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Efficient Urban Water Management

Smart Weather-Based Irrigation Controllers

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This publication is the second in a series on urban water management.

INTRODUCTION

Landscape plantings play important roles in urban communities. Well-placed plants reduce soil evaporation, cool urban heat islands, prevent soil erosion, provide habitat and ecosystem diversity, and increase aesthetics and property values. In addition, landscape trees store carbon produced by fossil fuels and provide shade.

Landscape plants require supplemental irrigation to augment natural precipitation supplied by rain and snow in most areas of California. Supplying adequate irrigation water while conserving as much water as possible is vital due to the anticipated increase of the state's population to 60 million by 2050 (Dieter and Maupin 2017), coupled with impacts of climate change already stretching limited water resources (Hanak and Lund 2012). Increasing landscape irrigation efficiency is an effective way of reducing overall residential water use, since homeowners use up to half of their water outdoors (The Alliance for Water Efficiency 2019; Buck et al. 2016).

Figure 1. Example of a weather-based smart irrigation controller. *Photo:* http://www.oldfaithfulsprinklers.com.

This publication focuses on the selection and use of smart weather-based irrigation controllers in California to increase landscape water conservation while maintaining healthy, attractive landscapes. Significant water savings have been associated with their use in Florida, California, North Carolina, and Nevada (Haghverdi et al. 2019; Davis et al. 2009; Devitt et al. 2008; Dobbs et al. 2014; Nautiyal et al. 2015).

This publication includes a description of standard terms and concepts related to landscape irrigation, typical controller settings, guidelines regarding selection, proper use and maintenance of smart controllers, and information about rebate programs to acquire smart controllers offered by major retail water agencies in California. This publication is the second part of a series of UC ANR publications on efficient urban water management.

SMART LANDSCAPE IRRIGATION CONTROLLERS

A residential irrigation system typically consists of a sprinkler and/or drip system, pipes, electric valves (solenoid valves), and an irrigation timer. The irrigation timer automatically turns electric valves on and off on preprogrammed schedules. Efficient irrigation is achieved by maintaining an optimum amount of water in the active root zone of plants while minimizing surface runoff and deep percolation. Over- or underwatering tend to happen if irrigation application is not calculated based on site conditions as well as plant water needs.

What makes an irrigation controller "smart"? The answer is its ability to receive and to respond to feedback from on-site or nearby sensors, allowing it to adjust water applications accurately based on site conditions. The two main categories of smart irrigation controllers are weather-based and soil moisture-based. The focus of this publication is on weather-based smart irrigation controllers (fig. 1), which are also called evapotranspiration (ET)-based smart controllers. Soil moisture-based smart controllers will be discussed in the next publication in this series.

FUNDAMENTALS OF WEATHER-BASED SMART IRRIGATION SCHEDULING

Evapotranspiration is the sum of water lost by evaporation from the soil and water lost by the plant back to the atmosphere through transpiration. The amount of water lost through ET needs to be replaced by natural precipitation and supplemental irrigation. A critical question is how to avoid overwatering and underwatering landscape plants while adapting to the changes in seasonal weather conditions (fig. 2). For example, landscape plants require more water on hot, dry days than they do on cold and cloudy days, and they require no irrigation when it is raining.

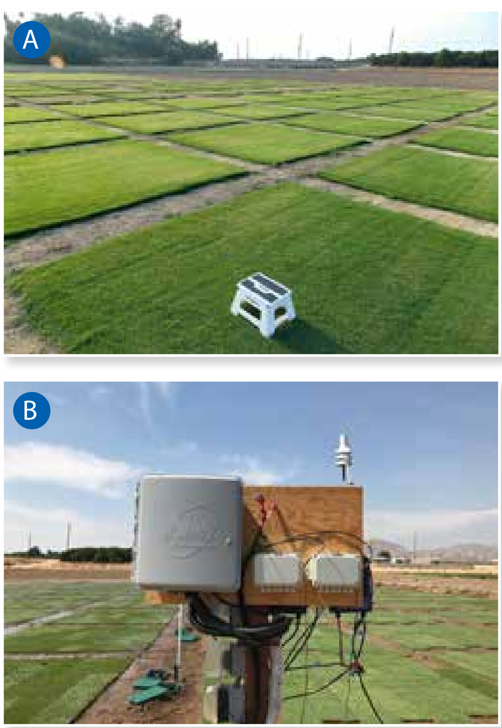

Figure 2. A turfgrass irrigation research trial at UC Riverside Agricultural Experiment Station (A), where irrigation applications are autonomously regulated by a weather-based smart irrigation controller (B). *Photos:* http://www.ucrwater.com.

