easily assess the efficacy of the system by performing a catch cup audit and inputting the results immediately into the app. This will automatically update the precipitation rate and efficiency values of the zone and water according to the equipment installed at that location.

Irritrol®

For over half a century, homeowners and irrigation professionals alike have been using Irritrol® professional-quality irrigation products. The company is located in Riverside, California, and is part of The Toro® Company. Irritrol® states its longstanding reputation is built on a legacy of quality, innovation, and service. They work to innovate solutions for a purpose and design with simplicity in mind, which is why they are willing to stand behind their full line of Irritrol® products with a 5-year warranty. Irritrol® is not available at



Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

DIY or “big box” retail outlets, but only sell through professional distribution channels in an effort to maximize quality of service and support. Irritrol® is an EPA WaterSense partner. Rain Master Control Systems® is part of the Irritrol® family of products (see the “Rain Master®” section in this report). To qualify as a smartcontroller (weather-based scheduling device), all Irritrol® controllers must be paired with a Climate Logic® onsite weather station.

Operational Features

The Climate Logic® onsite weather station collects temperature, rain, and solar radiation data that are transmitted to the Climate Logic® receiver module connected to an Irritrol® controller. The receiver module uses these data to create a water schedule. The module can be set to either adjust a base irrigation schedule or can be set to the automatic “follow the weather” schedule. As a backup, a 40-year average of local, historical ET and humidity is stored on a secure digital (SD) card in the module. The Climate Logic® module also has an automatic cold temperature shutoff and “dry-out” option.

Irritrol® offers two residential (Kwik Dial® and Rain Dial®-R) and three commercial models. The Kwik Dial® controller has a 31-day scheduling window, while the Rain Dial®-R offers a 365-day window. This allows for infrequent watering of low water use or native plants. Both controllers have three programs with three start times each—for a total of nine start times.

Programming options for all controllers include sequential stacking of overlapping start times or the ability to run multiple programs simultaneously depending on the product series. All Irritrol® controllers have a manual feature providing an “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 the commercial series.

Other features include inputs for crop coefficient values and community water restrictions (odd/even or selected watering days). The independent station adjust (water budgeting) feature allows for individual station adjustments from 0 to 200% in 10% 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.

Irritrol® controllers that have the Climate Logic® or CL-MR Mini Receiver attachment can also be expanded for online and smartphone application remote control with the addition of the Irritrol® SMRT Logic™ internet



Weather-Based Product Descriptions

gateway. The service is managed and accessed through the Toro®-Irritrol® website (SMRTscape.com). The SMRT Logic™ Hub can also be connected to compatible wireless lighting controllers.

Descriptions, Prices, and Warranty

The dimensions of the Kwik Dial® indoor models are 8⁷/₈ inches high by 6¹/₈ inches wide by 3 inches deep, and the dimensions of the outdoor models are 9 inches high by 6⁷/₈ inches wide by 4 inches deep. The dimensions of the Rain Dial®-R indoor models are 7³/₄ inches high by 7 inches wide by 3³/₄ inches deep, and the dimensions of the outdoor models are 7³/₄ inches high by 10³/₄ inches wide by 4 inches deep. All outdoor controllers include internal UL/Canadian Standards Association-listed transformers. The current capacity for each zone circuit is 0.5 A. The current capacity for the pump/master valve circuit is 0.375 A, with a total controller capacity of 1.0 A for 6, 9, or 12 stations and 1.2 A for 24 stations. The controllers will accept wire sizes from 12 to 18 AWG. 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 on the LCD. In addition to the wireless rain and rain/freeze sensors, a pump starter relay and wired rain sensor are available as optional accessories.

Irritrol® controllers, modules, and accessories may be purchased from authorized Irritrol® distributors and retailers. The Climate Logic® wireless weather station and receiver combo has an MSRP of \$229. This must be added to all of Irritrol's® controllers to qualify them as a smartcontroller. It is known that onsite weather station data provide a better estimate of ET when compared to any other offsite method (e.g., offsite weather stations, weather forecasts, etc.). Irritrol's® residential controllers range in price from the indoor, 4-station Kwik Dial® for an MSRP of \$124 to the outdoor, 12-station Rain Dial®-R for \$432. The addition of the SMRT Logic™ wireless gateway that allows access to the controller via a web browser or smartphone app costs \$155.

All Irritrol® controllers, the Climate Logic® system, and the SMRT Logic™ Hub come with a 5-year manufacturing defect warranty.

Installation

The Irritrol® 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, and a user guide with DVD is available upon request. Technical support is available from Irritrol® via its website (www.irritrol.com), by toll-free telephone (1-800-634-8873), and through field certified contractors. A wide variety of videos are also available on Irritrol's® YouTube® channel (www.youtube.com/user/irritrolchannel).

WaterSense Certification, Track Record, and Awards

All Irritrol® residential controllers with Climate Logic® modules have received EPA WaterSense Certification. Irritrol's® Climate Logic® is also part of the Texas A&M AgriLife Extension's *Smart Irrigation Controller Evaluation Program*.

MC Smart Controls

Founded in 2016, MC Smart Controls has a stated mission to conserve water in the residential, commercial, municipal, and agricultural sectors. They are the manufacturers of the Rainpal irrigation controller, which entered the market in 2016. The company maintains offices in South Jordan, Utah, and Santiago, Chile. It is a subsidiary of the Mani Group.



The Rainpal is a standalone controller that is suitable for residential-type locations. The unit uses weather forecast and solar radiation data to estimate ET; this includes temperature, humidity, wind, and solar radiation. Weather data can be collected over the internet from the closest weather station, which is part of the weather service company Weather Underground®, or an onsite weather station can be installed and interfaced into the Rainpal. A computer interface is used to set up zones and watering information. The user enters basic information for each zone including vegetation type, soil type, sun exposure, typical/base watering times, and base cycle/soak intervals.

The Rainpal is equipped with connectivity for a flow and rain sensor. The addition of MC Smart Control's flow sensing unit (FL-1000) enables the Rainpal to have leak and freeze detection. The user is notified via email of an issue and all the data collected by the sensor can be reviewed online or with the companion smartphone application. Note that the FL-1000 is not a flowmeter, but senses the movement of water and the water temperature. The Rainpal is compatible with most normally open or closed rain sensors. Data from the rain sensor are used to interrupt watering for the day. The ET algorithm used by the Rainpal includes adjustments for precipitation and suspended irrigation times. The Rainpal is also able to communicate with one of almost any industry standard sensors via a single onboard RS485 port. This could be used to connect a single additional sensor (e.g., a soil moisture, humidity, or solar radiation sensor.)

Any communication with the Rainpal is conducted via a computer or mobile device as the unit does not have a built-in screen or buttons. A companion smartphone application is also available for download from MC Smart Controls. The unit is typically connected to a local internet-accessible network through WiFi or Ethernet; however, connection via a serial port is also possible. The internet connection enables interaction with the controller from any internet-connected device. If the controller loses access to weather data from the internet, conservation

Weather-Based Product Descriptions

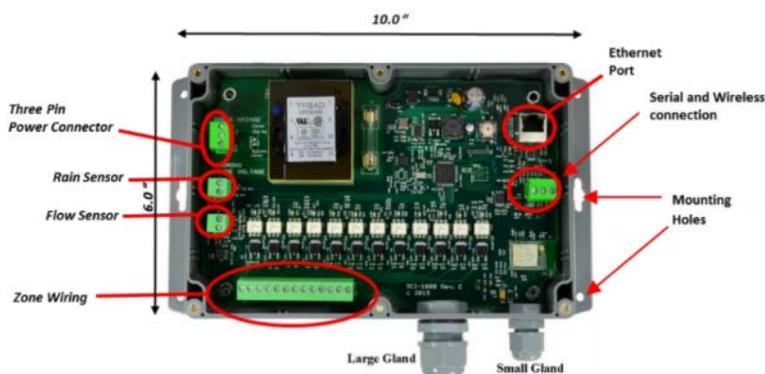
features such as freeze and leak detection still function. The unit will fall back to clock mode until internet access is restored. The Rainpal's controls can still be accessed via its WiFi access point.

The Rainpal comes standard with the ability to act as its own 802.11 a/b/g/n protocol WiFi access point. This means that to interact with the unit, a user does not need to connect to the WiFi network used by the controller to access the internet (e.g., a home network). This feature could increase home network security by reducing the number of devices that have access to the network. For example, if a homeowner allows a landscape professional to program the unit, the professional does not need access to the home WiFi network and can simply connect a WiFi-enabled device to the WiFi network created by the Rainpal irrigation controller.

The Rainpal also offers the flexibility of allowing zones to be designated for functions other than irrigation. This enables the unit to function, for instance, as a timer for exterior lighting.

Operational Features

The Rainpal comes standard in an Ingress Protection Code 66 (IP66)-rated enclosure suitable for outdoor installation. The controller has a 12-zone capacity. The unit can be powered by either 120 VAC, 60 Hz or 220 VAC, 50 Hz electrical power. The unit outputs 26.5 VAC at 1 A of electrical power to the irrigation system. Internet connectivity can be established using WiFi protocols 802.11 a/b/g/n or a hardwired, Ethernet connection. The unit can connect to a master valve or booster pump. Physically, the unit measures 10 inches long by 6 inches high by 3.5 inches wide. The unit is intended to be wall-mounted.



Descriptions, Prices, and Warranty

The Rainpal has an MSRP of \$250 for the 12-zone capacity model. The cost for the controller and the flow sensing unit (FL-1000), which enables freeze and leak detection, is \$300. Rain sensors are purchased separately, and the Rainpal is compatible with most brands. Currently, all updates are free and no subscription fees are charged. Weather data subscriptions are also free in the U.S. Each Rainpal comes with a 3-year, limited workmanship warranty (cost of shipping one-way not covered).

Installation

According to MC Smart Controls, professional installation is not required, but does require some electrical proficiency. Once physically installed and wiring is complete, the unit should be

connected to via either an Ethernet cable or the WiFi access point established by the Rainpal unit. Connection of the unit to a local WiFi network can then be initiated and irrigation scheduling setup started. Steps for unit installation and setup are presented in the user's manual.

WaterSense Certification, Track Record, and Awards

The Rainpal has received EPA WaterSense Certification. MC Smart Controls is now the owner of Brilliant Integrated Technologies, a company featured in the previous edition of this report. Brilliant Integrated Technologies's ICS-ONE controller received SWAT testing. MC Smart Controls states that the Rainpal is the same controller and, therefore, claim ICS-ONE SWAT test results also apply to the Rainpal.

Netro, Inc.

Netro, Inc.[®] (Netro), was founded in 2015. They are the makers of the Sprite smartcontroller and Whisperer companion wireless soil moisture sensor array. The company also has plans to eventually add a smart hose faucet timer to its product line as well. Though the Sprite can operate in manual clock mode, a home WiFi network is required to fully realize the benefits of these products.

The Sprite is a standalone smartcontroller that makes schedule adjustments based on forecasted weather and actual, measured precipitation data. Weather forecast data are sourced from Dark Sky[®] and Weather Underground[®]—including the personal weather station network. The Sprite is a WiFi-enabled controller with a companion smartphone application. Setup of the controller is completed using this companion app. The controller can automatically generate a watering schedule based on zone-specific information entered by the user. This information includes: vegetation type, soil type, sprinkler type, slope, and shade. This information is also used to automatically calculate cycle/soak periods. Since the controller is connected to the internet, the app also allows for remote control of the Sprite from anywhere with an internet connection. The app also allows for review of water use data. All scheduling and setup information is stored remotely on Netro's Cloud—a free service provided with the Sprite. Irrigation can also be controlled using Google's Assistant[®] or Amazon's Alexa[®] AI assistant.

The Whisperer is a small, solar-powered sensor array that can be used independent of the Sprite smartcontroller. The unit collects data on soil moisture, temperature, and sun exposure. Data from the Whisperer are transmitted wirelessly, via WiFi, to the Netro Cloud—a free service.



Weather-Based Product Descriptions

These data can then be reviewed via the companion smartphone app and, if used in conjunction with the Sprite, will be used to inform watering schedule adjustments. Soil moisture can also be read directly on the Whisperer. Aided by the Netro Cloud, the Whisperer and Sprite are claimed to be able to “self-learn” the soil parameters and sprinkler nozzle application efficiency by considering the data collected by the Whisperer and irrigation as initiated by the Sprite. Sans Sprite, the Whisperer can still aid in reducing overwatering by altering the user when watering is needed and the user can review the data prior to watering to assess if irrigation is necessary. Since it is solar-powered and transmits data via WiFi, the unit is entirely wireless. The Whisperer has a WiFi range of 200 ft.

Netro maintains a database of local watering restrictions. These restrictions are automatically incorporated into the watering schedule. Non-irrigation days can also be applied manually.

To adjust the watering schedule, the Sprite uses weather forecasts, actual measured rainfall, and optional onsite sensors. Local weather forecast information is updated daily. Weather data are compiled from multiple sources and used in a computer model to forecast the weather at the user’s address. Actual measured rainfall data from the previous day are also incorporated to reduce errors from imprecisely forecasted rainfall depths. The inclusion of both forecasted and measured rainfall allows the Sprite to adjust watering based on both past and future rainfall. With the addition of the Whisperer, onsite soil moisture, sun exposure, and temperature data will also be integrated into the watering schedule. The Whisperer also allows the system to

“self-learn” characteristics of the soil, sun exposure, and irrigation system efficiency. Another learning feature offered is based on user behavior. Over time, the system is able to learn the user’s habits and include this information in scheduling. A simple example would be if a user is frequently initiating additional watering beyond what the controller is scheduling automatically, the controller will begin to increase watering frequency. Conversely, if the user is frequently skipping watering, the controller will reduce the frequency of watering. Therefore, the more the user interacts with the controller, the better it will understand the user’s preferences.



Operational Features

The Sprite smartcontroller comes in an indoor-suitable enclosure. The unit is intended to be wall-mounted. An external 24-VAC power transformer is supplied. The controller outputs 24 VAC to the valves. WiFi connections are established via the onboard 802.11 n, 2.4 GHz WiFi module. Physically, the unit measures 5.7 by 5.7 by 1.2 inches and weighs just 0.51 lb.

The Sprite comes in either 6- or 12-zone capacities each with a master valve connection. If additional zone capacity is needed, multiple Sprites can be used. As scheduling is handled via the smartphone app and stored remotely on the Netro Cloud, there is no practical limit to the number of programs or start times.

The Whisperer sensor array unit is suitable for outdoor installation. Physically, the unit measures 7.8 by 2.3 by 3 inches and weighs 6.0 ounces. The unit is solar powered, and comes with a rechargeable, replaceable battery.

Descriptions, Prices, and Warranty

The Sprite smartcontroller is available in 6-zone (\$120) and 12-zone (\$150) models. If additional zones are needed, multiple Sprite controllers can be installed and managed in conjunction with the smartphone app. The Whisperer wireless soil moisture, sunlight, and temperature sensor sells for ~\$50 and, since it is solar powered, no battery replacement is necessary. Both products come with a 2-year limited hardware warranty.

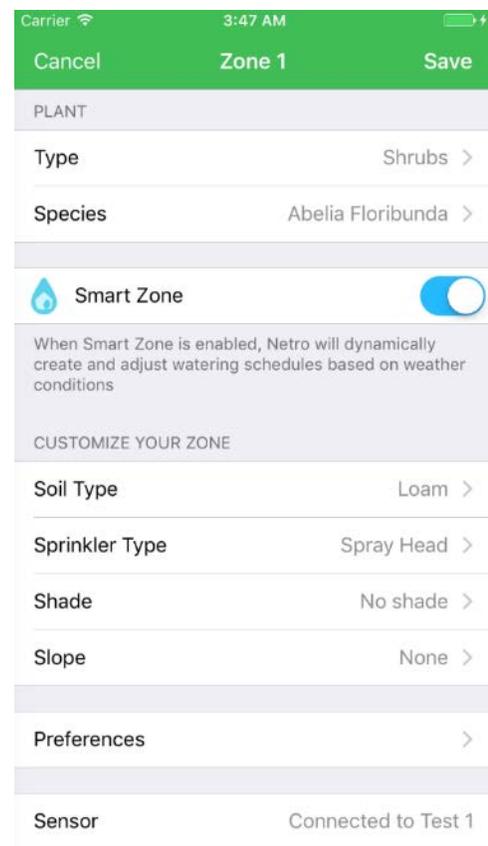
Installation

Netro states their products are simple to install and do not require professional installation. When replacing an existing controller, the Sprite can be installed in approximately 15 minutes. WiFi setup is accomplished via the companion smartphone app. During setup, the Sprite will generate its own WiFi network that the user connects to allowing setup of the connection between the Sprite and the user's home WiFi network. A video covering the setup process is available on the Netro Home YouTube channel

(www.youtube.com/channel/UCiFYdxYp0ogMX-SBSsXgIRQ). To have the Sprite generate a watering schedule automatically, the user enters zone-specific information including: vegetation type, soil type, sprinkler type, shade, and slope. This information is also used to automatically calculate cycle/soak periods.

WaterSense Certification, Track Record, and Awards

The Sprite has received EPA WaterSense Certification. The development of the Whisperer was crowd-funded through Kickstarter®. During the campaign, Netro exceeded their funding goal by receiving 105% of their fiscal request.



Weather-Based Product Descriptions

NxEco

NxEco, Inc.[®] (NxEco), located in Newport Beach, California, manufactures three smartcontroller models. The NxEco controllers entered the market in late 2015. The weather-based controllers can be controlled from anywhere by smartphone and WiFi connection.



Operational Features

NxEco controllers can be used to control any standard 24-volt irrigation system. Current 8- and 12-zone models are available with up to 24-zone extension modules (HWN24-2EXT) available soon, which will extend the range on current generation 12-zone controllers. NxEco states their controllers are easy to install and program. Single or multiple controllers can be accessed and operated via a free smartphone application that is available for Android[®] and iOS[®]. This allows the user to securely connect to their controller from anywhere for programming, sprinkler system monitoring, and manual control. NxEco states the app provides a proven reliable system, and its controllers have a unique and easy-to-use control panel that allows the user direct operation from the controller. Thus, even without an internet connection, users can still run their irrigation similar to a traditional controller.

The NxEco controllers automatically adjust run times based on current local weather information and forecasts. The user sets station run times for current conditions, and the run times are adjusted by the Smart NxEco System as weather conditions change. NxEco controllers access automatically updated weather data from local National Oceanic and Atmospheric Administration (NOAA) weather stations. From anywhere in the world, a controller can receive global weather information from the professional web station (www.worldweatheronline.com). The baseline irrigation run times are adjusted monthly based on local ET and precipitation data from the weather station. The existing schedule is then adjusted from the NxEco server automatically. An optional rain sensor can be connected to certain controller models for automatic rain delays if desired.

NxEco controllers can accommodate most any schedule of duration and frequency, including restricted watering day schedules. The user may also assign custom controller names and zone names (e.g., "Front Lawn"). The user can manually adjust scheduled station run times by a percentage factor and initiate manual irrigations by zone.

NxEco controllers can be programmed for up to four 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 smart watering virtual temperature sensor suspends irrigation during freezing weather and allows longer irrigation run times during excessively hot weather.

Descriptions, Prices, and Warranty

The NxEco controller models consist of the 8-station (model HWN8-100) and the 12-station (models HWN12-100 and HWN12-200). All three models have WiFi connectivity. Model HWN12-100 can be connected by a universal serial bus (USB) port and model HWN12-200 can be connected by Ethernet. All models can have station 12 dedicated as a master valve or pump start. Model HWN12-200 provides a rain sensor and 10-pin port, which connects to the 24-zone extension module (model HWN24-2EXT).