Reference crop evapotranspiration (ET_{ref}) is the amount of water required by a well-irrigated and healthy, 2-inch tall, cool-season grass that is completely shading the soil. ET_{ref} is estimated by weather stations based on air temperature, soil radiation, wind speed, and relative humidity. The California Irrigation Management Information System (CIMIS), developed in 1982, consists of a statewide network of over 145 automated weather stations that regularly measure these weather parameters to estimate ET_{ref} (fig. 3). The maximum ET for a particular landscape species may be determined by multiplying the ET_{ref} by a plant factor (PF) or crop coefficient (Kc) determined for that species.

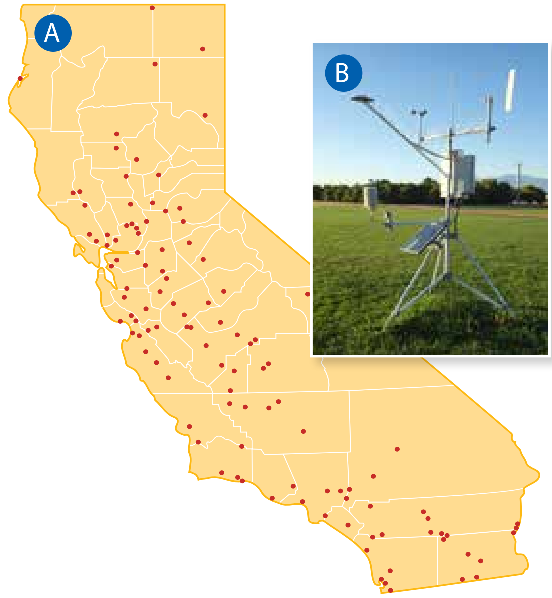

Figure 3. (A) Distribution of CIMIS weather stations across the state of California, and (B) a typical CIMIS weather station. *Sources:* (A) CIMIS Urban Resource Book, and (B) http://www.ucrwater.com.

Californians are encouraged to conserve water by irrigating landscape plants only as much as is needed to maintain their health and function. In almost all cases, established, well-rooted landscape plants can grow and function adequately at 20 to 60 percent of their maximum ET (Hartin et al. 2018; Pittenger et al. 2009). Thus, the final step is dividing the percent of ET required to maintain plant health by the irrigation system efficiency (see appendix 2 for a simple practical example).

There are many theoretical and empirical equations to estimate ET_{ref}. The choice of the equation depends on the accuracy of the equation under a given set of conditions and the availability of the required input data. A weather station with a full set of sensors that regularly measures air temperature, solar radiation, wind speed, and relative humidity will give a better estimation of ET_{ref} than a weather station with a limited set of sensors. However, since installing fully functional weather stations at residences is not economically feasible, controllers usually use more simplified methods for ET_{ref} calculations, which are easier to implement but are often less accurate (see table 1). The Hargreaves equation (Hargreaves and Samani 1985) is an alternative approach to estimate ET_{ref} and can be calculated based on only maximum and minimum air temperatures along with solar radiation. Some weather-based smart controllers estimate solar radiation as the average of the historical (averaged over several years) data for the given latitude of the site, measuring only air temperature on-site.

COMMON SETTINGS AND TERMINOLOGY OF WEATHER-BASED SMART CONTROLLERS

It is essential to understand the use of various terms and acronyms related to weather-based smart controllers as well as standard settings. The following is a summary of the most common terms and settings. Users should refer to the manufacturer instruction manuals for additional information regarding the installation and programming of specific brands of smart controllers.

- **Irrigation system program:** Allows users to set irrigation system start times, run times, and schedules to maximize precision and versatility. Multiple programs allow the user to maximize water conservation by irrigating hydrozones containing plants with similar water needs on the same schedule.
- **Zone:** A part of the irrigation system served by a single control valve that allows hydrozones containing plants with similar water needs to be irrigated independently from hydrozones with different water requirements and hydrozone designations.
- **Days to water:** This setting allows a user to select the days of the week to irrigate. Typical options include irrigating every other day, every 3 days, etc. This is a useful option to conform to restrictions imposed by water districts during a drought.
- **Start time:** This setting allows a user to select a start time to begin the irrigation event on the scheduled watering days. The first zone in the program will typically start watering at the set start time, and the other zones follow in sequence.
- **Run time:** This setting allows a user to select the amount of time each zone is irrigated during an irrigation event. It could vary from a few minutes to hours and mostly depends on the type of irrigation system, soil conditions, and plant type.
- **Cycle and soak:** This setting allows the user to divide the total zone run time into shorter periods of watering (cycle) and pause (soak). The cycle is intended to allow the proper water infiltration into the root zone to avoid runoff. The actual cycle

Table 1. The average percent difference for each month in the last 2 decades between temperature-based ET (Hargreaves equation) and CIMIS ET for some CIMIS stations across the state of California

City	Jan	Feb	Mar	April	May	June	July	Aug	Sep	Oct	Nov	Dec	Annual
Five Points (2)*	26	17	16	18	16	12	9	11	14	18	21	29	17
Shafter (5)	17	12	9	10	9	5	5	5	6	9	12	17	10
Riverside (44)	23	18	14	12	7	5	5	6	8	12	20	25	13
Temecula (62)	29	22	13	9	7	5	5	5	9	17	26	30	15
Modesto (71)	23	17	15	15	14	12	9	7	8	12	16	24	14
Irvine (75)	19	14	9	7	6	5	5	5	7	11	17	24	11
Pomona (78)	14	12	7	7	6	6	5	4	6	10	12	15	9
Fresno State (80)	17	12	9	10	10	8	6	6	7	8	11	18	10
Santa Monica (99)	17	13	9	7	6	8	9	8	10	12	16	19	11
Fair Oaks (131)	18	12	9	8	7	5	8	4	5	9	14	19	10
Long Beach (174)	13	10	8	6	6	8	9	8	9	12	14	15	10
San Diego (184)	18	11	8	6	6	7	9	7	8	11	15	16	10
Gilroy (211)	17	18	15	16	14	12	10	9	12	16	16	21	15
Hollywood (223)	15	7	6	5	4	6	5	6	9	9	11	19	8
Oakland (254)	13	12	8	6	4	3	2	3	3	11	13	17	8

Note: *Number in parenthesis after each city refers to the ID of the CIMIS station.

and soak times can be determined by the user in some cases or can be automatically calculated in others, depending on the specific model of controllers. This setting is especially useful when there is a significant slope that would cause water to run off before being taken up and when water enters the soil slowly to cause runoff on flatter surfaces.

- **Rain shut-off:** This automatic setting interrupts (stops) the cycle of automatic irrigation for a specified period during or after an event of rainfall.
- **Water budget:** This setting allows the user to set the controller to increase or decrease station run times by a certain percentage to adjust for changes in weather.
- **Distribution uniformity (DU):** This is a measurement of how evenly the water is applied across the landscape during irrigation. A low DU can result in large amounts of water being lost in sprinkler-irrigated turf and groundcover plantings, and it is a major cause of high-tier water bills.
- **Plant factor (PF):** (also called crop coefficient, Kc): These are coefficients that convert ET_{ref} to ET for specific landscape species ($ET = PF$ or $Kc \times ET_{ref}$).
- **Application rate (precipitation rate):** It is usually expressed as inches of water per hour and should be specified for each zone.

HOW TO SET UP AND PROGRAM THE WEATHER-BASED SMART IRRIGATION CONTROLLERS

During the initial setup of the controllers, users need to provide various information regarding the irrigation system (e.g., sprinkler type, uniformity of the system and application rate), landscape (e.g., plant type, plant factor for each species, rooting depth), site conditions (e.g., soil type, shading, slope), and intended irrigation schedule (e.g., irrigation days, irrigation time, number of zones). Based on the user inputs and weather data collected, controllers adjust the irrigation run times and cycles, thus regulating the amount of water applied.