NxEco controllers are designed for indoor installation, but an optional outdoor enclosure or cabinet (UCC100) is available. The cabinet dimensions for the controllers are 6.5 by 9.8 by 1.4 inches.

NxEco controllers are powered via a 24-VAC external transformer and work with all 24 VAC irrigation systems. The controller terminal connections will accept 12 to 20 AWG wire for ease of installation.

NxEco controllers have nonvolatile memory and include a replaceable 3.0-volt CR2030 lithium battery to provide backup power. Onboard surge and lightning protection is provided by a power protection circuit and replaceable 2-A fuse. Nominal operational current is 0.75 A.

Current retail prices for models HWN8-100, HWN12-100, and HWN12-200 are \$120, \$140, and \$215, respectively, on www.amazon.com. The weather-resistant enclosure (cabinet) price is \$30. Models HWN8-100, HWN12-100, and HWN12-200 and the weather-resistant enclosure (cabinet) can also be purchased via the Nxeco website (www.nxeco.com) or at numerous “big box” retailers. A manufacturer’s warranty covers Nxeco controllers for defects in materials and workmanship for a period of 2 years from the date of purchase. There are no subscription fees for use or access to Nxeco Cloud-based apps, and any software and firmware updates are free of charge and are automatically pushed to all Nxeco owner smartphones.



Weather-Based Product Descriptions

Installation

NxEco states typical homeowner installation and programming time is under 30 minutes. NxEco controllers can replace most traditional controllers.

Technical support is available by email, live online chat, and toll-free telephone (855-MYNXECO), in addition to the support provided on the company's website.

WaterSense Certification, Track Record, and Awards

NxEco controllers have been tested and have earned the EPA WaterSense label.

NxEco performed a water savings analysis on five California sites where its controllers were installed, based on 1 year of data (November 2016 through October 2017). The report is available upon request from NxEco.

Orbit

Orbit Irrigation Products, Inc., located in Bountiful, Utah, is a manufacturer and supplier of irrigation products for residential and commercial markets and has been in business since 1986. Orbit® (Orbit) manufactures and distributes over 2,000 products to 40 countries on five continents.

Orbit's B-hyve® (B-hyve) Indoor/Outdoor Smart Sprinkler Controller, introduced in 2016, is a WiFi irrigation timer that can be controlled through a web-based dashboard and an Android® or iOS® app. Orbit also has the B-hyve Smart Indoor Sprinkler Controller and a Smart Hose Faucet Timer that were launched in 2018. Orbit also manufactures the light commercial B-hyve Pro that is marketed by Hydro-Rain®, a subsidiary of Orbit (see the "Hydro-Rain" section in this report for B-hyve Pro models).

Operational Features

The B-hyve indoor/outdoor units can be installed as a new controller, or one that replaces an existing clock-type controller, to allow the user to remotely monitor and manage their landscape irrigation. During controller setup, a signal is sent to the B-hyve from a remote device (computer, smartphone, etc.) connecting it to the internet through a WiFi network. With an internet connection, the user can control their irrigation system with the B-hyve app on their smartphone, tablet, or the web-



Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

dashboard from anywhere in the world. Users can also control the B-hyve with the manual controls on the timer. The B-hyve is compatible with Amazon's Alexa[®] AI assistant and is Apple Homekit[®]-ready.

In addition to customizable control, users can enable the smart watering feature so that the B-hyve will automatically adjust their irrigation schedule based on seasonality and weather events. Using WeatherSense technology, the B-hyve automatically checks the weather forecast and issues adjustments based on ET and precipitation data to replenish soil moisture depletion; users do not need to be online nor does the computer need to be on. The B-hyve's irrigation scheduling algorithms are based on industry-standard practices to estimate soil moisture depletion.

Smart watering functionality automatically adjusts irrigation based on weather events. The B-hyve checks the weather forecast every hour and estimates the daily ET while also taking into account past rainfall for a 2-week period. After a weather event, the B-hyve looks back to see how much rain fell and adjusts the schedule according to the updated report. This allows B-hyve controllers to minimize over or underwatering.

The WeatherSense software communicates with each B-hyve controller on a daily basis via WiFi to send any required watering adjustments. The B-hyve can accommodate schedules of a wide variety of duration and frequency, including schedules that require watering on an infrequent basis (e.g., every 21 days) and/or restricted watering schedules. After the initial setup and schedule confirmation, no further user intervention should be required for smart watering. If needed, the B-hyve has a plus/minus ET tuning feature to adjust for over or underwatering.

There is also a "next water event" feature that can be accessed on the controller screen or remote control device, in addition to irrigation history. B-hyve controllers can operate independently if communication to the WeatherSense server 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.

The B-hyve also considers soil type, sprinkler type, slope, and sun exposure. The B-hyve can be programmed to 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.

The B-hyve will also suspend irrigation events if rain is forecasted within the next 24 hours. Similarly, the controller will automatically suspend irrigation events when the temperature forecast approaches the freezing point. Onsite rain and freeze sensors can be installed (not included) to cause circuit interruption and suspend irrigations when significant rainfall or freezing temperatures occur. (The B-hyve controller will accommodate popular brands of rain and temperature sensors.) The B-hyve maintains a log of all water usage and displays a variety of water usage and saving reports.

Weather-Based Product Descriptions

The B-hyve indoor controller provides all the same app controls and smart features as the original B-hyve Smart Indoor/Outdoor Controller. Customers can control their timer via WiFi from anywhere in the world using their mobile device and enable smart watering capabilities for water savings. Just mount it indoors in the house, a shed, or the garage and program it using the app.



The B-hyve Smart Hose Faucet Timer combines the smart features of other B-hyve timers with the versatility of a hose faucet controller, turning any outdoor faucet into an app-controlled water source. Just like other B-hyve timers, users can control their hose faucet watering from anywhere in the world via WiFi using their mobile device.

The B-hyve hose faucet also has a built-in flowmeter that lets users know how much water they are using to water their plants, wash their car, or fill their pool. It can even be set to water by volume, not just by time. It is programmable by seconds, making it ideal not only for gardening, but also for hydroponics and greenhouse applications too.



The B-hyve hose faucet also uses Bluetooth meshing to allow users' systems to expand beyond the signal strength of the B-hyve Hub by passing the signal through other B-hyve hose faucet timers. This is ideal for larger properties with multiple timers in different locations.

Users can expand their system to control one or multiple timers with the B-hyve app. Combined with the network meshing enabled through WiFi, the timers will communicate with each other to ensure they do not water simultaneously. It can also be connected to WiFi with the B-hyve Hub, the 2018 version of the B-hyve underground timers, other B-hyve hose faucet timers or function as a zone with an underground timer.

Descriptions, Prices, and Warranty

B-hyve Smart Indoor/Outdoor Controllers are available in 6-zone (model 57946) and 12-zone (model 57950). Customers can purchase online via Orbit's website (<http://store.orbitonline.com>) or at several "big box" stores. Suggested retail prices are \$100 for the 6-zone model and \$120 for the 12-zone model. In addition to the regular station circuits, the controllers provide a master

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valve/pump start circuit. If additional zones are needed, another controller can be installed and operated under the same account. The B-hyve is designed for indoor or outdoor installation and both models' dimensions are 3.75 by 9.375 by 8.625 inches.

The B-Hyve will accept wire sizes ranging from 14 to 22 AWG and the per-station circuit rating is 0.4 A. It is powered via an internal transformer rated for 0.75 amp and works with the majority of 24-VAC irrigation systems. Remote control is by 2.4 GHz WiFi or Bluetooth 4.1 and mobile devices with iOS® 7.1+ or Android® 4.3+. B-Hyve includes a backup battery, nonvolatile memory, and UL 1951-approved primary and secondary surge protection.

The B-hyve Smart Indoor Sprinkler Controllers are available in 4-zone (model 57915) and 8-zone (model 57925). Customers can check their local retailer for availability. MSRPs are \$60 for the 4-zone model and \$80 for the 8-zone model. Orbit has a 30-day “satisfaction or money back” guarantee, plus a limited 2-year manufacturer’s warranty on the B-Hyve. Software and firmware updates are free and are automatically pushed to the user’s smartphone and B-Hyve hardware.

Orbit Product Pricing Summary

Description	Number of Stations	Model	MSRP
B-hyve Indoor/Outdoor Timer	6	57946	\$100
B-hyve Indoor/Outdoor Timer	12	57950	\$120
B-hyve Indoor Sprinkler Timer	4	57915	\$60
B-hyve Indoor Sprinkler Timer	8	57925	\$80
B-hyve Hose Faucet Timer With Hub	1	21004	\$70
B-hyve Hose Faucet Timer	1	21005	\$40

Installation

When users are selecting a location for their timer, they should choose one near an electrical outlet where there is a good WiFi signal, placed out of direct sunlight, and is easily accessible to the sprinkler wires from the valves. They should also ensure operating temperatures are not below 32° or above 158°F (below 0° or above 70°C).

Controllers come with pre-installed batteries. Installation involves mounting the controller, attaching sprinkler wires, plugging in the pigtail, and then pairing the controller with the smartphone app. B-hyve controllers do not require professional installation, although the company recommends that a professional or irrigation contractor install their controller products.

Installation and technical support is available at support@orbitbhyve.com or by calling 1-800-488-6156. Additional information and details are included in the installation and programming manual, which is available for download from the B-hyve website (<https://bhyve.orbitonline.com>).

Weather-Based Product Descriptions

WaterSense Certification, Track Record, and Awards

The B-Hyve has received EPA WaterSense labeling. Orbit tested their B-hyve Indoor/Outdoor Controllers on 60 metered homes in the Weber Basin, Utah. The test results are available upon request from the company.

The B-hyve app offers water audit features, including their award-winning catch cup process. This feature allows a homeowner, contractor, or irrigation auditor to quickly and easily assess the efficacy of the system by performing a catch cup audit and inputting the results immediately into the app. This will automatically update the precipitation rate and efficiency values of the zone and water according to the equipment installed at that location.

Plaid Systems, LLC.

Plaid Systems, LLC. (Plaid Systems), was founded in 2012, and is the company behind the Spruce® (Spruce) smartcontroller. Plaid Systems tries to tap into the creativity of their customers to create products that simplify their lives through automation. The Spruce controller is a standalone, weather-based irrigation controller with optional wireless soil moisture sensors. The Spruce controller is in its second generation, with the first generation being discontinued in 2016. The controller connects to a local WiFi network. All setup, programming, and interaction with the controller can be done through a companion smartphone application. The unit can be controlled via smartphone or AI assistant (e.g., Google's Assistant® or Amazon's Alexa®).



The Spruce controller can automatically generate a watering schedule based on zone-specific parameters input by the user. Parameters are input to the controller through the companion smartphone app and include application rate, nozzle type, soil, plant type, sun exposure, and slope. Alternatively, custom application rates, crop coefficients, or depletion rates can be entered. Many inputs are selected from a predefined list (e.g., soil types: sand, loam, clay, etc.) that simplifies setup. Plant type includes a new plant establishment option. The unit can also automatically include cycle-soak periods into



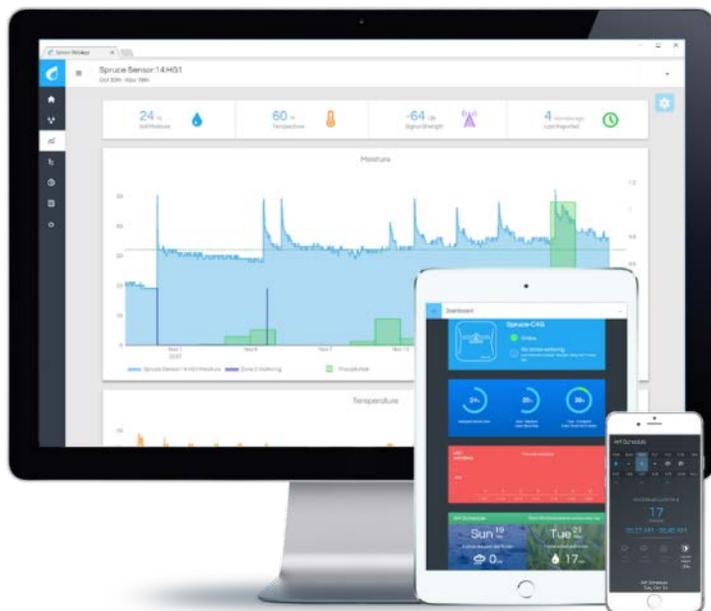
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the watering schedule using the supplied data. Cycle/soak periods can also be defined manually. Dates and times can be specified when watering cannot occur to comply with local watering restrictions. Schedules can be set to start at a specific time or relative to sunrise or sunset and will adjust the time each day.

Adjustments to the watering schedule are made based on weather forecasts received via the WiFi connection. Forecasts are downloaded from Darksky.net and are updated when initiating irrigation. This ensures the most recent forecast data are being used. If the controller loses its internet connection (or connection to any additional sensors such as the soil moisture sensor), programming reverts to the most recent watering schedule that was run.

With the addition of the optional Spruce soil moisture sensors, watering schedule adjustments can be made based on measured soil moisture. Soil moisture data are used to adjust watering time and frequency by evaluating the soil moisture compared to a user-defined or “learned” setpoint. The system can “learn” what setpoint is needed by observing a calculated water schedule and then setting a setpoint to target. Depending on the soil moisture mode selected, the system will allow moisture depletion until the setpoint is reached and then initiate watering. A hybrid approach is also available which maintains the targeted soil moisture setpoint by adjusting scheduled time and frequency. Soil moisture sensors are battery-powered by a CR2477 size battery, and transmit all data wirelessly to the controller. The system allows for one sensor per zone or several similar zones can share one sensor. Spruce can also implement an optional freeze delay based on a user-specified temperature threshold; the device uses forecasted temperatures. Spruce is compatible with third-party, normally closed rain sensors and 2-wire pulse flowmeters that are wired directly into the controller. The sensor can be configured to initiate a rain watering delay. All data collected by the unit are stored and can be reviewed graphically in the web-interface or smartphone app. Water use charts can display minutes or gallons (estimated or measured by a flowmeter) by day, month, or year. Data can also be filtered by zone, schedule, landscape type, nozzle, etc. Soil moisture data are charted over time against precipitation, watering events, and weather.

Spruce soil moisture sensors are paired directly to the Spruce smartcontroller through a connection wizard in the app. They use a 2.4-GHz (Zigbee) wireless protocol. The connection is established by touching the included magnet to the side of the sensor to initiate the pair routine. Expanding the range of the sensors can be achieved with low-cost, third-party plug-in electrical outlets, which are used to expand the wireless network. The Spruce soil moisture sensors can also be paired with an existing Samsung



Weather-Based Product Descriptions

SmartThings® Hub. This allows a larger mesh network for expanded range. The Spruce smartcontroller can also be connected to the SmartThings Hub and will receive the sensor data through the cloud connection. Additionally, Samsung SmartThings® can be used to start, stop, or pause Spruce zones or schedules.

Operational Features

A single Spruce controller can support up to 16 zones and a master pump. If more zones are required, multiple Spruce controllers can be managed through the app or web interface. Soil moisture sensors can only be used with one controller, but multiple zones may share a sensor if the primary zone parameters are the same (e.g., nozzle, landscape, soil, etc.).

The Spruce controller is powered by a standard household, 110-VAC outlet and comes with an external 1-A power transformer. The unit requires 24 VAC and a minimum of 0.4 A to operate. It is protected from overcurrent with an internal self-reset fuse, and each zone and sensor terminal is diode-protected against lightning and power surges.

The Spruce controller incorporates valve current detection and monitors for faulty or disconnected valves. Faulty or disconnected valves are automatically skipped when watering. When a master pump is used, this stops the pump from overcurrent or overpressure due to a valve that is not really open.

Physically, the unit measures 6.3 inches long by 6.3 inches high by 1.4 inches wide and weighs in at 1.9 lbs (0.8 lb without the power supply). The unit is intended to be wall-mounted and is not suitable for outdoor installation. Purchase of a third-party enclosure allows the controller to be mounted outdoors.

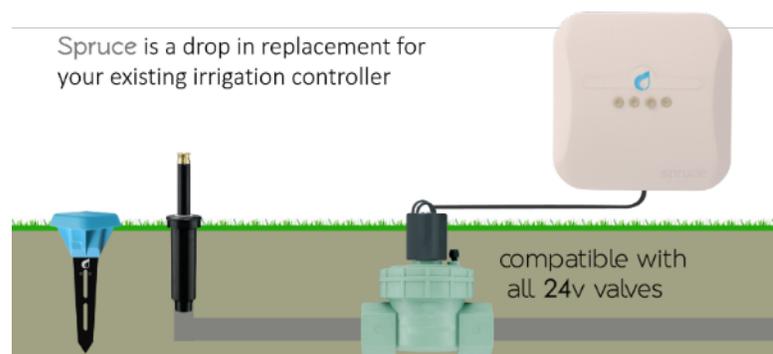
Descriptions, Prices, and Warranty

The Spruce controller supports 16 zones and has an MSRP of \$249 with no ongoing subscription fees. Optional soil moisture sensors run ~\$50 each.

Each Spruce controller and soil-moisture sensor comes with a 1-year workmanship warranty. An unopen unit can also be returned within 30 days of the shipment date.

Installation

Spruce has invested time in making the controller simple to install and program. Professional installation is not necessary. Programming can be automated through automatic generation of a watering schedule based on zone-specific parameters input by the user. The Spruce



website (<http://support.spruceirrigation.com>) provides documentation on installation and setup. Spruce support can also be contacted directly through an online form (<http://support.spruceirrigation.com/contact/>).

WaterSense Certification, Track Record, and Awards

Spruce is new to the market and has not yet received EPA WaterSense Certification or participated in any third-party studies; however, the Spruce controller is currently undergoing certification. Verification of EPA WaterSense Certification can be found on the EPA WaterSense product search website.

Rain Bird

The Rain Bird Corporation, based in Glendora, California, began business in 1933. Over 13,000 Rain Bird® (Rain Bird) products are sold in more than 120 countries. Rain Bird owns more than 130 patents and 30 trademarks. Residential and light commercial solutions include standalone weather-based controllers, as well as WiFi-enabled controllers that leverage the Rain Bird app (iOS®, Android®) to source weather data. Commercial-grade master control systems leveraging weather data include Maxicom™, SiteControl™, and IQ™ systems for golf, commercial, and light commercial markets.



Operational Features

Rain Bird currently markets several WiFi-ready smartcontrollers that are EPA WaterSense-certified and leverage cloud-based weather data to automatically adjust irrigation schedules. These controllers include models:

- ◆ ST8-WIFI (residential)
- ◆ ESP-TM2 (residential)
- ◆ ESP-Me (residential and light commercial)
- ◆ ESP-RZXe (residential, international)

Weather-Based Product Descriptions

These controllers all leverage the Rain Bird LNK™ WiFi Module, bundled or sold separately, as the means to connect to the internet for cloud-based, automatic seasonal watering adjustments and weather information—required for EPA WaterSense Certification. Models ST8 WIFI, ESP-TM2, and ESP-RZXe are also compatible with the Rain Bird RSD wired rain sensor or Rain Bird WR2 (EPA WaterSense) wireless rain sensor to suspend irrigation based on locally sensed rain or temperature events.



When Rain Bird WiFi controllers are coupled with the LNK WiFi Module and WaterSense approved rain sensors, they become EPA WaterSense-certified. Setup of these controllers entails users to create and program a watering schedule based on the hottest month of the year and activating the “Automatic Seasonal Adjustment” (ASA) feature.