During the initial setup when the user provides information for each hydrozone, the controller uses preprogrammed plant factors set by the manufacturer to convert ET_{ref} to irrigation water requirements for each hydrozone. Custom plant factors may also be programmed by the user, depending on the controller. This feature can be advantageous, since plant factors typically vary geographically, and preprogrammed plant factor information is only available for a small selection of species. In California, a popular option for obtaining water-use data based on very low ($PF < 0.1$), low ($PF = 0.1$-0.3), medium ($PF = 0.4$-0.6), and high ($PF = 0.7$-0.9) water use plant categories is the Water Use Classification of Landscape Plants (WUCOLS) database, which includes over 3,000 plants (Costello and Jones 2014). WUCOLS was compiled by the consensus of professionals knowledgeable about plant performance under various irrigation regimes in each of six climate zones in California. The controller then converts the irrigation water requirement values to zone run times based on the irrigation system information, irrigation scheduling criteria, and site conditions.

For a specific amount of water, a higher precipitation rate results in a relatively shorter run time to complete the irrigation requirement. Application rate estimations for typical irrigation packages (i.e., spray, rotor, drip, and bubbler) are often preprogrammed in the smart irrigation controllers for users to select. Sprinkler specifications can also be obtained from manufacturers' sprinkler specifications guidelines. If the application rate is unknown, homeowners can estimate the application rate (see appendix 1 for a practical example of calculating the application rate). Slope and soil type information is typically used to automatically calculate the maximum run time (cycle/soak) to avoid runoff.

TYPES OF WEATHER-BASED SMART IRRIGATION CONTROLLERS

Table 2 summarizes the settings and features of some commercially available weather-based smart irrigation controllers. Readers should note that not all manufactured products labeled as "smart controllers" follow the science-based approaches articulated in this publication to estimate crop water needs accurately and to schedule irrigation efficiently. Recommended controllers have been evaluated and certified by Irrigation Association (IA)'s Smart Water Applications Technology (https://www.irrigation.org/SWAT) and EPA Water Sense programs.

Currently available weather-based irrigation controllers can be divided into multiple groups, as follows:

- **Fully automatic versus semiautomatic controllers:** Semiautomatic controllers require the user to enter a base daily irrigation schedule from which the controller adjusts the frequency of irrigation and/or irrigation run time. In contrast, fully automatic controllers generate an irrigation schedule and run times based on the inputs that the user provides during the initial setup. Based on the programming inputs, some of these controllers adjust irrigation schedules by

Table 2. Product features for ET-based smart irrigation controllers on the market

Features	Hunter (Solar Sync)	Hunter (Hydrawise)	Hydropoint	Skydrop	Toro Evolution	Weathermatic	Irritol	Orbit
Weather data source	On-site sensors, historical data	On-site sensors (optional), public and private weather stations, weather forecasts	Public and private weather stations	Public and private weather stations	Historical data, on-site temperature, solar and rain sensors	On-site temperature, rain sensor. solar radiation estimated based on latitude	Historic data, on-site temperature, solar and rain sensors	Public and private weather stations
Stand-alone/add-on						stand-alone	controller with add-on	stand-alone
Fully automatic		X	X	X		X	X	
Base schedule required	X				X			X
Can operated in manual mode	X	X	X		X	X	X	X
Zone capacity		4–54	6–48		4–16	4–96		4–12
On-site rain sensor	X	optional	optional	optional	X	X	X	optional
Wind shut-off			optional					
Temperature sensor/ freeze shut off	X		optional	X	X	X	X	X
On-site solar radiation sensor	X				X		X	
On-site humidity sensor								
Available start times						8	9	
Schedule periods			odd/even, weekdays	odd/even, manual selection	odd/even days, manual selection, interval (1–30 days)	odd/even days, manual selection	31 or 365	odd/even, intervals, manual select
Number of programs		28			4	4	3	
Cycle/soak periods		X	X	X	X	X	X	
Computer interface/ smart phone app						X	optional	X
Irrigation adjust feature		X	X		X	X	X	X
SWAT test report	X		X		X	X	X	
EPA watersense certificate	X	X	X	X	X	X	X	X
Residential models	2	3	1	1	1	1	2	4
Commercial models	2	2	2			3	3	

Table 2. Product features for ET-based smart irrigation controllers on the market, continued