The ASA values are calculated by a proprietary Rain Bird protocol that takes into consideration average historical ET values for the local area, yesterday’s ASA accuracy based on known weather data, and tomorrow’s weather forecast. Every day at midnight, the controllers receive an updated ASA adjustment in the form of a percentage adjustment that is applied to all active run times scheduled for that day, and visible via the Rain Bird app. Further, connected rain sensors serve to provide a preprogrammed delay to current irrigation schedules based on threshold precipitation values.

To help users create a baseline irrigation schedule and program settings into these smartcontroller products, Rain Bird offers a free Run Time Calculator via their website (<https://ww3.rainbird.com/support/RunTimeCalculator>). This scheduler program tailors an irrigation schedule to a specific landscape and the characteristics of the irrigation system. The user enters information for each station and landscape characteristics including plant type, soil type, ground slope, and sprinkler type 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, it can be printed out and entered into the irrigation controller. The scheduler program can be accessed via Rain Bird’s website.



Rain Bird also offers the ESP-SMTe smartcontroller, which integrates with a rain/temperature sensor that uses ET-based scheduling to regularly adjust the planned

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

irrigation schedule based on local weather events. The ESP-SMTe controller uses an internally stored historical ET database, together with a specially designed tipping bucket rain sensor and temperature sensor to automatically adjust irrigation schedules to suit local climate conditions without the need for internet connectivity. When in “smart mode,” the controller can also automatically set up initial irrigation schedules based on 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 controller is programmed for “Allowed Irrigation Days”, “Allowed Water Windows” for weather-based schedules, and an optional “Grow-In Water Window” for establishing newly planted areas. After a user-set number of days, the controller will automatically convert these zones to weather-based irrigation.

Three data points (daily solar radiation, historical monthly wind speed, and historical monthly humidity) are combined with daily high and low temperatures and rainfall 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 daily weather data (high and low temperature, reference ET, and 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.

Descriptions, Prices, and Warranty

The ST8-WIFI, ESP-TM2, and ESP-RZXe models are all fixed station controllers offered with indoor or outdoor enclosures. The ST8-WIFI model is fixed at an 8-zone capacity and measures 6.25 by 6.25 by 1.54 inches. The ESP-Me model can be expanded from the standard 4 zones to up to 22 zones. It is available in both indoor and outdoor enclosures. For earlier ESP-Me model controllers (manufactured before November 2016), Rain Bird offers an upgrade face panel that allows owners to upgrade to WiFi compatibility without having to replace the entire controller.

The ESP-SMTe model controller comes standard with a 4-zone capacity, but is expandable up to 22 zones. It can be ordered in either an indoor or outdoor enclosure. The unit is approximately 10.7 by 7.7 by 4.4 inches. The included weather station can be wall-mounted and is 6.0 by 8.8 by 5.9 inches.

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 website (www.rainbird.com). All Rain Bird controller products come with a 3-year trade warranty.

Weather-Based Product Descriptions

Rain Bird Product Pricing Summary (Residential and Light Commercial)

Model	Description	MSRP
ESP4SMTEI	Four-station/zone smart control system for indoor installations. Includes the controller and onsite weather sensor.	\$313
ESP4SMTE	Four-station/zone smart control system for outdoor installations. Includes the controller and onsite weather sensor.	\$347
ESP-SM3	Three-station expansion module to expand the ESP-SMTe, ESP-Me.	\$55
ESP-SM6	Six-station expansion module to expand the ESP-SMTe, ESP-Me to a maximum of 22 stations/zones.	\$100
ESP-TM2	4-, 6-, 8-, or 12-station ESP-TM2 controller, WiFi-ready.	\$115-290
LNK-WIFI	LNK WiFi module for use with all WiFi-ready controllers.	\$125
ESPMEPANEL	ESP-Me smart panel upgrade for WiFi connectivity.	\$75
ESP-4MEI	Module WiFi-ready controller with 4 stations (standard), expandable up to 22-station capability, indoor model.	\$154
ESP-4ME	Module WiFi-ready controller with 4 stations (standard), expandable up to 22-station capability, outdoor model.	\$179
ST8-WIFI	Eight-station smartcontrollerwith built-in WiFi.	\$179-229
WR2-RFC	Wireless Rain/Freeze Sensor System.	\$96
RSD-BEX	Wired Rain Sensor System.	\$30

Installation

Although installation by a Rain Bird trained professional is strongly recommended, Rain Bird states installation may be performed by some homeowners. Installation and programming instructions in English and Spanish are provided with the controller.

WaterSense Certification, Track Record, and Awards

Rain Bird has field tested their smartcontroller products at numerous locations throughout the U.S., and SWAT test performance reports are posted for the ET Manager, ET Manager Cartridge, and ESP-SMTe model series.

Rain Bird states that the field test contractors who participated in ESP-SMTe model field test surveys 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 EPA WaterSense Program and both ESP-SMTe and ESP-ET models are EPA WaterSense-certified. Rain Bird controllers have also been included in the Texas A&M AgriLife Extension’s *Smart Irrigation Controller Evaluation Program*.

Rain Master®

Since 1981, Rain Master Control Systems® (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® i-Central™ internet-based system. The RME Eagle™/i-Central™ system (U.S. 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 2010, Irritrol®/Rain Master® introduced an improved version of the RME Eagle™, the Eagle™ Plus, offering more water conserving features, simplified user interface, two-wire capability, and GSM cellular communication technology with its i-Central™ internet system.

Rain Master® provides several ET source options for the Eagle™ models. ET may be entered manually into the controller; alternatively, the controller may be directly connected to a Rain Master® Weather Center weather station or receive California Irrigation Management Information System (CIMIS) data (California only). When configured with Rain Master's® i-Central™ 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 weather station. The Eagle™ Plus can also operate with the Weather Center II, which can interface with a tipping bucket rain gauge. If daily ET is unavailable, the controller will use 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® website (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% programming error can occur based on just a 10-minute run time).

Weather-Based Product Descriptions

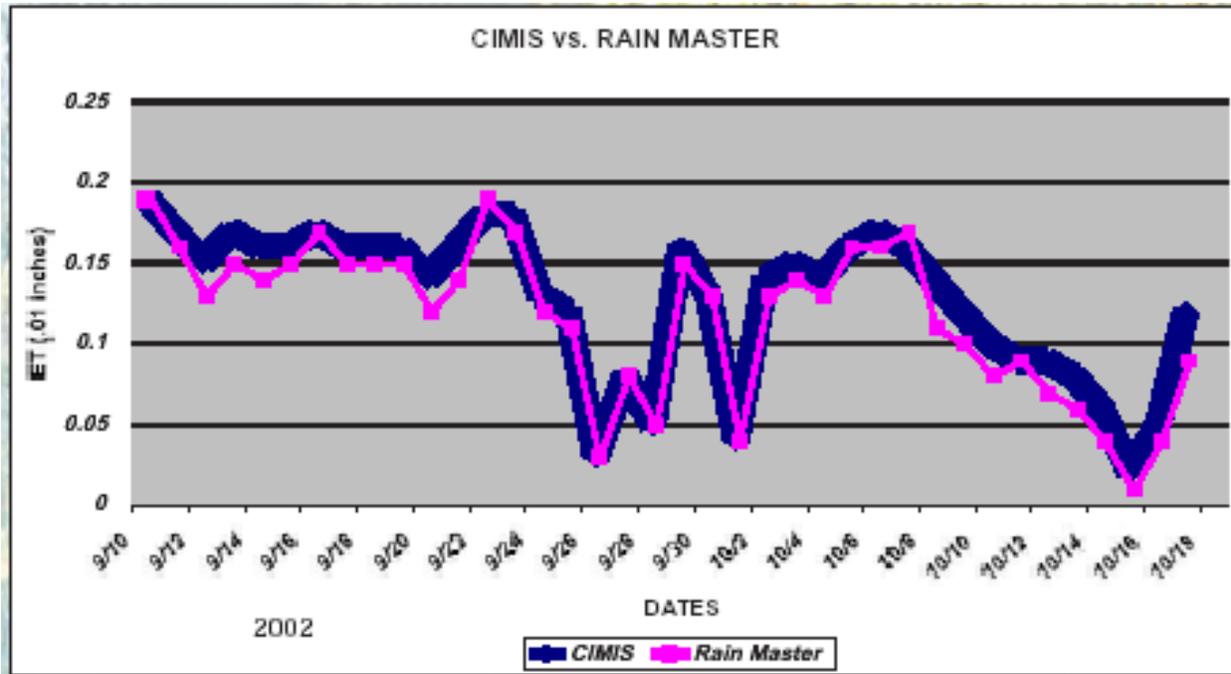
Rain Master's® ZipET™ is an ET data collection and dissemination service for Rain Master® i-Central™ internet customers. Rain Master® collects raw weather information on a daily basis from thousands of weather stations throughout the U.S. The weather information is validated and converted, as necessary, 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 is then delivered automatically to each controller via the two-way wireless communications card (iCard). The Rain Master® i-Central™ website provides daily reports on all ET weather information that was successfully delivered to each controller (two-way confirmation).

An alternative ZipET™ service is available for users who require the accuracy of an onsite weather station. Rain Master's® commercial grade, computer-controlled Weather Center 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-ft-tall, vandal-resistant tower with all connections made within the tower's terminal block. The controller supplies power to the system. The Weather Center was compared with nearby CIMIS data in 2002 and found to have good agreement.



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. Use of manually entered ET data in conjunction with historical ET data can significantly improve irrigation efficiency. The controller will use 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 entered 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 i-Central™ 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® website. 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.



*Actual data CIMIS #99 Santa Monica, CA

Rain Master® Weather Center; ET versus CIMIS reference ET.

The Rain Master® i-Central™ website 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 website allows the user to command a rain shutdown, modify controller setup information, and manually turn on/off any station or program. The website 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 discussed hereafter, suitable programs are downloaded throughout the year in addition to the daily ET adjustments that are sent to the controller. The scheduler algorithm uses the IA’s “Landscape Irrigation Scheduling and Water Management” equations.



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.

Weather-Based Product Descriptions

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 i-Central™ scheduler, the user must program the controller with a base schedule. The base schedule's total run times and cycle/soak 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 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 conservation features include:

- ◆ 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 scheduling station starts when other stations are satisfying their “Soak Time.”
- ◆ 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.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

When connected to an optional Rain Master® flow sensor, the Eagle™ and Eagle™ Plus controllers 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 controllers’ 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. CAD files and component explode-view drawings of the company’s products are available on their website along with system design tools. The Eagle™ and Eagle™ Plus controllers are UL-approved, Federal Communications Commission-certified for emissions, include an internal 24-VAC transformer, and current capacity is 1.0 A (Eagle™ Plus is 1.5 A) per station and/or master valve circuit(s). The controllers have terminal screw connections and will accept 12 AWG 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 U.S. at all major irrigation distributors. A distributor search engine can be accessed at Rain Master’s® website. The MSRP for the 8-station Eagle™ Plus starts at \$1,200. A full list of MSRP’s for all Rain Master products is available on the company’s website. 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 \$5,700. 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 from trained technicians is available at 1-800-777-1477 from 7:30 a.m. through 4:00 p.m., Pacific time. Online and email support are also available.

Installation

Rain Master® states 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.

WaterSense Certification, Track Record, and Awards

Rain Master® states that thousands of Eagle™ controllers have been installed throughout the U.S. and that the Rain Master® RME Eagle™ controller has been recognized and accepted by more than 40 water purveyors/agencies across the Nation.

The RME Eagle™ was SWAT tested; however, these reports are no longer available. Rain Master® controllers have received EPA WaterSense Certification.

Weather-Based Product Descriptions

Scotts Miracle-Gro

Blossom, now marketed as the Gro™ 7 Zone Controller (Gro) is owned by The Scotts Miracle-Gro® Company, LLC. (Scotts), located in Marysville, Ohio. The initial launch included a Blossom 12 smart watering controller in 2015. A Blossom 7 smart watering controller was added in 2017. Both products can be controlled from anywhere by a smartphone or tablet through an Android® or iOS® app via cloud computing and a home WiFi connection.



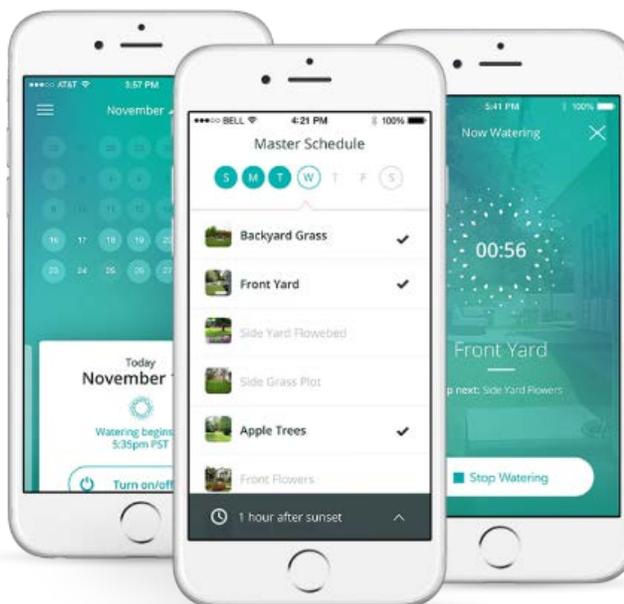
Operational Features

The controllers can be installed as a new standalone controller or one that replaces an existing clock-type controller. Scotts states that their controllers are easy to install and that it takes less than 30 minutes to set up. The Gro controller connects to the user's home network router via WiFi and, once installed, the smartphone app can then access the controller from anywhere to program and monitor the sprinkler system. The Gro integrates with both Google's Assistant® and Amazon's Alexa® AI assistant.

In addition to instantaneous control, the Gro controller can be set to automatically adjust irrigation schedules. Automated scheduling is optimized for water efficiency and landscape health by taking into account variables including weather, seasonality, landscape characteristics, water budgeting, and vegetation.

To enter landscape information, users go to the smartphone app and log into their account using their email address and password. Options include plant/vegetation type, irrigation emitter type, and cycle/soak configuration. After the initial setup and schedule confirmation, no further user intervention should be required.

The Gro controller automatically checks weather forecasts and issues adjustments based on ET and precipitation data to match soil moisture depletion. Weather and schedule adjustments are updated



Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

automatically; the user does not need to be online nor does a computer need to be on. The Gro Cloud-based software communicates with each controller on a daily basis via WiFi to send any required watering adjustments.

The Gro controller 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 (e.g., “Front Lawn”), adjust the total station run times by a percentage factor, and initiate manual irrigations by zone.

The Gro irrigation scheduling algorithms are based on real-time local weather data, satellite imagery-based weather forecasts (Weather Analytics, LLC.), and landscape factors (Xona™ Technology) needed to estimate soil moisture depletion. The Gro can be configured with cycle and soak irrigation events to eliminate/reduce runoff or to allow multiple watering cycles per day, per zone. The Gro uses rain data and will suspend irrigation events if rain is forecasted within the next 24 hours. In colder weather, the Gro automatically suspends irrigation events when the temperature forecast approaches the freezing point. The Gro maintains a log of water usage and displays a variety of water usage statistics for the previous week.



Descriptions, Prices, and Warranty

In addition to the regular station circuits, the controller provides a master valve/pump start circuit. The Gro is designed for indoor installation and its dimensions are 6.93 by 6.93 by 1.55 inches.

The Gro is powered by a 120-VAC plug and works all 24-VAC irrigation systems. The controller’s connection terminal can accept existing wire sizes typical for irrigation systems and the circuit current rating is 0.5 A. The Gro also includes an internal backup battery and has nonvolatile memory for power outage protection.

The Gro is \$150 and can be purchased online via the company’s website (www.mygro.com) or from numerous “big box” retailers. A manufacturer’s warranty covers Gro controller defects in materials and workmanship for a period of 2 years from the date of purchase. There are no subscription fees for use or access to the Gro Cloud-based apps and software, and firmware updates are free and automatically pushed to all Gro owner smartphones.



Weather-Based Product Descriptions

Installation

Scotts states typical homeowner installation and programming time is under 30 minutes. During installation, the Gro automatically detects each connected sprinkler valve by performing a circuit test to validate the wiring for each zone.

Technical support is available by toll-free telephone in addition to the support provided on the company's website.

WaterSense Certification, Track Record, and Awards

The Gro is EPA WaterSense-certified.

Signature Control Systems

Signature Control Systems, Inc., was founded in 2000, and is headquartered in Irvine, California, with its manufacturing facility in Peoria, Illinois. Signature® (Signature) manufactures a range of residential, commercial, and golf course irrigation controllers. In 2013, the company launched the 8250 model weather-based smart irrigation controller that uses the Signature Share™ (Share) communication platform to communicate through the internet using an Ethernet connection. Signature's Cloud-based smartcontroller product offering has now expanded to include a range of weather-based irrigation controllers for all residential, commercial and municipal market segments. The residential WiFi connected smartcontroller portfolio now includes the 8210, 8310, 8240, and 8800 models, which run on the Signature Share central control communication platform. All 8200 and 8300 series models come standard as a 4-station irrigation controller with the capability to be expanded to 12 stations online via the Signature Share app. The 8800 model has the capacity to handle 24 stations. Each controller includes two data-ready sensor inputs for a combination of any two of the following sensors: rain, flow, moisture, or temperature. Each controller is an internet-based controller with a contemporary design, incorporating Signature Share Cloud-based software making it a smart ET-based residential controller and qualifying as an EPA WaterSense-labeled controller.



Operational Features

Connection and programming control can be done via any computer anywhere in the world with an internet connectivity, via the Signature Share website (<https://scs-share.com/>).

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

The Signature 8200 series, 8300 series, and 8800 models controllers can also be accessed via an iOS® 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 Signature Share centralized database. This allows access to the controller from anywhere, at any time, through the convenience of a smartphone or tablet.

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 that include:

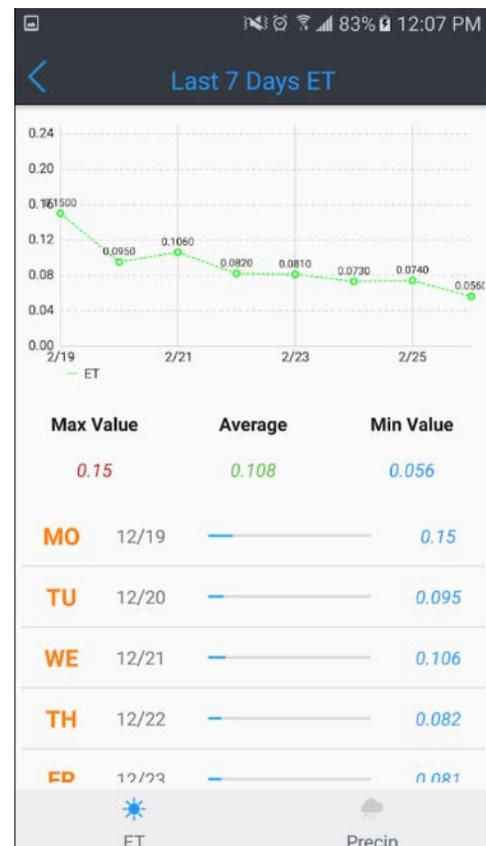
- Rotor type by zone
- Planting type by zone
- Specific conditions by zone (i.e., slope, sun/shade, and soil type)
- Zone precipitation rate, field capacity, and current depletion rate

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.

Signature Share software will calculate cycle/soak times based on the application rates, 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 rates and power consumption efficiency.

Signature Share controllers have no buttons or complex keypad. All programming inputs are done via either the internet or the smartphone app, which has multiple languages. Signature states 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.

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



Weather-Based Product Descriptions

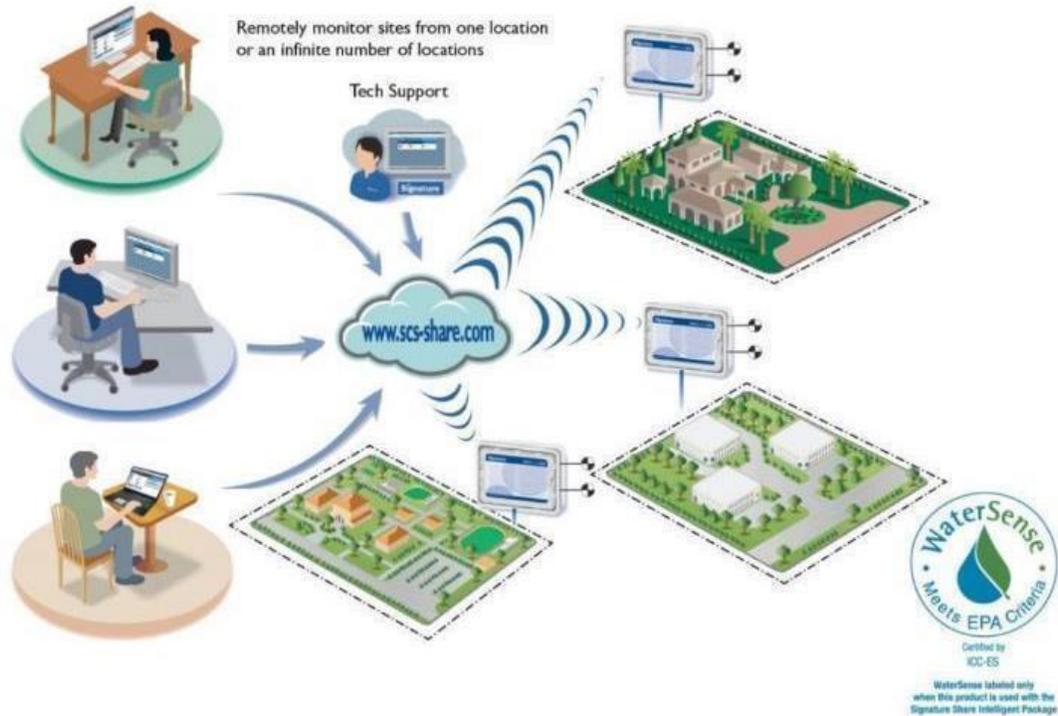
Diagnostic features include a 1.0-A self-resetting fuse for short circuit zone protection, a manual test button for maintenance without an internet connection, and intelligent station current monitoring of the station wiring and solenoid valve. The maximum station output configuration per controller is 12 stations at 24 VAC per station, with a maximum loading per station of 0.50 A.

For the 8250 model, additional items may be required for operation if a LAN connection is not available and are sold separately (i.e., Ethernet to PLC adaptor or Ethernet to WiFi adaptor).

USAGE EXAMPLE: SIGNATURE SHARE™ — Single User / Single Site



USAGE EXAMPLE: SIGNATURE SHARE™ — Multiple Users / Multiple Sites



Descriptions, Prices, and Warranty

Signature controllers are available either in a plastic, wall-mounted indoor cabinet with a plug-in external transformer (8200 series models) or in a plastic, wall-mounted outdoor cabinet with an internal transformer (8300 and 8800 series models). All controllers come with a 2-year trade warranty.

All 8200 series, 8300 series, and 8800 models controllers come with a 1-year “Operation & Management Plan,” which enables the controller to operate in the “Intelligent” mode. After the initial 1-year period of operation, the owner of the device can continue for free with the “Silver” plan or choose one of the two pay for subscription services (“Gold” or “Platinum”) Operation & Management Plans in subsequent years.

Weather-Based Product Descriptions

Signature Control Systems Product Pricing Summary as of March 2018

Indoor Mount Controller Descriptions	Model	MSRP
8250 - Residential, Ethernet, Indoor Web-Based Controller and Web Portal - 4 Stations (Expandable Online to 12 Stations)	8250-04-I12-USA	\$246
8210 - Residential, Indoor WiFi App-Based Controller - 4 Stations (Expandable Online to 12 Stations)	8210-04-I10-USA	\$222
8240 - Residential, WiFi, Indoor Web-Based Controller and Web Portal - 4 Stations (Expandable Online to 12 Stations)	8240-04-I10-USA	\$264
Outdoor Mount Controller Descriptions	Model	MSRP
8310 - Residential, Indoor WiFi App-Based Controller - 4 Stations (Expandable Online to 12 Stations)	8310-04-I4-USA	\$252
8340 - Residential, WiFi, Outdoor Web-Based Controller and Web Portal - 4 Stations (Expandable Online to 12 Stations)	8340-04-I10-USA	\$284
8800 - Residential, WiFi, Outdoor Web-Based Controller and Web Portal - 16 Stations (Expandable Online to 12 Stations)	8800-16-I10-USA	\$485
Single Station Expansion Descriptions	Model	MSRP
8250 - Single Station Expansion (Purchase Each Incremental Station Online via Signature Share App)	8250-01-X-USA	\$9.60
8210 - Single Station Expansion (Purchase Each Incremental Station Online via Signature Share App)	8210-01-X-USA	\$8.40
8240 - Single Station Expansion (Purchase Each Incremental Station Online via Signature Share App)	8240-01-X-USA	\$8.40
8310 - Single Station Expansion (Purchase Each Incremental Station Online via Signature Share App)	8310-01-X-USA	\$10.60
8340 - Single Station Expansion (Purchase Each Incremental Station Online via Signature Share App)	8340-01-X-USA	\$10.60
8800 - Single Station Expansion (Purchase Each Incremental Station Online via Signature Share App)	8800-01-X-USA	\$35.80
Operation & Management Plans - Annual Subscriptions	Model	MSRP
Silver Plan - Includes "Basic" Irrigation Capabilities, iOS and Android App Control, Daily Weather Forecast Email, Daily Alerts/Reports - Up to 3 Users	SILVRW	No Charge
Gold Plan - All of "Silver" Plan Plus "Intelligent" Irrigation Programming, Critical Event Notifications, Flow Measurement and Reporting, Firmware Updates - Up to 10 Users	GOLDW	\$92.40
Platinum Plan - All of "Gold" Plan Plus Flow Monitoring and Management - Up to 100 Users	PLTMW	\$132

Installation

Signature states 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 their website (www.signaturecontrolsyste.ms.com). Signature states that setting up controllers on the Share platform can also be done by the

homeowner by logging into <https://scs-share.com/>, clicking on “Create a New Account” and following the setup wizard. Once this is done, the user can log in to their secured Signature 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’s 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.

WaterSense Certification, Track Record, and Awards

Signature obtained EPA WaterSense Certification in June 2013 and on all 8200 series, 8300 series, and 8800 models in subsequent years.

Toro®

The Toro® Company was established in 1914, and has grown to become an internationally recognized supplier of irrigation and landscape maintenance products. Toro’s® corporate headquarters are located in Bloomington, Minnesota, and its Irrigation Division is headquartered in Riverside, California.



Operational Features

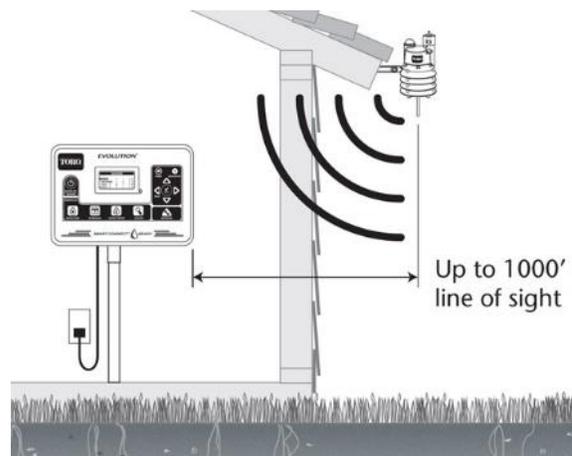
Toro’s® EVOLUTION® series of residential controllers were designed with ease-of-use and water conservation in mind. To qualify as a smartcontroller (weather-based scheduling), the EVOLUTION® controller must be paired with the Wireless ET Weather Sensor (model EVO-WS), the EVOLUTION’s® onsite weather station. The Wireless ET Weather Sensor collects temperature, rain, and solar-radiation data that are transmitted directly to the EVOLUTION® controller via a Smart Connect® receiver.

The Wireless ET Weather Sensor operates on a standard 9-volt battery. To connect to the Wireless ET Weather Sensor, the EVOLUTION® controller must be fitted with a Smart Connect® module. This module also allows for wireless connection to many of the other available companion sensors. The EVOLUTION® then uses those collected data to make real-time adjustments to the watering schedule. In addition, 40 years of location-based, historical ET data are stored in the EVOLUTION®, which can be used by the controller in cases where communication with the Wireless ET Weather Sensor is compromised (e.g., loss of battery power). The EVOLUTION® and Wireless ET Weather Sensor combination also provide an automatic shutoff feature in the event of freezing temperatures, as well as a “dry-out” option. The dry-out option is a customizable feature wherein a user can determine how many days irrigation should be suspended after a rain event.

Weather-Based Product Descriptions

Programming options for EVOLUTION® series controllers include sequential stacking of overlapping start times, or the ability to run multiple programs simultaneously. Further, EVOLUTION® controllers have a manual “Water Now” feature that allows irrigation in 1-minute increments up to 6 hours for plant establishment, or the ability to check the irrigation system on a valve-by-valve basis. A rain delay mode allows the user to shut off irrigation in 1-day increments for up to 14 days. Schedules can also be saved to and loaded from a USB drive.

Other features include cycle/soak programming, grow-in scheduling for the establishment of new plant material, zone-by-zone diagnostic feature, master valve and pump relay, and field upgradeable firmware. The EVOLUTION® is also compatible with Toro® wired rain sensors, the wireless Precision® Soil Sensor, wireless handheld maintenance remote, wireless auxiliary relays, and the SMRT Logic® landscape control platform. The SMRT Logic® allows the remote control of the EVOLUTION® via a smartphone, tablet, or computer via Toro’s® SMRTscape platform (www.smrtscape.com®).



Descriptions, Prices, and Warranty

Both the indoor and outdoor configurations feature a UV- and weather-resistant acrylonitrile butadiene styrene (ABS) cabinet with hinged door; the outdoor model features a locking door. The controller dimensions are 10.4 inches wide by 6.25 inches high by 4.5 inches deep (with door closed). The controllers have a 2.625- by 1.375-inch information LCD and button-type controls. All controllers include an internal UL/Canadian Standards Association-listed transformer. The transformer operates 120 VAC input and has an output of 24 VAC and 1.25 A. The total maximum load for the transformer is 1.0 A and 24 VAC. The nonvolatile memory maintains programming, and the backup 9-volt battery maintains the date and time during power outages. EVOLUTION® controllers and the Wireless ET Weather Sensor both come with a 5-year manufacturing defect warranty.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Toro® EVOLUTION® Series Controllers and Accessories List Prices as of February 2018

Description	Model	MSRP
4- to 16-Station Modular, Indoor Controller	EVO-4ID	\$155
4- to 16-Station Modular, Outdoor Controller	EVO-4OD	\$185
4-Station Expansion Module	EMOD-4	\$49
12-Station Expansion Module	EMOD-12	\$165
Wireless Receiver, Smart Connect®	EVO-SC	\$99
ET Weather Sensor, Wireless	EVO-WS	\$99
Precision® Soil Sensor, Wireless	PSS-SEN	\$102
Handheld Maintenance Remote, Wireless	EVO-HH	\$104
Auxiliary Relay, Wireless	EVO-AR	\$155
SMRT Logic® internet Gateway	SMRT-T	\$145
RainSensor, Wired	TRS	\$33
Rain/Freeze Sensor, Wired	53853	\$53

Installation

The EVOLUTION® series controllers and add-on accessories do not require professional installation, although trained installation is recommended. Typical installation times range from 1 to 2.5 hours, depending on the size of the landscape 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. Technical support is available from Toro® by a toll-free number (1-877-345-8676), via their website (www.toro.com), and through field certified contractors.

WaterSense Certification, Track Record, and Awards

When used in combination, the EVOLUTION® controller and Wireless ET Weather Sensor are EPA WaterSense-certified. Previous Toro® controllers have been included in the Texas A&M AgriLife Extension's *Smart Irrigation Controller Evaluation Program*.

Weather-Based Product Descriptions

Tucor

Tucor, Inc. (Tucor), who was incorporated in 1995, and based in Wexford, Pennsylvania, was the first company to market residential and commercial two-wire, weather-based controllers. Tucor's controller is also now available for conventional, 24-VAC irrigation wiring, making it an option for water-saving retrofits to existing conventional wired systems.

Tucor's basic controllers include the RKD+ (two-wire), RKS+ (conventional), and RKW+ (wireless)—hereinafter referred to as the RKx. All of the controllers are capable of handling up to 100 zones, with up to 10 valves, a master valve, booster pump, and cutoff valve running simultaneously. The RKx can run 10 unique programs with 12 daily start times. For the RKD+ and RKS+ models, wireless control can still be achieved using RealNet—Tucor's web-based, real-time water management platform.



Weather-based control is achieved with onsite or shared weather station data. Tucor offers a sophisticated solid-state wireless weather station (model ET-500) and a more affordable, solar-powered wireless device (ET-300-W). The weather station is installed in the field and can communicate up to 1,000 ft line-of-sight to the RKx. The weather station data may be shared among multiple controllers, either through RealNet or by broadcasting the data directly to other nearby controllers. Provided software allows monitoring and sharing data using a Windows-based PC. Tucor also offers soil moisture sensor products, which are covered in the “Soil Moisture-Based Product Descriptions” section in this report.

With Tucor's recently patented Total Cycle Management (TCM) process, a soil moisture sensor dynamically adjusts the ET-based scheduling with the principle being:

“Wet soils when watered using ET tend to stay wet and dry soils when watered using ET tend to stay dry. The principal of this patented technology is that high moisture readings of the soils shall reduce the ET applied to the ET balance and low moisture readings shall increase the ET applied to the ET balance. TCM adjusts the frequency and duration of ET-based irrigation cycles.”

Operational Features

The RKD+ is a decoder-based two-wire system. Tucor's two-wire systems have been used since 1995. The decoders are shipped “blank” and are programmed to the selected station by the user.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Programming is done at the RKD+ or with an optional hand-held device. Diagnostics allow for testing of the decoders in the field or at the controller. Decoders may be reprogrammed to different stations.

Tucor states typical two-wire benefits include: installation efficiencies, easy expansion, long distances (3 miles with 16 AWG), simplified troubleshooting, quick repairs, and multiple valves running simultaneously.

The RKS+, specifically, uses discrete wires to each valve with a common to all valves. It has a 25-station physical capacity; additional 25-station capacities are added by using an RKXT module (model XT), which allows up to three XTs for a total of 100 valves. The RKS+ controls the XT add-ons. An XT is connected to the RKS+ via a direct wire or wirelessly up to 3,000 ft line-of-sight. Stations may be added individually or may be spread individually over multiple XTs. That is, the RKS+ could have 12 stations, XT1 with 10 stations, XT2 with 16 stations, XT3 with 24 stations, for a total of 62 stations. Effectively, four conventional controllers could be replaced by one RKS+.

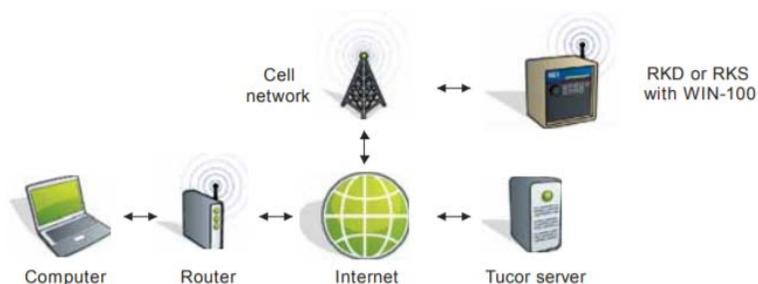
The RKW+ is a wireless system that uses a 1-watt 900-megahertz (MHz)-spread spectrum radio network for broadband communication to the controller from an access point and from the controller to valves, flowmeters, pump start relays, weather stations, and soil moisture sensors for a completely wireless installation.



Weather-Based Product Descriptions

Additional RKx features include remote real-time monitoring and control; inputs for ET, flow sensor, soil moisture sensor, and rain alarm; program flow stacking; misting (timing in seconds); cycle-and-soak; learn flow (per station); and water budget (0 to 250%). Alarm actions are based on short circuits and unexpectedly high deviation from normal flows. Actions can also include notifying the user by email.

All controllers may be accessed over the internet in real-time from any operating system's web browser. Internet connections to the controllers—Tucor's "RealNet"—are made with either an AT&T® wireless internet module (standalone), WiFi, or a serial-Ethernet LAN module (for



use with the end-user's LAN), which can be hardwired or be a part of a 900-MHz radio network. RealNet also allows for interaction with a controller via Tucor's companion smartphone and tablet Java-based app. Through this app, the user can, among many things: start and stop programs and stations, verify real-time flows, and check the controller's electrical status.

ET and rain data are supplied as pulses to the RKx, via front-panel terminals. Each pulse is defined by the user in the RKx to represent an increment of ET or rain. Accumulated ET is stored in the controller and may be adjusted by the user at the controller. ET adjustments to a given day's irrigation are made by automatically modifying the station run times of the chosen programs, based on the ET accumulated prior to that day, and modified by the day's rainfall accumulation. Base program and station run time scheduling is simplified using a Microsoft Excel® spreadsheet. Historic ET may be defined and stored in the RKx (based on 12 monthly values), which are then automatically subdivided into daily ET values, to be used either as the primary or fallback method. Soil moisture data for TCM are supplied in an ASCII format via RS-232 communication through hard wire or radio.

Descriptions, Pricing, and Warranty

The RKx is housed in a wall-mounted, plastic locking enclosure. Options include stainless steel pedestals and other enclosures. It is powered by an internal, Class 2, 50-voltampere transformer with a ½-inch National Pipe Thread nipple mounting. Dimensions are approximately 12 by 12 by 5 inches. The RKx's firmware is nonvolatile and may be "flash" upgraded. Program memory is backed up via a lithium cell with a lifetime rating of 10 years. The display is a 40-character, 2-line backlit LCD.

Tucor products are available through certified distributors. A list of distributors is available from Tucor upon request (800-272-7472) or on their website (<http://dealerlocator.tucor.com/locator-map/>). Base warranty on the controller and decoders is 1 year and may be extended up to 5 years.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

Tucor Product Pricing Summary as of March 2018

Description	Model	MSRP
100-Valve 2-Wire Decoder Controller	RKD	\$1,975
100-Valve 2-Wire Decoder Controller (stainless steel version)	RKD-SS	\$2,590
100-Valve 2-Wire Decoder controller (panel version)	RKDP	\$1,480
Singe-Valve Line Decoder for Use With the RKD+	RKLD-050	\$90
100-Zone Capacity, Conventional Output Controller (must add zone count; individually priced). Includes 25-Zone Terminal Connections.	RKS	\$1,165
25-Zone Extension Cabinet for Zone Count 26–50, 51–75, 76–100	RKS-EXT	\$840
License Key for 1 Zone	RKS-Z	\$32
100-Zone Capacity, Conventional Output Controller (stainless steel version)	RKS-SS	\$1,875
100-Zone Capacity, Conventional Output Controller (panel version)	RKSP	\$865
25-Zone Extension Cabinet for Zone Count 26–50, 51–75, 76–100 (panel only)	RKS-EXTP	\$512
CSI (Irrisoft) WR7 Weather Reach Receiver	WR-T	\$795
Solar-Powered, Wireless Weather Station With ET and Rain Pulse	ET-300-W	\$1,440
Solid-State Wireless Weather Station	ET-500	\$12,875
Wireless Logger Receiver; Includes Output Logger	ET-WLR	\$678
Wireless Logger Receiver; Includes Output Logger and Outdoor Enclosure	ET-WLRX	\$776
Pulse Output Tipping Spoon Rain Gauge	TRB-100	\$240

Installation

Tucor recommends that the RKx be installed by a certified professional. They do offer several online video tutorials on installation of accessory modules.