Features	Radio	Rainbird (ST8 Wifi)	Rainbird (ESP-SMTe)	Aeon Matrix/ Yardian	Calsense	GreenIQ	Netro Inc.	Rain Master
Weather data source	Weather data from public and private stations	Public and private weather stations	On-site rain/ temperature sensor	Weather forecast	Historical data, evaporative atometertype ET sensor, weather station or CIMIS data	Public and private weather stations, optional on-site sensors	Weather forecast, rainfall data from internet, and optional on-site sensor	Automatic (by internet), historic, manually entered ET, or optional on-site weather station
Stand-alone/add-on		stand-alone and add-on	stand-alone	stand-alone	stand-alone	stand-alone	stand-alone	stand-alone
Fully automatic	X		X	X			X	optional
Base schedule required	X	X			X	X		X
Can operated in manual mode	X	X	X	X	X	X	X	X
Zone capacity	8–16	4–22	4–22		8–48	8,16	6–12	6–200
On-site rain sensor	optional	X		optional	tipping bucket rain gauge	optional	rain shut-off from forecast	tipping bucket rain gauge (optional)
Wind shut-off	optional	X			optional	optional		optional
Temperature sensor/ freeze shut off	optional		X			optional	optional	optional
On-site solar radiation sensor	optional				optional		optional	optional
On-site humidity sensor	optional				optional	optional		optional
Available start times		3–4	6	8	6			5–8
Schedule periods	1 to every 21 days	days of week, odd/even, cyclical	days of week, odd/even, cyclical		7, 14, 21, or 28 day			7 or 30 day
Number of programs	X	3–4	2	9–13	7		unlimited	4–16
Cycle/soak periods		X	X	X	X	X	X	X
Computer interface/ smart phone app		X		X	X		X	X
Irrigation adjust feature	X	X	X	X	X	X		X
SWAT test report	X	X						
EPA watersense certificate	X	X	X	X	X	X	X	X
Residential models		8	2	4		2	2	
Commercial models					1	2		2

controlling irrigation run frequency or run times. In addition, almost all the commercially available smart controllers allow the user to set watering days and can also be overridden manually.

- **On-site versus remotely programmable controllers:** Some new versions of weather-based smart irrigation controllers come with telemetry capability, which makes it possible for users to change the settings, view and control the irrigation schedules, and execute programs remotely via a mobile phone application or web-based interface. The web-based interface usually provides additional information, including current weather conditions, weather forecasts, and historical water applications in the form of tables and graphs.
- **Stand-alone controllers versus add-on devices:** Smart controllers are typically

stand-alone products, although some can be connected to existing controllers and allow modification of irrigation schedules. The stand-alone controllers are more sophisticated and provide more options to schedule irrigation events with greater precision. The add-on devices (also called plug-in devices) are typically more affordable, but they may not be compatible with existing controllers. In addition, the add-on devices sometimes are not capable of calculating run times and, instead, either adjust only present run times or act as an on/off switch to bypass scheduled irrigation events when specific user-defined, weather-related criteria are met.

- **On-site measurements versus remote and historical ET:** Controllers with on-site measurement capabilities utilize devices such as temperature and solar radiation sensors to calculate real-time ET_{ref} and adjust irrigation accordingly. Signal-based controllers do not collect on-site data but instead receive data remotely from local weather stations. ET_{ref} data could be sent directly to this type of controller, or the controller itself can calculate it on-site, based on received weather data. A major disadvantage of signal-based controllers is that the remote data might not be representative of the local site conditions. Another type of controller relies solely on historical, long-term average ET_{ref} data to schedule irrigations. As discussed previously, using this method can result in plants receiving too much or not enough water based on the actual weather conditions.

Table 3. Summary statistics of the number of agencies that provided rebate programs for weather-based smart irrigation controllers in 2019

Southern California region		
County	**Number of agencies in the survey**	**Number of agencies with rebate programs for weather-based smart irrigation controllers**
Imperial	2	1
Los Angeles	44	21
Orange	22	8
Riverside	14	8
San Bernardino	18	11
San Diego	18	14
Ventura	8	6
Northern California region		
County	**Number of agencies in the survey**	**Number of agencies with rebate programs for weather-based smart irrigation controllers**
Alameda	8	3
Butte	3	1
Contra Costa	7	3
San Luis Obispo	4	1
San Mateo	9	1
Santa Clara	12	4
Solano	6	1
Total	**175**	**83**

REBATE PROGRAMS ON WEATHER-BASED IRRIGATION CONTROLLERS

Water agencies in California often offer residential rebate programs to offset the purchase of smart irrigation controllers in the interest of water conservation. We have collected information through an online survey of 175 water agencies across California to showcase the number of agencies with rebate programs for smart irrigation controllers in 2019. As indicated in table 3, almost half of the major water agencies in the survey provided a rebate for installing weather-based smart irrigation controllers. There are a variety of terms used by agencies to refer to smart controllers, such as smart irrigation devices, smart controllers, weather-based irrigation, and weather-based irrigation controllers. Terms and conditions for eligibility vary among water agencies as well, leading to different rebate amounts and criteria based on landscape size and other criteria. In 2019, among the water agencies in this survey, the rebate amount ranged from $45 to $300. Most agencies provide rebates for only one controller per residential household. Additional information about the rebate programs is available on websites of the water agencies.