WaterSense Certification, Track Record, and Awards

A SWAT performance report for the RKS and Tipping Rain Bucket with historical ET was posted in May 2009. The RKx is EPA WaterSense-certified.

Weathermatic

Weathermatic® (Weathermatic), established in 1945, is a worldwide manufacturing company of a full line of irrigation products. The company, headquartered near 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™ (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 fine-tune zone 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. These estimates 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 standalone 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 2004.

Weathermatic continues to develop the SmartLine brand through Next Generation firmware updates. 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 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. The Next Generation firmware also has an automatic change feature for daylight saving 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 24 zones for their SL1600 model to accommodate various size residential and light-commercial landscapes. Model SL1620 has a fixed zone capacity of 20. A larger commercial model, the SL4800, provides module and wiring space for up to 48 zones. A decoder-based two-wire option model, the SL9600TW, is available in 48- or 96-zone capacity. Models SL1600, SL1620, SL4800, and SL9600TW are all suitable for indoor or outdoor installation. The SL800 is an indoor model.

Descriptions, Prices, and Warranty

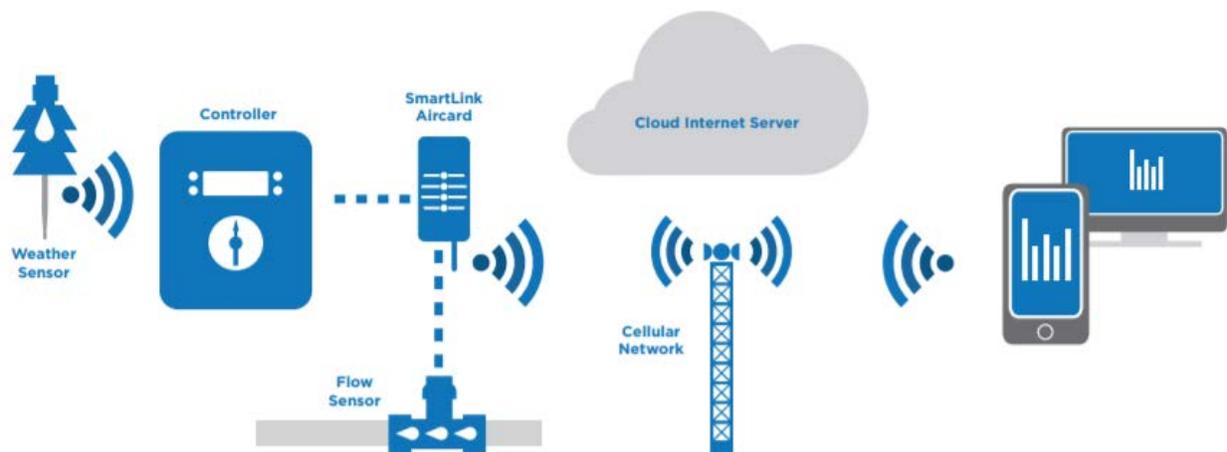
The SL800 model controller is a fixed, four-zone unit that can be expanded to six or eight zones with two-zone modules (series SLM2). The SL1600 model controller is shipped standard with a 4-zone module and can be expanded to 8, 12, or 16 zones with additional 4-zone modules (series SLM4). It can also be expanded to 24 zones by adding 12-zone modules (model SLM12-1600). The SL1620 model controller is a fixed 20-zone unit. The SL4800 model controller is shipped with 12 zones included. The 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 model SL800; 9.1 by 10.1 by 4 inches for the SL1600 model series; and 15 by 16.5 by 5.8 inches for models SL4800 and SL9600TW. Model SL800 has an external transformer power supply with a barrel connector that plugs into the side of the controller for fast installation. The SL1600 model series have internal transformers with a prewired plug-in cord that will accept 120 or 240 VAC. Models SL4800 and SL9600TW have a 120/240-VAC internal transformer, but without a prewired plug-in cord (professional installation required). For the SL800 model 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 A for the SL800 model; the SL1600, SL4800, and SL9600TW models are rated at 1.2 A. Weathermatic states these capacities are adequate for running three-zone valves concurrently, including a master/pump valve, for the SL800 model and SL1600 model. In addition, Weathermatic states that these capacities are also adequate for running five-zones concurrently, including a master/pump valve, for models SL4800 and SL9600TW. Accepted wire sizes range from 14 to 18 AWG.

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. The user can also omit specific calendar event dates, days of the week, and times of the day when no watering is allowed. This is useful for complying with local watering restrictions.

Weathermatic also developed SmartLink® (SmartLink), which 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, a user can manage all sites from any computer or mobile device with an internet connection—companion smartphone and tablet applications are available. No software or long-term contracts are required. A flow version of the SmartLink Aircard is also available, which can set flow limits by zone and detect leaks or broken heads. The SmartLink Wireless Landscape Network features an onsite inspection report (sprinkler check) with proposal pricing integration and asset mapping capability, as well as Snapshot Program Backup and full run time, gallons used, and deficit reporting capabilities. 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. SmartLink also enables control via Amazon's Alexa® AI assistant.

Weather-Based Product Descriptions



Weathermatic offers a two-wire option with the SL9600TW model controller. The SL9600TW model controller includes connections for up to three different two-wire paths and includes a light-emitting diode (LED) display and status lights for programming, operation status, and troubleshooting. The valve decoders used to decode the signals from the SL9600TW model controller 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 AWG wiring, surge protection, and functional distance up to 100 ft from the valve.

Weathermatic's onsite Weather Sensor includes a temperature 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. Available weather sensor models are the SLW1 wired unit and the SLW5 and wireless units. The SLW5 model has line-of-sight operation up to 1,500 ft. The SLW1 model has no onboard power requirement (battery) to replace. Operation limit is 200 wire-ft from the controller. The SLW5 model requires onboard battery power. The addition of the Weather Sensor has the potential to considerably improve the SmartLine controller's ability to apply an appropriate amount of water.



SmartLine Solar is a solar-powered package available in 24- and 48-zone conventional-wired models and 48- and 96-zone two-wire decoder models for operating standard 24-VAC solenoids. The package allows a SmartLine irrigation system be placed where needed. The included batteries are capable of powering the system for up to 7 days without a charge.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

SmartLine controllers are distributed through Weathermatic’s established wholesale suppliers (specialty irrigation suppliers) and installation professionals. 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:

- ◆ Ten Years—11000CR and 8200CR series valves and S24B solenoid
- ◆ Five Years—Rotors, spray equipment, nozzles, and S20P solenoids
- ◆ Three Years—SmartWire when used with SLWIRE
- ◆ Two Years— SmartLine controller products, SmartLink products, and N-100 and 12000 series valves
- ◆ One Year—SmartWire when used without SLWIRE
- ◆ Extended warranties are available for SmartLine® controller products and SmartLink products
- ◆ SmartLine controllers (models SL800, SL1600, SL4800, and SL9600TW) and weather stations (model SLW) are covered under warranty for lightning damage

Weathermatic SmartLine Product Pricing Summary

Description	Model	MSRP
4- to 8-Zone Indoor Controller (with two zones included in base price)	SL800	\$127.58
4- to 24-Zone Residential Controller (with four zones included in base price)	SL1600	\$243.04
20-Zone Commercial Controller	SL1620	\$636.64
48-Zone Commercial Controller (with 12 zones included in base price)	SL4800	\$625.75
2-Zone Module for SL800	SLM2	\$42.49
4-Zone Module for SL1600	SLM4	\$72.88
12-Zone Module for SL1600	SLM12-1600	\$231.47
12-Zone Module for SL4800	SLM12-4800	\$231.47
48-Zone Commercial Two-Wire Controller (with 48 zones included in base price)	SL9648TW	\$1,146.52
48-Zone Commercial Two-Wire Controller (with 48 zones included in base price)	SL9696TW	\$2,257.50
Two-Wire Decoder for One Valve	SLDEC1	\$145.87
Two-Wire Decoder for Two Valves	SLDEC2	\$291.72
Two-Wire Decoder for Four Valves	SLDEC4	\$413.27
Economy Onsite Weather Sensor	SLW1	\$165.32
Wireless Weather Sensor, 900 MHz	SLW5	\$367.45
SmartLink Aircard for AT&T Cellular Network	SL-AIRCARD-ATT	\$499.95
SmartLink Aircard With Flow for AT&T Cellular Network	SL-AIRCARDFLOW-ATT	\$599.60

Weather-Based Product Descriptions

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 application rates and prescribe an exact numerical application rate for the zone, from 0.2 inch to 3.0 inches per hour. Users will select the standard setting (“STD”) for zones not included in the ET “Auto Adjust” watering. Plant type works similarly to the sprinkler type input whereby 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 of the U.S., 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 can 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%.

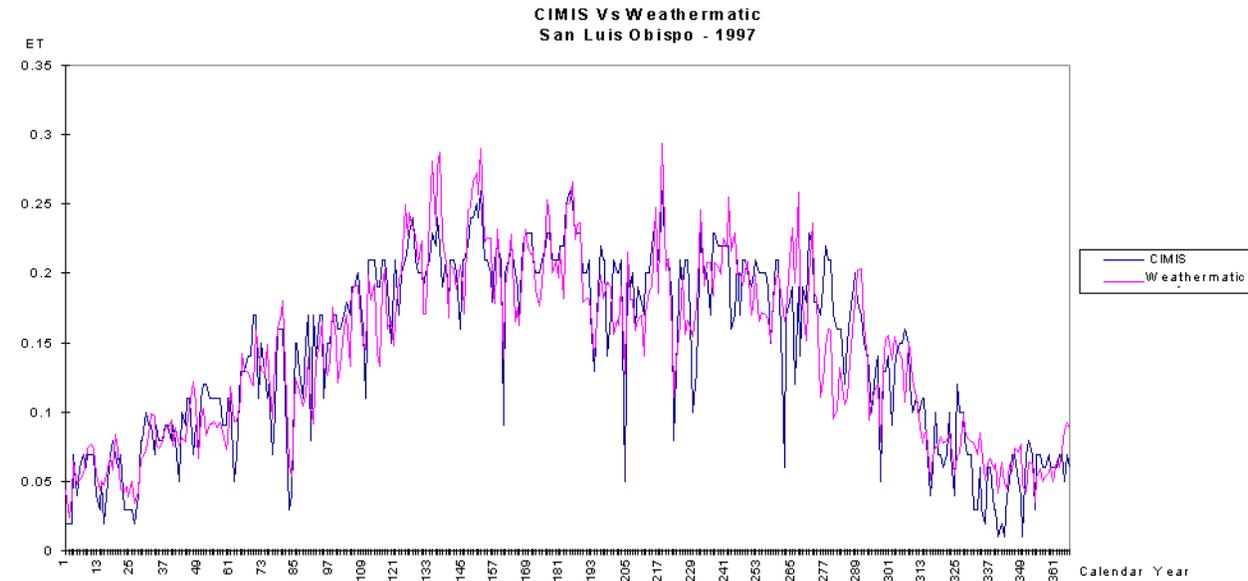
The controller’s irrigation schedule is based on the user-prescribed irrigation days, start times, and omit times (dates, days, and times of day) to conform to local watering restrictions and also accommodate site-specific hydraulic issues that vary by time of day. Once programmed, the controller calculates 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.

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 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. Installation and programming instructional manuals and videos are available on Weathermatic’s website (www.weathermatic.com/). A DVD is also available upon request.

WaterSense Certification, Track Record, and Awards

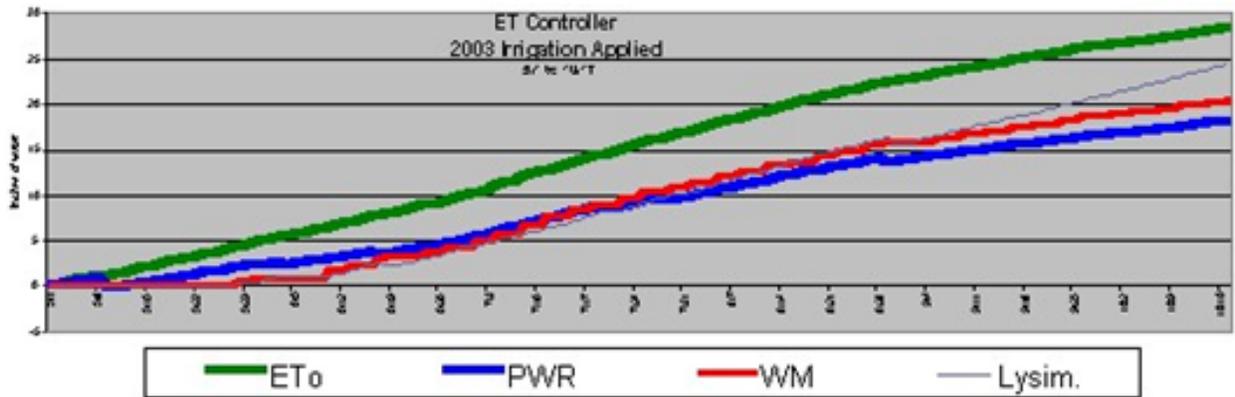
Weathermatic tested its Hargreaves equation-based ET calculation algorithm and controller functionality extensively for 8 years. For comparing ET calculations, CIMIS weather station reference ET values were compared to those using the Weathermatic controller/weather monitor methodology at 10 geographically diverse sites over a 7-year period, for a total of 70 years of combined data. Weathermatic states there is good correlation between the CIMIS and Weathermatic ET data at all sites.



CIMIS versus Weathermatic ET data in 1997.

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 a lysimeter), reference ET (ET degree calculated with onsite weather station data), and net plant watering requirements (PWR).

Weather-Based Product Descriptions



Sample of 3-year study results of applied irrigation from 2003.

The Weathermatic SmartLine controllers were also part of a field pilot program conducted by the Marin Municipal Water District in Marin County, California. 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. Results of this study are available upon request from the manufacturer.

Weathermatic's controllers have undergone SWAT testing; however, these reports are no longer available. One of the company's controllers has been part of the Texas A&M AgriLife Extension's *Smart Irrigation Controller Evaluation Program*. All Weathermatic controllers have received EPA WaterSense Certification with the addition of the Weathermatic Weather Sensor unit.

Soil Moisture-Based Irrigation Control System Principles

All of the soil moisture-based products reviewed operate on the principle 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 soil retains the maximum amount of water it is able, after seepage and surface drainage cease. The wilting point occurs when soil moisture is depleted to the point at which plants can no longer extract water from the soil and wilt without. 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 mass of water to the mass of soil holding that water. 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 drops to a threshold 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 (overwatering). 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. Some products adjust 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 standalone controller and others include an add-on device that works with an existing clock-type controller. Regardless of standalone 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.

Soil Moisture-Based Irrigation Control System Principles

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 hereafter. 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 60 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 25 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. In addition, 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; it is recommended that 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) that 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 is then converted to a soil moisture measurement. FDR sensors, which operate at high frequency (greater than 20 MHz), 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 following "Installation" section in this report).

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 state 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, while 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 on their company's websites. 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 regrows.

Standalone 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 standalone 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 standalone 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 standalone controller features that 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 (standalone 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 relative to the sensor reading. 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. Almost 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. In addition, 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 standalone 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 standalone 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. This could lead to problems with cost, maintenance, accessibility, among other factors. An option for a majority of smartcontrollers is the ability to use a two-wire system in lieu of the traditional multi-wire configuration. The two-wire system eliminates the need for separate wires at each valve and sensor, replacing the wires with a single two-wire path. A decoder is required at each connection to a valve or sensor. In some applications, the two-wire system could lead to a large savings in wiring costs, as well as simplify installation—linear systems like highway corridors and green

Soil Moisture-Based Control Product Features and Comparison Criteria

belts where large quantities of wiring would be required for traditional circuitry. This can allow for flexibility in the controller location, and the two-wire approach streamlines the process of adding zones to the irrigation system.

Another alternative to the traditional wiring circuitry is the emerging use of wireless valve control systems. Solenoids are signaled via a radio transmitter connected to the irrigation controller. If the radio signal is lost, outputs will go back to user-defined conditions until the signal is re-acquired. What sets the wireless systems apart from the other two options is the ease of installation and modular additions to the irrigation system, since no wires are required. The technology is still very new and has had limited use, unlike the traditional and two-wire systems.

Warranties and Reliability

All of the products reviewed include a warranty. Warranty details are discussed under the product descriptions in this report. In some cases, the manufacturers' warranty periods vary for its different products. Although the warranty periods may or may not be indicative of the service life expectancy of the products, some cases there appears to be a correlation between the cost of a 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, in general, 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.

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 their respective product descriptions for input prior to being incorporated into this report.

Baseline

Baseline, Inc. (Baseline), located in Boise, Idaho, designs and manufactures site management systems featuring responsive technology. Baseline began business in 1998, and their first soil moisture-sensing products entered the market in 2002. Their systems include add-on and standalone controllers, as well as centralized control systems. Baseline states their products are easy to use and require minimal administration time.

Baseline's biSensor™ (biSensor) soil moisture sensors 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 predetermined 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 three models—a 6-inch rigid sensor used with the WaterTec S100™ (WaterTec S100) soil moisture monitor, a 5-inch rigid compact sensor typically used in green roof and greenhouse applications, 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 up to 25 sensors per controller that would be associated with various



Soil Moisture-Based Product Descriptions

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 at least 25 years in the soil, regardless of climate.

Baseline's soil moisture sensors work by sending a high-frequency, electrical pulse 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 one-tenth of a percent of change in volumetric soil moisture. 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 standalone controllers can communicate to a cloud-based central control interface, BaseManager™ (BaseManager), through a variety of wired and wireless communications. BaseManager allows users to manage an unlimited number of controllers remotely over the internet from a computer, tablet, and/or smartphone. BaseManager users can do everything they would normally do at the controller from the convenience of their internet-connected device while leveraging additional features such as a map-based interface. BaseManager has a free version as well as subscription services that offer additional features.

Controller Descriptions, Prices, and Warranty

Baseline's controllers include one add-on model and two stand-alone models. The standalone controllers can use traditional valve wiring, a two-wire system, or a combination of two-wire and conventional wire. The add-on unit, the WaterTec S100, has a single biSensor that integrates with just about any existing irrigation timer. Multiple biSensors can be connected to Baseline's standalone 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 suspend irrigation. Baseline's standalone controllers can use either the lower threshold or the upper threshold sensor-based watering strategies. The WaterTec S100 uses the lower threshold watering strategy where the sensor only allows irrigation when the soil has dried out to a level at, or below, the threshold. With the upper threshold, the user can choose which day and what time of day to start watering, and the sensor will cease watering when soil moisture reaches the upper threshold.

The WaterTec S100 is an add-on device for use with an existing controller and a single biSensor. The WaterTec S100 monitor is constructed of heavy-duty water-resistant plastic and is



Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

appropriate for outdoor installation. Its dimensions are 4.6 by 2.6 by 1.5 inches, and it has a three-character, one-line LCD and touchpad-type controls. The WaterTec S100 comes with a 6-inch biSensor soil moisture sensor.

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

The BaseStation 3200™ (BaseStation 3200) is a standalone controller supporting up to 200 zones in any combination of two-wire and conventional wire that is certified by the EPA WaterSense Program. The BaseStation 3200 allows users to optimize their irrigation management using both soil moisture sensors and weather-based data. 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 in order to expand the conventional wire capacity. The BaseStation 3200 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 cycle/soak times. Users can manage the BaseStation 3200 controller remotely with BaseManager. The BaseStation 3200 control panel has a high contrast 3.5-inch color LCD, an option selection dial, and programming buttons.

The BaseStation 1000™ (BaseStation 1000) is a standalone controller supporting up to 100 zones in any combination of two-wire and conventional wire that is certified by the EPA WaterSense Program. 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 cycle/soak times. Users can manage the BaseStation 1000 controller remotely with BaseManager. 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, option selection buttons, and programming buttons.

The BaseStation 3200 and BaseStation 1000 are available in indoor/outdoor wall mount cabinets or an outdoor pedestal. The 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.

Baseline products are available from its distributors, and a distributor list is available on the Baseline website (www.baselinesystems.com). All Baseline products are eligible for a 10-year warranty.

Soil Moisture-Based Product Descriptions

Baseline Product Pricing Summary

Description	Model	MSRP
WaterTec Add-On Soil Moisture Monitor With biSensor	S100	\$165
200-Zone Two-Wire Standalone Controller in a Large Wall Mount Cabinet	3200X	\$2,778
200-Zone Two-Wire Standalone Controller in a Pedestal	3200P	\$5,049
200-Zone Two-Wire Controller With 12-Station Conventional Wire Board in a Wall Mount Cabinet	3200X-R12	\$3,099
200-Zone Two-Wire Controller With 24-Station Conventional Wire Board in a Wall Mount Cabinet	3200X-R24	\$3,417
200-Zone Two-Wire Controller With 36-Station Conventional Wire Board in a Wall Mount Cabinet	3200X-R36	\$3,732
200-Zone Two-Wire Controller With 48-Station Conventional Wire Board in a Wall Mount Cabinet	3200X-R48	\$4,050
200-Zone Two-Wire Controller With 12-Station Conventional Wire Board in a Pedestal	3200P-R12	\$5,412
200-Zone Two-Wire Controller With 24-Station Conventional Wire Board in a Pedestal	3200P-R24	\$5,733
200-Zone Two-Wire Controller With 36-Station Conventional Wire Board in a Pedestal	3200P-R36	\$6,048
200-Zone Two-Wire Controller With 48-Station Conventional Wire Board in a Pedestal	3200P-R48	\$6,369
100-Zone Two-Wire Standalone Controller in a Large Wall Mount Cabinet	1000X	\$1,449
100-Zone Two-Wire Standalone Controller in a Pedestal	1000P	\$3,765
100-Zone Two-Wire With 12-Station Conventional Wire Board in a Large Wall Mount Cabinet	1000X-R12	\$1,764
100-Zone Two-Wire Controller With 24-Station Conventional Wire Board in a Large Wall Mount Cabinet	1000X-R24	\$2,085
100-Zone Two-Wire Controller With 36-Station Conventional Wire Board in a Large Wall Mount Cabinet	1000X-R36	\$2,406
100-Zone Two-Wire Controller With 48-Station Conventional Wire Board in a Large Wall Mount Cabinet	1000X-R48	\$2,721
100-Zone Two-Wire Controller With 12-Station Conventional Wire Board in a Pedestal	1000P-R12	\$4,080
100-Zone Two-Wire Controller With 24-Station Conventional Wire Board in a Pedestal	1000P-R24	\$4,401
100-Zone Two-Wire Controller With 36-Station Conventional Wire Board in a Pedestal	1000P-R36	\$4,719
100-Zone Two-Wire Controller With 48-Station Conventional Wire Board in a Pedestal	1000P-R48	\$5,040
biSensor Soil Moisture Sensor (1.5 ft)	5315B	\$255
Compact biSensor Soil Moisture Sensor (5 in)	5311	\$255
biCoder Two-Wire Valve Adapter (single zone)	5201	\$150
biCoder Two-Wire Valve Adapter (two-zone)	5202	\$210
biCoder Two-Wire Valve Adapter (four-zone)	5204	\$294

Installation

Although Baseline recommends installation by a landscape professional, they state 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 and BaseStation 1000 are reported to be less labor intensive to install than the majority of industry smartcontrollers, Baseline recommends that these systems be installed by a landscape professional. The company offers extensive resources on installation and programming on their website.

SWAT Testing, Track Record, and Awards

SWAT calibration test reports for Baseline's WaterTec S100 and biSensor 5315B sensors were posted in 2010. The BaseStation 3200 and BaseStation 1000 standalone controllers have received EPA WaterSense Certification.

Baseline maintains a number of case study reports on their website that the reader is encouraged to review. One such example includes a 3-year pilot study implemented by the Portland Water Bureau who investigated the ability of soil moisture sensor-based irrigation controllers. 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 the 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. 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.”

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



Soil Moisture-Based Product Descriptions

manage 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 standalone or add-on landscape irrigation scheduling devices.

Sensor Description and Operation

Dynamax's SM150 is an FDR-type of dielectric sensor that measures volumetric soil moisture content from 0 to 60 with a 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 states 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 (ML3) 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 0.5% for temperature. With the addition of a thermistor sensor, it allows 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 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 standalone controller, Dynamax's 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 using the two soil moisture-level setpoints. 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

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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 soil moisture sensors may be connected to the GP1, and it has terminals for up to two temperature sensors, a flow sensor, and a rain AWG. 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 on and off irrigation.

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. A minimum of approximately 6 ft of 12 AWG wire is required to connect the GP1 to the existing controller. The GP1 is programmed using a PC or a personal digital assistant (PDA) device. Programming software is included with the GP1, 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 ML3s 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.



Dynamax products may be ordered directly by contacting the sales department through their website (www.dynamax.com), by toll-free telephone (800-896-7108), or through its distributors and irrigation design consultants. A distributor search engine is also available on their website. Dynamax provides a 1-year warranty with its soil moisture sensor control systems.

Soil Moisture-Based Product Descriptions

Dynamax Product Pricing Summary

Description	Model	MSRP
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 ft 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 attached to a 1.5-inch-diameter pipe.

The SM150 and ML3 soil moisture probes have connectors so that cables up to 300 ft long (or 100 meters) 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.

SWAT Testing, Track Record, and Awards

The ML3, 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 setpoints 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 website.

ET Water Systems

ET Water Systems, Inc. (ETwater®), based in Novato, California, is a manufacturer of weather-based irrigation controllers for the residential and commercial markets. ETwater® (ETwater) was incorporated in 2002 and began manufacturing controllers in March 2005. The company manufactures in California and distributes its systems throughout the U.S. ETwater offers standalone 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 17 weather variables including ET, wind, and solar, among others, from big data sources and user-programmed information associated with specific landscape features. ETwater's system can also use optional public, private, or onsite weather station data in its scheduling algorithm.

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. Changes can then be applied quickly to all stations within the group. For example, if a water manager needed to change the run time for all turf stations in an HOA 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 those stations.

To improve water management decisions, the *ETwater Manager* (a web-based smart irrigation management system) 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), wind, solar, cloud cover, and other variables. 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. The water use monitoring option could be useful for water agencies interested in quantifying water conservation.

Soil Moisture-Based Product Descriptions



Additional features of the *ETwater Manager* include:

- ◆ **At-A-Glance Dashboard:** The dashboard feature provides a single, at-a-glance view of alarms, controller status, and schedules across all controllers on all sites.
- ◆ **Water Budgeting Toolkit:** A water budget tool that calculates water usage and provides graphs and reports to track a site's water usage against monthly water budgets to identify overwatering.
- ◆ **Troubleshooting:** A filtering tool provides instant access to critical data such as high-flow faults and faulty valve wiring.
- ◆ **Bundled Configuring:** A 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 calculated 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 used via the ETwater central server as discussed hereafter. 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 website (<http://etwatermanager.com/customer/Login.cfm>). 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, 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, the ETwater server maintains all controllers watering activity forever so users can review their watering history on ETwater's website in a 30- to 360-day calendar view or downloadable report template (<http://etwater.com>). 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 website 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 pulldown menus or click-on picture options (e.g., plant-type pictures). The program 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 and distribution uniformity may be entered, or default measures may be selected in the absence of precise precipitation rate and distribution uniformity 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 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 non-irrigation days, adjust the total station run times by a percentage factor, and initiate manual irrigations by station at the controller or remotely through the *ETwater Manager*. The user may review system and irrigation history information on the website. 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



Soil Moisture-Based Product Descriptions

used, which offers a more efficient means of programming. Adjustments to specific site factors may be made at any time via ETwater's website. 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. 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 states that the irrigation scheduling algorithms they use is 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. These algorithms automatically generate daily schedules for each station with cycle/soak times based on a station's sprinkler application rate, soil intake rate, and slope conditions. The station cycle/soak runs 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/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 controllers will accommodate popular brands of rain sensors or rain gauges. The use of a standard rain sensor will cause circuit interruption and suspend irrigations when significant rainfall occurs.

The QuickDraw[®] (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 controller suspensions, and check controller status.

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 and turbine flow sensors or their equivalents.

Enhancements to ETwater products include:

- ◆ January 2017: Release of open application programming interface for developers to integrate ETwater algorithms and services in building management systems or other applications.
- ◆ October 2014: Switched from weather station to big data sources for calculating ET and daily watering schedules.
- ◆ October 2013: ETwater was an early adopter in the irrigation sector of including PTCRB-certified cellular modems in their smartcontrollers that allow for “Over-the-Air Programming” capability. Over-the-air programming 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 rainfall 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. This communicates actionable water savings data and helps the user stay within a monthly water budget. 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.

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™ controllers are designed for new construction or when an old system needs to be completely replaced. This is a complete controller in a weatherproof 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 2 A maximum, and the station terminals will accept 12 to 20 AWG wire. The retail price for an ETwater SmartBox™ controller is range from \$2,100 to \$3,800 for 8 to 48 stations.

Soil Moisture-Based Product Descriptions

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's® MC Plus® controller; Rain Master's® Sentar™, Eagle™, Hawk™, and Evolution DX2™ systems; and many of Rain Bird's® Maxicom® controllers. These panels make installation rapid and sell for less than a full ETwater controller, yielding savings on both installation labor and equipment. Panels range in price from \$2,100 to \$3,300.

The ETwater HermitCrab® (HermitCrab) is an add-on device that upgrades most brands of conventional controllers 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.

The second generation HermitCrab 2 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 *ETwater Manager* account. The HermitCrab is compatible with over 50 controller models that have a remote access port, including Hunter®, Irritrol®, Rain Bird®, Rain Master®, Toro®, and Superior™/Sterling™ controllers. The list price for a HermitCrab is \$950, which includes the first year of *ETwater Manager* service. The cable connecting the HermitCrab to the host controller costs \$75 and is specific to the brand of host controller.



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 \$184 to \$230. Optional flow monitoring and control service is \$56 to \$70 annually.

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 by factory-trained individuals or irrigation contractors for all their products. 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 (1-800-685-5505), email (care@etwater.com), or online chat (<http://etwater.com>). ETwater also provides installation instructions on their smartphone companion app.

SWAT Testing, Track Record, and Awards

ETwater has completed SWAT testing and a performance report was posted on the IA website. ETwater has earned EPA WaterSense Certification for its entire product line, including SmartBox controllers, SmartWorks panels, and HermitCrabs. An ETwater controller has also been evaluated by the Texas A&M AgriLife Extension's *Smart Irrigation Controller Evaluation Program*. Results of the testing are available through their website.

Documentation of irrigation watering adequacy of ETwater products is available upon request from the company.



Hunter Industries

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

Operational Features

Soil-Clik uses a granular matrix style moisture sensor to obtain a relative moisture level reading, and interrupts irrigation when a user-programmed 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.

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 (discussed previously in the “Weather-Based Product Descriptions” section in this report) 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 moisture contents are still sufficient.

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 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 also 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 website (www.hunterindustries.com/irrigation-product/sensors/soil-cliktm). The retail price for the Soil-Clik is \$153. The price range for compatible Hunter controllers is from \$115 to \$2,250. Soil-Clik comes with a 5-year warranty.

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 ft from the module. The sensor should be placed in the sunniest, driest area of the landscape to avoid deficit irrigating some sections 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 two-thirds 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 on Hunter's website (www.hunterindustries.com) and contains detailed installation and programming information.

SWAT Testing, Track Record, and Awards

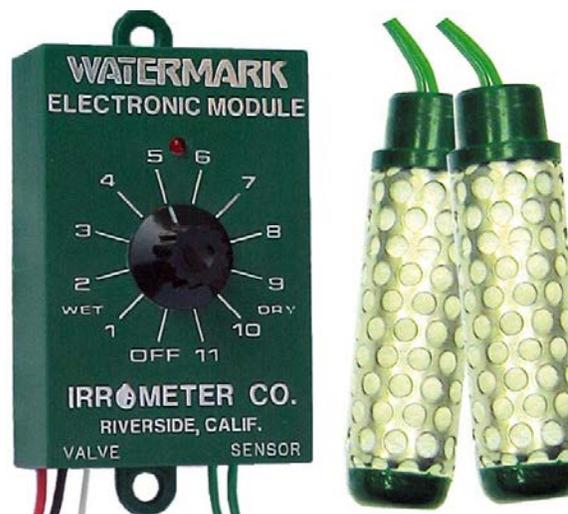
The Soil-Clik probe's design has a long history in agricultural and landscape irrigation. The Hunter Soil-Clik will function as a complementary component in an EPA WaterSense-approved application with Hunter Solar Sync and compatible controllers, but has no rating of its own at this time.

Hunter has had 10 to 15 years' experience with ET-based irrigation. The Soil-Clik is positioned either as a standalone 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® (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. The WaterPerfect Turf and Landscape Irrigation Scheduling and Water Management software is included with the purchase of an IRROMETER control system. This software program aids the user in the proper scheduling of irrigation using 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 states that it 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 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 (model WS1), WATERMARK Electronic Module (model WEM), Battery WEM (model WEM-B), and WATERMARK Multiple Hydrozone System (model MHS). 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 model 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 ft using 18 AWG 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 module 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 module, 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 the module 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 use of multiple modules and sensors. For retrofit of an existing system where multiple sensors are needed, the WATERMARK Multiple Hydrozone System device (wired or wireless) should be used rather than installing the needed additional common wiring.



The WATERMARK Electronic Module'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 module's dimensions are 3 by 2 by 1.5 inches. The module is adjustable from 10 to 120 centibars by a simple dial that has an "OFF" position to allow for overriding the sensors. The module's indicator light comes on when the clock/controller is powering a valve controlled by the module, 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 a simple wiring configuration and easy installation. Both function similar to the WATERMARK Electronic Module 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, which make it small enough to mount inside many controller cabinets. The WaterSwitch is powered by the 24-VAC supply from the clock/controller.



Soil Moisture-Based Product Descriptions

The Battery WEM is designed for use with a direct current (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 a waterproof battery compartment.

The most advanced of IRROMETER's Landscape Automation Products is the WATERMARK Multiple Hydrozone System. Where the WaterSwitch and the WATERMARK Electronic Module are designed to manage a single valve or hydrozone (area of specific plant type or irrigation need, such as turf, shrubs, trees, etc.), the WATERMARK Multiple Hydrozone System is designed to manage many different plant types, generally in a larger or commercial application. Both the wired (MHS) and wireless (W-MHS) 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 and report watering history, and will display the percentage of water saved. A manual override feature is also included.

The wired MHS model requires a base unit and a pair of WATERMARK sensors for each hydrozone. The wireless W-MHS model requires the base unit and a wireless transmitter for every two hydrozones. Two pair of WATERMARK sensors are included with each transmitter. Both models 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.

IRROMETER products are available through irrigation equipment distributors, some of which are listed on their website (www.irrometer.com). IRROMETER provides a 1-year warranty with its soil moisture sensor control systems.



Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

IRROMETER Product Pricing Summary

Description	Model	MSRP
WaterSwitch Add-On Controller	WS1	\$100 ¹
WATERMARK Electronic Module Add-On Controller	WEM	\$200 ²
Battery WATERMARK Electronic Module 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-ft)	MHS-C	\$123
WATERMARK Soil Moisture Sensor Pair (5-ft lead wire)	200SS-5PR	\$70

¹Price includes one WATERMARK soil moisture sensor.

²Price includes two WATERMARK soil moisture sensors.

³Price includes 15-ft connection cable.

⁴Price includes four WATERMARK soil moisture sensors.

Installation

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

SWAT Testing, Track Record, and Awards

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, Aquacraft, Inc., conducting the study and published numerous papers from 1995 to 2001 for the IA, American Society of Agricultural Engineers, American Water Resources Journal, and the American Water Works Association. The following excerpt and graph are from one of their published papers:

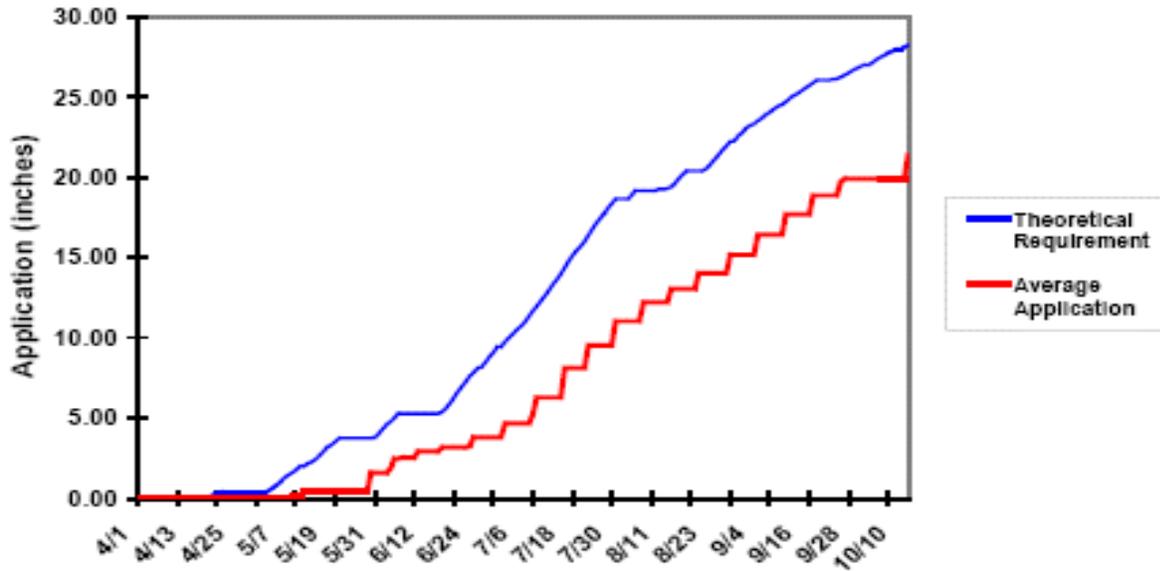
“The results of this study were quite encouraging from the standpoint of both irrigation efficiency and cost effectiveness. On a seasonal basis, the systems limited applications to an average of 76% of theoretical requirement when all sites are combined.”