SUMMARY AND CONCLUDING REMARKS

- A wide range of weather-based smart controllers are commercially available. To maximize water savings and reduce water bills, it is important to select a controller that is compatible with the technical ability of the end user. Proper installation, programming, and maintenance remain critical for achieving the full potential of smart irrigation controllers. A detailed technical review of the commercially available smart irrigation controllers on the market has been recently published by the Bureau of Reclamation (Bureau of Reclamation 2018). (See their website, https://www.usbr.gov/watersmart/docs/2018/6thEd_WeatherSoilMoisture-BasedLandscapeIrrigationSchedulingDevices.pdf.)

- Weather-based controllers differ substantially in their scheduling algorithms, and not all controllers manufactured as smart controllers follow science-based approaches to estimate crop water needs and schedule irrigation. Only controllers that have been evaluated and tested by university researchers or programs such as Irrigation Association's (IA) Smart Water Applications Technology (https://www.irrigation.org/SWAT) program and EPA Water Sense (https://www.epa.gov/watersense) are recommended.
- Users can contact their water provider via their website or by calling a representative to obtain specific information on currently available rebate programs for weather-based smart irrigation controllers. Water agencies may limit the dollar amount or number of controllers per rebate, and the rebate amount might vary based on the size of the landscape.

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APPENDIX 1: IRRIGATION APPLICATION RATE CALCULATION EXAMPLES

Example 1: When flow readings are available:

A homeowner has installed a dedicated flow meter to monitor the outdoor irrigation water application for her 750-square-foot sprinkler-irrigated yard. She ran the irrigation system for 100 minutes and recorded the flow data. If the flow meter values before and after the irrigation are 1,530 and 2,465 gallons, what is the average precipitation rate (PR, inches per hour) for her sprinkler system?

$$PR = (96.3 \times \text{gal}) / (\text{Area} \times \text{time}) = (96.3 \times (2{,}465 - 1{,}530))/(750 \times 100) = 1.2 \text{ inches per hour}$$

Example 2: When catch-can test result is available:

On a day that was not windy, a homeowner ran an irrigation uniformity test by putting 30 identical catch devices in his 300-square-foot sprinkler-irrigated yard and running the irrigation system for 12 minutes. He then measured the collected water in each catch device. What is the average precipitation rate for the sprinkler system if the average volume of water collected in catch devices is equal to 27 millimeters and the area of the catch-can throat is 9.5 square inches?

$$PR = (3.66 \times \text{Average volume})/(\text{Throat area} \times \text{time}) = (3.66 \times 27)/(9.5 \times 12) = 0.87 \text{ inches per hour}$$

APPENDIX 2: IRRIGATION RUN TIME CALCULATION EXAMPLES

A homeowner divided her sprinkler-irrigated landscape into three hydrozones. She is interested in using evapotranspiration data from a nearby CIMIS station to calculate appropriate irrigation run times for each hydrozone for the first week of July. Hydrozone 1 is planted in warm-season turfgrass with a plant factor of 0.6. Hydrozone 2 and 3 consist of multiple shrubs and flowers with a plant factor of 0.4 and 0.5, respectively. The irrigation efficiency (IE) for her sprinkler system is 75 percent and the total reference evapotranspiration (ET_{ref}, obtained from CIMIS) for the first week of July is equal to 1.8 inches. What is the total irrigation water requirement (IWR) for each hydrozone for this week?

$$\text{Hydrozone 1} = (PF \times ET_{ref})/IE = (0.6 \times 1.8)/0.75 = 1.44 \text{ inches of water}$$

$$\text{Hydrozone 2} = (PF \times ET_{ref})/IE = (0.4 \times 1.8)/0.75 = 0.96 \text{ inches of water}$$

$$\text{Hydrozone 3} = (PF \times ET_{ref})/IE = (0.5 \times 1.8)/0.75 = 1.20 \text{ inches of water}$$