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

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

Soil Moisture-Based Product Descriptions

Theoretical and Actual Irrigation Application, 1997
23 sites, Boulder, CO



WATERMARK performance compared to turf water requirement.

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™ (AguaMiser) landscape irrigation system includes add-on control devices that integrate with Decagon Devices ECH2O soil moisture sensors.

The AguaMiser interrupts programmed irrigation events when soil moisture is at or above a user-defined level or “trigger point.” The trigger point is determined using an easy-to-follow procedure that calculates field capacity of the soil. This is then used set the trigger point soil moisture lower-bound. 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 SCADA 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.

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 inches by 0.7 inch. It comes with a 16-ft cable that can be extended up to 250 ft with an extension kit.



AguaMiser™ Multi-zone controller

Controller Description, Prices, and Warranty

The AguaMiser's cabinets are suitable for indoor and outdoor installation. The AguaMiser can be purchased online via MorphH₂O's website (www.morph2o.com) or from the local distributors listed on the website. Prices for AguaMiser systems range from a single probe-wired controller, including sensor, for \$250 to basic wireless models with probes that start at \$300. A sensor wiring extension kit is \$0.75 per ft, plus \$4 per splice kit.

The MorphH₂O warranty on the AguaMiser and EC-5 is 2 years and includes replacement or repair to correct material or workmanship defects.



Installation

MorphH₂O recommends professional installation, but states most homeowners can perform installation using the installation guide included on their website. The installation guide includes instructions on wiring, calibration, sensor placement, troubleshooting, and setting appropriate run times.

SWAT Testing, Track Record, and Awards

MorphH₂O has conducted multiple tests at sites in Utah, Nevada, and California. Published test results are available by contacting the company. Tests conducted in Magna City, Utah; at an Ogden, Utah, school; and at Brigham Young University in Provo, Utah, all indicate proper interruption of over-irrigation. A SWAT calibration test report for the ECH2O EC-5 soil moisture sensor was posted in November 2008.

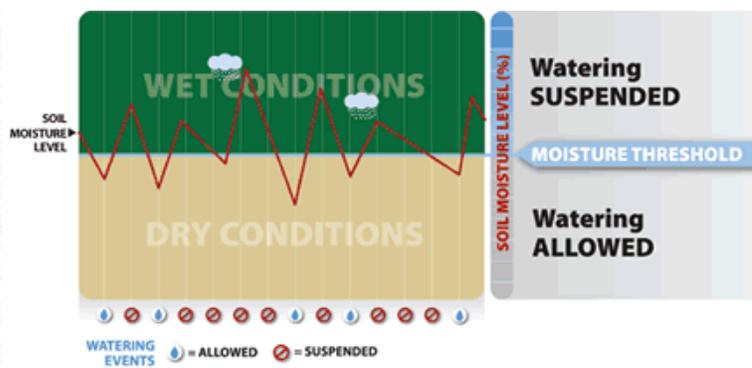
Rain Bird

As discussed in the “Weather-Based Product Descriptions” section in this report, the 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 (SMRT-Y) from Rain Bird® (Rain Bird) was introduced in 2009, and is an add-on soil moisture sensor with control box 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 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. 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 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.

Description, Prices, and Warranty

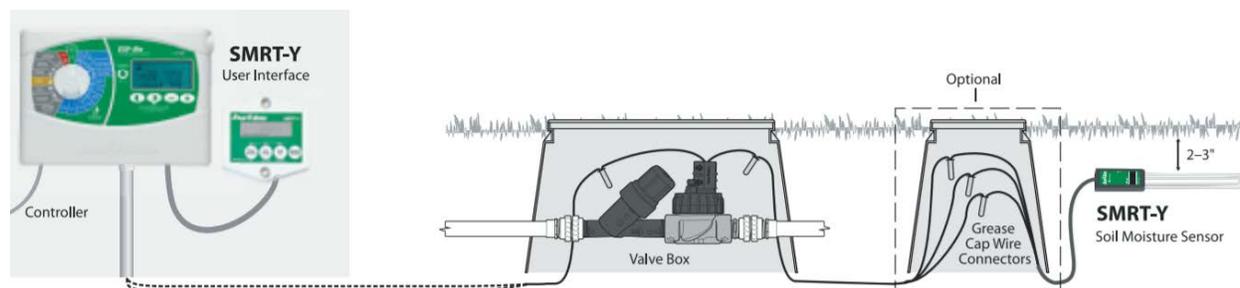
The SMRT-Y control box is constructed of heavy-duty plastic and can be installed indoors or outdoors. Its dimensions are 3 inches by 3 inches by 0.75 inch and operates on 25 VAC at 12-watt current supplied by the existing timer/controller. Its operating temperature range is -4 to 158 °F (-20 to 70 °C). The control box 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 sensor comes with 42 inches of 18 AWG lead wire. The sensor dimensions are 8 inches by 2 inches by 0.5 inch.

The SMRT-Y kit (control box, sensor, mounting hardware, and manual) retails for \$209. It can be purchased online through Rain Bird's website (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 states that installation may be performed by some homeowners. Installation information and a guide to choosing the optimal location for the sensor is available on Rain Bird's website. Installation and programming instructions in English and Spanish are provided with the controller.

Soil Moisture-Based Product Descriptions



Track Record, Water Savings, and SWAT Testing

In addition to water conservation, Rain Bird states that the SMRT-Y can prevent overwatering, 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.

Tucor

As discussed in the “Weather-Based Product Descriptions” section in this report, Tucor, Inc. (Tucor), is a manufacturer of two-wire, wireless, and conventional wired irrigation controllers that possess weather-based control features and combined weather and soil moisture. Tucor’s RKD, RKW, and RKS (hereafter referred to as RKx) controllers also operate with soil moisture sensor input, and up to 10 sensors may be used with a controller. (The reader is encouraged to review the Tucor discussion in the “Weather-Based Product Descriptions” section in this report. Several compelling features offered by Tucor are covered in that section.)



Sensor Description and Operation

Tucor’s soil moisture sensors come in five styles—one being a “Fin” Sensor that has one sensor embedded, and four being “Probes” that have multiple embedded sensors. The probes contain 6 to 15 sensors spaced over 12 to 60 inches. All Tucor soil moisture sensors are capacitance- or FDR-type sensors.

Within the probes, one sensor can be chosen by the user to affect the RKx’s programs. Each program in the RKx can be adjusted by data from the selected sensor, and each sensor can affect one or more programs. That is, since the RKx can run 10 unique programs, each program can be controlled by any 1 of 10 sensors; or one sensor can control all programs; or any combination thereof.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

The RKx is either programmed manually or automatically with weather-based features (historical ET, weather station, etc.), and then irrigation may be interrupted based on soil moisture input. The soil moisture sensors interrupt irrigation based on a percent measured moisture level for a specific sensor. The soil moisture percent value is defined by the user. When a selected sensor's moisture level is triggered—indicating that the soil moisture at that depth is sufficient—the program assigned to that sensor, if running, will continue to run for the duration of all valves scheduled within the program (the program will not be interrupted midway through the cycle). If the trigger is enabled before the program begins, the entire program will be disabled until the next scheduled run time. The RKx monitors all sensors, and up to 150 sensors may be monitored (maximum of 10 probes with each having 15 sensors). Data feedback consists of soil moisture percentage and temperature values. Data feedback per sensor may be viewed at the controller or, optionally, via a web-interface. Alarms based on selected criteria may be generated from the sensor data, and email notifications may be sent based on the alarms. Users can also set up alerts using the companion smartphone app.



The connections from the sensors to the RKx are by dedicated, four-conductor, direct-burial wire, which is connected to the RKx's serial input. Multiple sensors may be on the same wire, and total wire length may be up to 2,000 ft.

A soil moisture sensor may be used in conjunction with the Tumor Weather Station to ensure valid soil moisture when using ET. Since ET only ensures replenishment of lost moisture, using a soil moisture sensor validates the initial moisture levels and monitors the accuracy of the ET data. The controller can be set to the optimum soil moisture level and the soil moisture sensor input will adjust the ET-based schedules to maintain those levels.

Controller Descriptions, Prices, and Warranty

The RKx is housed in a wall-mounted, plastic, locking enclosure. Options include stainless steel pedestals and other enclosures. It is powered by an internal, Class 2, 50-VAC transformer with a ½-inch National Pipe Thread nipple mounting. Dimensions are approximately 12 by 12 by 5 inches. The RKx's firmware is nonvolatile and may be "flash" upgraded. Program memory is backed up via a lithium cell with a lifetime rating of 10 years. The display is a 40-character, 2-line backlit LCD. Additional information and pricing of RKx features are included under the Tumor discussion in the "Weather-Based Product Descriptions" section in this report.

Base warranty on the controllers and sensors is 1 year and may be extended up to 5 years.

Soil Moisture-Based Product Descriptions

Tucor Product Pricing Summary

Description	Model	MSRP
Single Soil Moisture and Temperature Sensor With 13 ft of cable	SMS-100	\$180
12-Inch Turf Soil Moisture and Temperature Probe With 6 sensors and 13 ft of cable	SMP-12	\$1,040
20-Inch Soil Moisture and Temperature Probe With 5 sensors and 13 ft of cable	SMP-20	\$820
40-Inch Soil Moisture and Temperature Probe With 10 sensors and 13 ft of cable	SMP-40	\$1,395
60-Inch Soil Moisture and Temperature Probe With 15 sensors and 13 ft of cable	SMP-60	\$1,975
Soil Moisture Interface	SMI-232	\$195
Tucor 18/4 Sensor Wire With Ground	TW18/4-G	\$0.44

Installation

Tucor recommends RKx be installed by a certified professional. They do offer several online video tutorials on installation of accessory modules.

SWAT Testing, Track Record, and Awards

A SWAT calibration report for Tucor soil moisture sensors was not available for this report.

UgMO Technologies

UgMO™ Technologies (UgMO—“Underground Monitoring”) 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 UgMO Solution uses 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 UG400S 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. These wireless sensor data are transmitted to the UgMO irrigation controller or base station, both of which use its patented watering algorithms to deliver only the water that 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 U.S. industrial, scientific, and medical radio band (ISM) between 902 and 928 MHz. Currently, the system is configured for a minimum of a 2,000-ft range aboveground with direct line of site at an antenna height of 5 ft 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 does not require a base schedule or site variables (e.g., slope, soil type, etc.) to operate. The 36-zone standalone controller is fully software-upgradeable to incorporate future features; helping the unit be future-proof. Its dimensions are 12.75 by 9.13 by 4.38 inches and will accept wire sizes up to 14 AWG. The UG1000 can be combined with the advanced *UgMO Knows* web-based software platform for agronomic analytics and environmental monitoring, along with leak detection, remote control, and configuration.

The sensors broadcast soil moisture, temperature, and salinity 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 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 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



Soil Moisture-Based Product Descriptions

sprinkler heads. In essence, UgMO sensors operate like a thermostat that maintains temperature levels, except for the goal of maintaining optimal moisture levels to ensure plant health. 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 adaptive learning protocols and can act, if desired, autonomously. Remotely upgradeable, new features and functions can be added after installation.



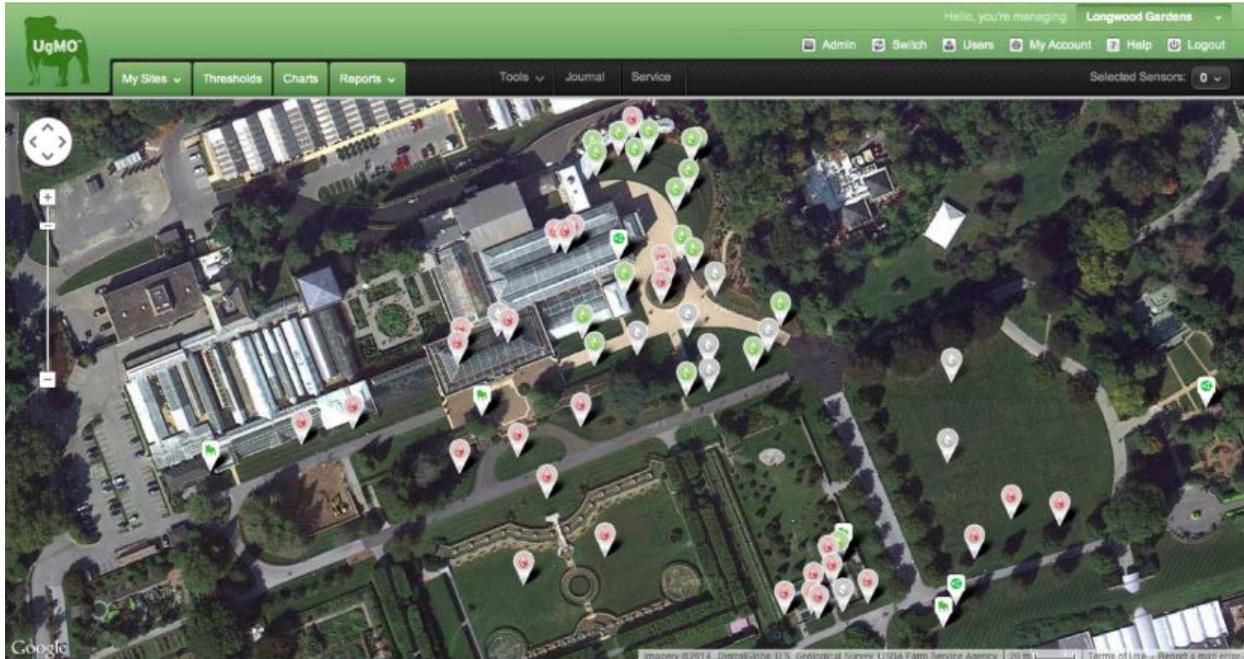
A key feature of the UgMO system is that while the system applies water, it also monitors changes in soil moisture as a result of irrigation. Thus, UgMO data act as a full “soil laboratory” where the controller learns autonomously and without human setting—all the required parameters for efficient irrigation management. For example, the UgMO system 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 on 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 the UgMO system to operate effectively in irrigation 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 conservation 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 can implement 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.

Weather- and Soil Moisture-Based Landscape Irrigation Scheduling Devices

UgMO Knows is a web-based data visualization server that can be used from any internet-accessible device. It is password protected and offers various levels 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.



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

Soil Moisture-Based Product Descriptions



Example of *UgMO Knows* soil moisture and temperature monitoring.

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 *UgMO Knows*. When combined with actual irrigation event data, the system can send alerts to responsible parties by email, text, or a smartphone application.

UgMO enters into a Service Agreement with their customers that includes installation of their equipment, along with ongoing service and warranty for the life of the contract. The contract is nonbinding and can be cancelled at any time, meaning UgMO has to perform every month. UgMO will guarantee that the low-fixed monthly service payment is less than the cost of the total water conservation, meaning there is a net savings to the customer. The return on investment for UgMO's customers is day one with no capital expenditure.

Installation

The UgMO Solution system is installed by UgMO personnel or an authorized installer. The company can be contacted directly via their website (www.ugmo.com) or by email (info@ugmo.com) to arrange for installation and/or inquire about contract pricing.

SWAT Testing, Track Record, and Awards

UgMO states 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.

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Attachments

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

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

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

Company Info		Aeon Matrix	Blossom	Calsense (ET)	ETwater Systems	GreenIQ	Hydro-Rain	Hunter Ind. (Solar Sync)	Hunter Ind. (Hydawise)
Telephone		(669) 235-5866	(949) 453-8080	(800) 572-8608	(415) 945-9383	(800) 972-5612		(760) 591-7344	(760) 487-2144
Contact Person		Wen Tseng	Justin Houston-Brown	Rick Capitanio	Kevin Heverin	Keren Israel Michaeli		Dave Shoup	Anthony Long
Email		support@aeonmatrix.com	justinemrsich@lages.com	info@calsense.com	info@etwater.com	keren@greeniq.co		david.shoup@hunterindustries.com	anthony.long@hunterindustries.com
Website		www.yardian.com	myblossom.com	www.calsense.com	www.etwater.com	greeniq.co	bhyve.hydorain.com	www.hunterindustries.com	www.hydawise.com
Number of Residential Models		4	2		2	2		2	3
Number of Commercial Models				1	3	2	2	2	2
Year Product(s) Entered Market		2017		1993	2005	2013	2017	2009	2016
Method of Estimating Water Need									
Basis for Schedule:	Historical Data	Back-up		✓	✓	✓		✓	
	On-site Station/Sensor(s)	✓		✓ ¹	✓ ¹	✓ ¹		✓	✓ ¹
	Remote Station(s)/Sensor(s)				✓	✓ ³			✓
	Weather Forecasts	✓	✓		✓	✓	✓		✓
Weather Data Source		Weather forecast received from the internet	Real-time weather data from local stations and satellites	Historic ET data, evaporative atmometer type ET sensor, weather station or CIMIS data	Big data sources with a coordinate based system. Option to add Public, ETWS, or on-site weather stations.	Public weather/forecasts and optional on-site sensors	Weather forecast received from the internet	On-site temp, solar radiation, and rain/freeze sensors	Weather forecast downloaded from the internet.
Product Features									
Standalone Controller or Add-on to Existing Station or Zone Capacity		Standalone	Stand-alone	Standalone	Standalone & Add-on	Stand-alone	Stand-alone	Add-on	Standalone
Master Valve or Pump Circuit(s)		8 - 12	8 - 12	8 - 48	8 - 48	8, 16	8 - 16		4 - 54
Internal Power Transformer		1	✓	2	2	✓	✓		✓
Battery Powered - DC		✓		✓	✓		✓		✓
Station Circuit Current Rating (Amperes)		0.75		1.5	2.0	1.0	0.4		
Terminal Wire Size Range (Gauge)		14 - 22		14	12 and smaller	14 - 26	14 - 22	20	14 - 20
Outdoor Installation		✓	✓	✓	✓	✓ ¹	✓	✓	Some Models
On-site Rain Gauge or Sensor w/ Rain Shutoff/Delay		✓ ¹		Tipping Bucket Rain Gauge ¹	Rain Sensor or Gauge ¹	✓ ¹	✓	Electronic Rain Sensor	✓ ¹
Rain Shutoff/Delay by Remote Sensor or Forecast		✓	✓		✓	✓	✓		✓
Rainfall Irrigation Schedule Compensation		✓			✓	✓			✓
On-site Wind Gauge w/ High Wind Shut-off				✓ ¹		✓ ¹			
High Wind Shut-off by Remote Sensor					✓ ¹	✓ ³			
On-site Temperature Sensor w/ Freeze Shut-off				✓		✓ ¹	✓	✓	
On-site Temperature Sensor w/ High Temp On or Off Freeze or High Temp Shut-off by Remote Sensor			✓		✓ ¹	✓ ¹	✓		✓ ¹
On-site Evaporative Atmometer Type "ET Sensor"				✓ ¹		✓ ¹			
On-site Solar Radiation Sensor				✓ ¹		✓ ¹		✓	
On-site Humidity Sensor				✓ ¹		✓ ¹			
Flow Sensor(s) Connectivity				✓	✓	✓			✓
Additional Sensor Terminals				✓	✓	✓			✓
Internet or Computer Interface		✓	✓	✓	✓	✓	✓		✓
Remote Control Device(s) for Controller		✓	✓	✓ ¹	✓	✓	✓		✓
Two-way Communication with Server		✓			✓	✓			✓
Station Circuit Testing		✓	✓	✓	✓	✓			✓
Surge and/or Lightning Protection		✓		✓ ¹	✓	✓	✓		✓
EPA WaterSense Certification		✓			✓	✓	✓	✓	✓
Scheduling Features									
Fully Automatic Schedule Generation		✓	✓		✓				✓
Base Irrigation Schedule Required				✓		✓	✓	✓	
User May Define Non-Irrigation Days		✓ ²	✓	✓	✓	✓	✓	✓	✓
Operable in Manual Clock Mode		✓		✓	✓	✓	✓	✓	✓
Manual Operation by Station or Program		✓	✓	✓	✓	✓	✓	✓	✓
Variable Total Run Times		✓	✓	✓	✓	✓		✓	✓
Number of Irrigation Schedule Period(s)				7, 14, 21, or 28 Day	Unlimited Days				✓
Number of Available Start Times		8		6 per manual program	9				✓
Cycle/Soak Manual Input				✓	✓				✓
Cycle/Soak Periods Automatically Calculated		✓			✓				✓
Runs Concurrent Stations				✓	✓	✓			✓
Number of Programs		9 - 13		7	Unlimited	✓			28
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		2 years	2 years	10 years	3 years	2 years	2 years	5 & 10 years	2 years
Support:	On-site Service Technicians			✓	✓			✓	
All companies offer email support	Telephone Technicians		✓	✓	✓	✓	✓		✓
	Online Chat			✓	✓	✓			✓
	Local Distributors			✓	✓	✓		✓	✓
Installation, Maintenance, & Cost									
Professional Installation & Programming Recommended				✓	✓		✓	✓	✓
Ongoing Maintenance Required				Clean Sensors				Clean Sensors	
Battery Replacement Required							✓		
Suggested Retail Price		\$200 - \$250	\$149 - \$199	\$1,075 - \$3,950	\$950 - \$3,800	\$200-\$250	\$185 - \$225	\$120 - \$225	\$279 - \$825
Annual Service Cost					\$184 - \$300				\$0 - \$708

1 - Optional add-on feature not included in controller price(s) shown; 2 - Automatically applies local non-irrigation day restrictions; 3 - Using IFTTT applet; 4 - ST8-WIFI controller only; 5 - ESP-TM2 & ESP-Me only

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

Company Info		Irritrol®	MC Smart Controls	Netro, Inc.	NxEco	Orbit	Plaid Systems, LLC.	Rain Bird (ST8-WIFI & ESP-TM2 or ESP-Me w/LNK)	Rain Bird (ESP-SMTe)
Telephone		(951) 785-3512	(801) 739-7009	(866) 346-3876	(855) 696-9326			(800) 724-6247	(800) 724-6247
Contact Person		Keith Shepersky	Customer Service	Arlene Zheng	Liang Li			James Harris	Nick Kelsch
Email		keith.shepersky@irritrol.com	info@mcsmartcontrols.com	info@netrohome.com	support@nxeco.com		Online Form	jharris@rainbird.com	nkelsch@rainbird.com
Website		www.irritrol.com	www.mcsmartcontrols.com	www.netrohome.com	nxeco.com	bhyve.orbitonline.com	spruceirrigation.com	wifi-pro.rainbird.com	wifi.rainbird.com
Number of Residential Models		2	1	2	3	4	1	8	2
Number of Commercial Models		3	1		1				
Year Product(s) Entered Market		2011	2017	2016	2015	2016	2017	2016	2016
Method of Estimating Water Need									
Basis for Schedule:	Historical Data	✓		✓				✓	✓
	On-site Station/Sensor(s)	✓	✓	✓ ¹	✓ ¹		Optional		✓
	Remote Station(s)/Sensor(s)		✓		✓			✓	✓
	Weather Forecasts			✓	✓	✓	✓	✓	
Weather Data Source		On-site temp, solar, and rain sensors with historic data backup	Local or on-site weather station data received from the internet and on-site sensors	Weather forecast and measured rainfall received from the internet. Optional on-site sensor array.	Local NOAA weather stations & www.worldweatheronline.com	Weather forecast received from the internet	Optional wireless SMS. Weather forecast received from the internet and optional, on-site sensors.	Weather forecast received daily from the internet	Onsite rain/temperature sensor
Product Features									
Standalone Controller or Add-on to Existing Station or Zone Capacity		Controller w/ Add-on	Standalone	Standalone	Stand-alone	Stand-alone	Standalone	Stand-alone & Add-on	Stand-alone
Master Valve or Pump Circuit(s)		6 - 12	12	6 - 12	8 - 36	4 - 12	16	4 - 22	4 - 22
Internal Power Transformer		1	1	1	✓	✓	1	✓	✓
Battery Powered - DC		Some Models	✓			✓		Outdoor Models	Outdoor Models
Station Circuit Current Rating (Amperes)		1.0	1.0		0.75	0.4	0.9	1.0	1.0
Terminal Wire Size Range (Gauge)		12 - 18	14 - 24		12 - 20	14 - 22	18	14 - 20	14 - 20
Outdoor Installation		✓	✓		✓ ¹	✓		Outdoor Models	Outdoor Models
On-site Rain Gauge or Sensor w/ Rain Shutoff/Delay		Hygroscopic Rain Sensor	✓ ¹		✓ ¹	1	✓ ¹	✓	✓
Rain Shutoff/Delay by Remote Sensor or Forecast		✓	✓	✓	✓	✓	✓		
Rainfall Irrigation Schedule Compensation		✓	✓	✓	✓			✓	✓
On-site Wind Gauge w/ High Wind Shut-off									
High Wind Shut-off by Remote Sensor									
On-site Temperature Sensor w/ Freeze Shut-off		✓	✓ ¹	✓ ¹		✓			✓
On-site Temperature Sensor w/ High Temp On or Off Freeze or High Temp Shut-off by Remote Sensor			✓	✓ ¹	✓	✓	Freeze	Alarm ¹	
On-site Evaporative Atmometer Type "ET Sensor"			✓ ¹						
On-site Solar Radiation Sensor		✓	✓ ¹	✓ ¹					
On-site Humidity Sensor			✓ ¹						
Flow Sensor(s) Connectivity		✓ ¹	✓				✓		
Additional Sensor Terminals			1	Soil Moisture				Soil Moisture ¹	
Internet or Computer Interface		✓ ¹	✓	✓	✓	✓	✓	✓	✓ ¹
Remote Control Device(s) for Controller		✓ ¹	✓	✓	✓	✓	✓	✓	
Two-way Communication with Server			✓		✓			✓	
Station Circuit Testing							✓	✓	✓
Surge and/or Lightning Protection		✓	✓		✓		✓	✓	✓
EPA WaterSense Certification		✓	✓	✓	✓	✓	✓	✓	✓
Scheduling Features									
Fully Automatic Schedule Generation		✓		✓			✓		✓
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			✓		✓				
Number of Irrigation Schedule Period(s)		31 or 365	4				20	Days of Wk,Odd/Even, Cyclical	Days of Wk,Odd/Even, Cyclical
Number of Available Start Times		9	4					3 - 4	6
Cycle/Soak Manual Input			✓		✓		✓	✓ ⁴	✓
Cycle/Soak Periods Automatically Calculated		✓		✓	✓		✓	✓ ⁴	✓
Runs Concurrent Stations		✓			✓		✓		
Number of Programs		3		Unlimited			20	3 - 4	2
Percent Irrigation Adjust Feature		✓			✓	✓	✓	✓	✓
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		5 years	3 years	2 years	2 year	2 years	1 year	3 years	3 years
Support:	On-site Service Technicians		✓	✓	✓	✓		✓	✓
All companies offer email support	Telephone Technicians	✓		✓	✓	✓		✓	✓
	Online Chat				✓			✓	✓
	Local Distributors	✓			✓			✓	✓
Installation, Maintenance, & Cost									
Professional Installation & Programming Recommended		✓				✓		✓ ⁵	✓
Ongoing Maintenance Required		Clean Solar Sensor					Clean Sensors		Clean Sensor
Battery Replacement Required		✓				✓	Soil-Moisture Sensors		
Suggested Retail Price		\$353 - \$661	\$250	\$120 - \$150	\$120 - \$215	\$60 - \$120	\$249	\$179 - 415	\$313 - 347
Annual Service Cost					\$0				

1 - Optional add-on feature not included in controller price(s) shown; 2 - Automatically applies local non-irrigation day restrictions; 3 - Using IFTTT applet; 4 - ST8-WIFI controller only; 5 - ESP-TM2 & ESP-Me only

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

Company Info		Rain Master®	Scotts Miracle Gro	Signature Control Systems	Toro®	Tucor	Weathermatic®
Telephone		(951) 785-3453	937-553-4576	(949) 390-4778	(951) 785-3515	(800) 272-7472	(972) 278-6131
Contact Person		Sergio Ramos	Kim Markus	Don Clark	Robert Starr	Larry Sarver	Brodie Bruner
Email		sergio.ramos@rainmaster.com	kim.markus@scotts.com	don.clark@scsmail.com	robert.starr@toro.com	lsarver@tucor.com	info@weathermatic.com
Website		www.rainmaster.com	mygro.com	www.signaturecontrolsyste.ms.com	www.toro.com	www.tucor.com	www.weathermatic.com
Number of Residential Models		0	1	3	1	1	1
Number of Commercial Models		2		5		3	3
Year Product(s) Entered Market		2002	Jan 2018	2013	2013	1995	2004
Method of Estimating Water Need							
Basis for Schedule:	Historical Data	✓			✓	✓	
	On-site Station/Sensor(s)	✓ ¹		✓	✓	✓	✓
	Remote Station(s)/Sensor(s)	✓ ¹	✓	✓		✓	
	Weather Forecasts		✓	✓			
Weather Data Source		Automatic, historic or manually entered ET or with optional on-site weather station	Real-time weather data from local stations and satellites	Proprietary	On-site temp, solar, and rain sensors with historic data backup	Automatic, historic or manually entered ET or with optional on-site weather station	On-site temp & rain sensor and solar radiation estimated based on date & location
Product Features							
Standalone Controller or Add-on to Existing Station or Zone Capacity		Standalone	Stand-alone	Standalone	Controller w/ Add-on	Standalone	Standalone
Master Valve or Pump Circuit(s)		6 - 200	7	4 - 24	4 - 16	25 - 100	4 - 96
Internal Power Transformer		1 - 2	✓	✓	1	3	2
Battery Powered - DC		✓	✓	Outdoor Models	✓	✓	Some Models
Station Circuit Current Rating (Amperes)		1.0	0.5	0.5	1.25	Not Reported	Optional Solar
Terminal Wire Size Range (Gauge)		12 - 14		12 - 18		14, 16, 18	1.2
Outdoor Installation		✓		✓	Some Models	✓	14 - 18
On-site Rain Gauge or Sensor w/ Rain Shutoff/Delay		Tipping Bucket Rain Gauge ¹		✓ ¹	✓	✓	✓
Rain Shutoff/Delay by Remote Sensor or Forecast		✓ ¹	✓	✓	✓	✓	✓
Rainfall Irrigation Schedule Compensation		✓ ¹	✓	✓	✓	✓	✓
On-site Wind Gauge w/ High Wind Shut-off		✓ ¹		✓ ¹		✓	OEM add-on
High Wind Shut-off by Remote Sensor						✓	
On-site Temperature Sensor w/ Freeze Shut-off		✓ ¹		✓ ¹	✓	✓	✓
On-site Temperature Sensor w/ High Temp On or Off		✓ ¹		✓ ¹			
Freeze or High Temp Shut-off by Remote Sensor		✓ ¹	✓	✓ ¹			
On-site Evaporative Atmometer Type "ET Sensor"		✓ ¹					
On-site Solar Radiation Sensor		✓ ¹			✓	✓	
On-site Humidity Sensor		✓ ¹		✓ ¹		✓	
Flow Sensor(s) Connectivity		✓		✓	✓ ¹	✓	✓
Additional Sensor Terminals		✓				✓	✓
Internet or Computer Interface		✓	✓	✓	✓ ¹	✓	✓
Remote Control Device(s) for Controller		✓ ¹	✓	✓	✓ ¹	✓	✓
Two-way Communication with Server		✓ ¹		✓		✓	✓
Station Circuit Testing		✓	✓	✓		✓	✓
Surge and/or Lightning Protection		✓ ¹		✓	✓	✓ ¹	✓
EPA WaterSense Certification		✓	✓	✓	✓	✓	✓
Scheduling Features							
Fully Automatic Schedule Generation		✓ ¹	✓	✓		✓	✓
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		✓	✓	✓	✓	✓	✓
Number of Irrigation Schedule Period(s)		7 or 30 Day	✓	Up to 31 Days & Odd/Even	3	14 Day & Odd/Even	Days of Week/Mos. & Odd/Even
Number of Available Start Times		5 - 8	✓	4	4	12	8
Cycle/Soak Manual Input		✓	✓	✓	✓	✓	✓
Cycle/Soak Periods Automatically Calculated		✓	✓	✓			✓
Runs Concurrent Stations		✓			✓	✓	✓
Number of Programs		4 - 16		16	4	10	4
Percent Irrigation Adjust Feature		✓	✓	✓		✓	✓
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		5 years	2 years	2 years	5 years	1 - 5 years	2 - 10 years
Support:	On-site Service Technicians	✓					✓
All companies offer	Telephone Technicians	✓	✓	✓	✓	✓	✓
email support	Online Chat	✓					
	Local Distributors	✓		✓	✓	✓	✓
Installation, Maintenance, & Cost							
Professional Installation & Programming Recommended		✓		Yes, But Not Required		Recommended	✓
Ongoing Maintenance Required		Clean Sensors (If Applicable)				Clean Sensors	
Battery Replacement Required			✓		✓		✓
Suggested Retail Price		\$600 - \$6,000	\$150	\$222 - \$485	\$353 - \$548	\$1,290 - \$1,980	\$292 - \$2,625
Annual Service Cost		\$120 - \$180		Optional After First Year		\$72 - \$360	

1 - Optional add-on feature not included in controller price(s) shown; 2 - Automatically applies local non-irrigation day restrictions; 3 - Using IFTTT applet; 4 - ST8-WIFI controller only; 5 - ESP-TM2 & ESP-Me only

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

Company Info		Baseline	Calsense (SMS)	Dynamax	Hunter Industries	IRROMETER	MorphH2O	Rain Bird (SMS)	Tucor	UgMO Technologies
Telephone		(208) 323-1634	(951) 352-3891	(800) 896-7108	(760) 591-7344	(951) 689-1701	(801) 317-4239	(800) 724-6247	(800) 272-7472	(484) 690-0570
Contact Person		Bob Beers	Rick Capitanio	Gary Woods	Dave Shoup	Tom Penning	Kevin Wellard	Sean Azad	Larry Sarver	Brian Dalmass
Email		bbeers@baselinesystems.com	info@calsense.com	admin@dynamax.com	david.shoup@hunterindustries.com	sales@irrometer.com	sales@morph2o.com	sazad@rainbird.com	lsarver@tucor.com	info@ugmo.com
Website		www.baselinesystems.com	www.calsense.com	www.dynamax.com	www.hunterindustries.com	www.irrometer.com	www.morph2o.com	www.rainbird.com	www.tucor.com	ugmo.com
Number of Residential Model Types		1		1	1	1	1	1		1
Number of Commercial Model Types		3	1	2	1	3	1	1	2	1
Date Product(s) Entered Market		2002	1986	2006	2014	1985	2008	2009	2008	2009
Method of Operation										
Interrupts Operation of All Stations		✓		✓	✓	Residential Models			✓	✓
Interrupts Operation of Individual or Groups of Sta		✓	✓	Requires Multiple Controllers	✓	Commercial Models	✓	✓	✓	✓
Product Features										
Standalone Controller or Add-on to Existing		Standalone & Add-on	Standalone	Standalone & Add-on	Add-on	Add-on	Add-on	Add-on	Standalone	Standalone & Add-on
Type of Soil Moisture Sensor(s)		TDT	Tensiometer	FDR	Electrical Resistance	Electrical Resistance	FDR	TDT	FDR	FDR
Multiple Soil Moisture Sensors May Be Used		Commercial Models	✓	Requires Multiple Controllers	✓	Commercial Models			✓	✓
Soil Moisture Sensor Capacity		6 & 25	48	1 & 2		1 - 16	1	1	10	255
Connect to Existing Valve Wiring		✓	✓			Commercial Models	✓	✓		✓
Number of Soil Moisture Settings		Unlimited	Unlimited	51 & 0-60%	5	4, 9, & 11			Unlimited	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		12 - 200	8 - 48	Unlimited		Unlimited	4		25 - 100	36
Master Valve or Pump Circuit(s)		Commercial Models	2						3	✓
Internal Power Transformer		Commercial Models	✓						✓	✓
Battery Powered - DC		Commercial Models		Option Available		One Model				
Station Circuit Current Rating (Amperes)			1.5	3 & 10				2.5		✓
Outdoor Installation		✓ ¹	✓	✓ ¹	✓	All Models, Commercial option	✓	✓	✓ ¹	✓
Rain Gauge or Sensor Compatible w/ Rain Shut		✓	✓			✓		✓	✓	✓
Flow Sensor Compatible		Commercial Models	✓	✓		✓			✓	✓
Additional Sensor Terminals		Commercial Models	✓	✓		✓			✓	✓
Remote Control Device for Controller		Commercial Models	✓ ¹	✓					✓	Use Phone
System Testing and Diagnostics		✓	✓						✓	✓
Surge and/or Lightning Protection		✓	✓ ¹			✓		✓	✓	✓
SWAT Test Performance Report Available		✓				✓	✓	✓		✓
Scheduling Features (Standalone only)										
Fully Automatic Schedule (No Base Schedule Rec		Commercial Models		Commercial Models						✓
Variable Total Run Times		Commercial Models	✓	Commercial Models						✓
User May Define Non-Irrigation Days		Commercial Models	✓						✓	✓
Operable in Manual Clock Mode		✓	✓						✓	✓
Manual Operation by Station or Program		Commercial Models	✓						✓	✓
Irrigation Schedule Period(s)		All options available	7, 14, 21, or 28 day						✓	✓
Cycle/Soak Manual Input		✓	✓						✓	✓
Cycle/Soak Periods Automatically Calculated										✓
Available Start Times		8	6						12	6
Irrigation Pause/Resume		Commercial Models	✓						✓	✓
Runs Concurrent Stations		Commercial Models	✓	✓					10	3
Number of Programs		40 & 99	7	2					12	6
Syringe Cycle or Program		Commercial Models	✓						✓	✓
Review of Recent Irrigation Information		Commercial Models	✓						✓	✓
English and Spanish Languages Display			✓						Universal Display	
Product Support and Warranty										
Warranty		10 years	10 years	1 year	5 years	1 year	2 years	1 year	1 - 5 years	For life of contract
Support	On-site Service Technicians		✓	Some Locations	✓	Some locations				✓
All companies offer email support	Telephone Technicians	✓	✓	✓		✓	✓	✓	✓	✓
	Online Chat									
	Local Distributors		✓	Some Locations	✓	✓	✓	✓	✓	
Installation, Maintenance, & Cost										
Professional Installation & Programming Recomr		Commercial Models	✓	Commercial Models	✓	Commercial Models		✓	✓	✓
Battery Replacement Required				Optional			✓			Yes
Suggested Retail Price ²		\$165 - \$4,630	\$1,285 - \$4,160	\$525 - \$1,045	\$153	\$100 - \$3,146	\$250 and up	\$209	\$1,470 - \$2,160	

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**For copies of this report contact
Reclamation's Southern California Area Office in the
Lower Colorado Region at 951-695-5310 or perform an internet
search for "Reclamation Weather- and Soil Moisture-Based
Landscape Irrigation Scheduling Devices"**