The homeowner calculated a precipitation rate of 0.92 inches per hour for her sprinkler system (using the appendix 1 method). What is the total irrigation run time per day for each hydrozone for the first week of July, assuming the watering days are restricted to 3 days per week?

$$\text{Hydrozone 1} = (IWR \times 60)/PR = (1.44 \times 60)/0.92 = 94 \text{ min} \rightarrow \text{run time per day} = 94/3 \cong 31 \text{ minutes}$$

$$\text{Hydrozone 2} = (IWR \times 60)/PR = (0.96 \times 60)/0.92 = 93 \text{ min} \rightarrow \text{run time per day} = 93/3 \cong 21 \text{ minutes}$$

$$\text{Hydrozone 3} = (IWR \times 60)/PR = (1.2 \times 60)/0.92 = 78 \text{ min} \rightarrow \text{run time per day} = 78/3 \cong 26 \text{ minutes}$$

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Recommendations for Optimizing Use of Smart Irrigation Controllers

Support provided by

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INTRODUCTION

Recent research on landscape irrigation has found that homeowners using in-ground, automatic irrigation systems—typical in Florida—apply 260% more water than homeowners without automatic irrigation systems (DeOreo et al., 2016). This is largely due to a “set it and forget it” mentality despite seasonal fluctuations in plant water needs (Mayer et al. 1999).

To reduce the waste of irrigation water (e.g., after a substantial rain) in 1991 Florida pass a law—the Florida Statute 373.662—that stated that: “Any person who purchases and installs an automatic lawn sprinkler system after May 1, 1991, shall install, and must maintain and operate, a **rain sensor device or switch** that will override the irrigation cycle of the sprinkler system when adequate rainfall has occurred". With the development of new technologies, the statute was changed in 2010 to: “Any person who operates an automatic landscape irrigation system shall properly install, maintain, and operate **technology that inhibits or interrupts operation** of the system during periods of sufficient moisture".

"Smart irrigation control" technologies for irrigation have been developed to apply only the required amount of water to the landscape, reducing irrigation waste. Therefore, they comply with Florida Statute 373.662 and can be used instead of rain sensors. The Irrigation Association (www.irrigation.org) defines smart irrigation controllers as “controllers that reduce outdoor water use by monitoring and using information about site conditions (such as soil moisture, rain, wind, slope, soil, plant type, and more), and applying the right amount of water based on those factors”. Essentially, these irrigation controllers receive feedback from the irrigated area and schedule or adjust irrigation duration and/or frequency accordingly. For example, they would reduce watering in the cooler months compared to the hot and dry months. There are generally two types of smart controllers: soil moisture-based controllers and climatologically-based controllers, also known as evapotranspiration or ET controllers.

These controllers, however, cannot fix a poorly designed or poorly maintained irrigation system. Thus, it is important to have the irrigation system inspected regularly and to have necessary maintenance performed in a timely manner. Always check for proper operation of the automatic irrigation system before installing smart irrigation controllers. As a reference, an irrigation system evaluation form is included at the end of this guide as Appendix I. In addition, check lists for the installation of SMSs and ET controllers are provided in APPENDIX II and APPENDIX III, respectively.

SOIL MOISTURE SENSORS

Soil moisture sensors (SMSs) are add-on devices that connect to conventional irrigation system time clocks, or timers (Figures 1 and 2). The goal of adding a SMS is to skip unnecessary irrigation cycles already programmed in the timer. Limiting water or reduced watering, as done by a properly installed and maintained SMS, has not been found by UF to decrease turf quality, but to reduce overwatering.

Figure 1. Electromechanical to electronic timers, commonly used in the Tampa Bay Area.

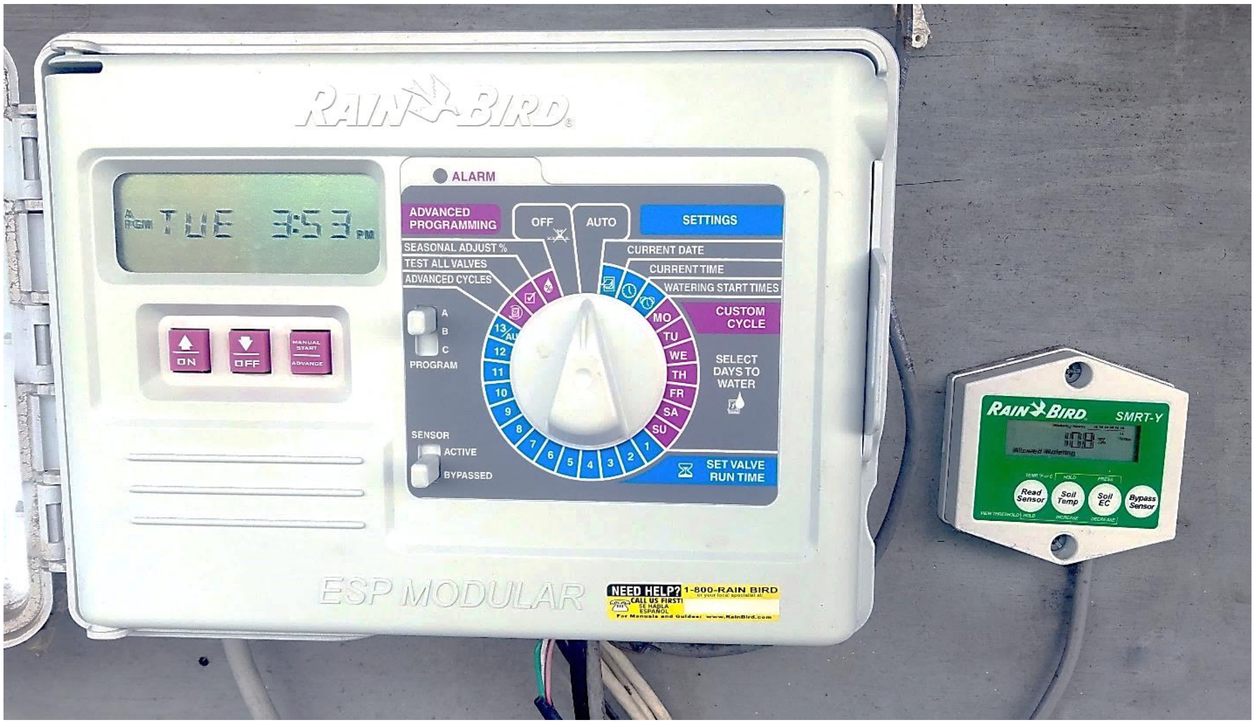

Figure 2. SMS controller connected to an irrigation timer

Commercially Available Systems

A SMS system includes a probe to be inserted in the soil and a controller where a user-adjustable soil water content threshold is set. Four current commercially available SMS systems that have been evaluated at the University of Florida are shown in Figure 3. Advantages and disadvantages of each are presented in Table 1.

Table 1. Currently available SMS systems evaluated at the University of Florida; advantages and disadvantages of each one.

Brand	Model	Advantages	Disadvantages
Baseline	WaterTec S100	2-wire sensor Easy connection to any valve	Wired
Rain Bird	SMRT-Y	3-wire sensor Easy connection to any valve	Wired Transform a 2 wire connection to a 3 wire connection
Toro	PSS	Wireless sensor More options for installing the sensor	Batteries last approximately 2 years Difficult to find it after 2 years
Hunter	Soil-Clik	Availability	Condition the sensor for 30 minutes before burying it Make a slurry to bury the sensor Wired Always install the sensor in the last zone No wiring to a valve option Wire must run from the sensor to the controller

Figure 3. Examples of SMS systems evaluated at the University of Florida.

Note: During the preparation of this guide, the Environmental Protection Agency (EPA) WaterSense program, is finalizing a protocol to test SMSs. If a commercially available SMS passes the test, EPA will grant that model a WaterSense label, meaning that it meets the criteria as a water-efficient product and as a resource to help save water. At that point, TBW will only endorse SMSs with a WaterSense label.

Irrigation Control

Two types of control strategies are employed with SMS controllers, "bypass" and "on-demand". The bypass configuration will be explained in this document, since it is the most common for small sites such as residential and light commercial.

Typically, a bypass SMS controller has a soil moisture threshold adjustment from "dry" to "wet", which can be adjusted by the user to suit specific plant, soil, and microclimate needs. The soil moisture content is routinely checked by the sensor and compared to the threshold setpoint. When the timer sends the electric signal to initiate irrigation, if the measured soil moisture is above the setpoint (too wet), irrigation is not allowed. The typical mechanism used by SMS systems to bypass an irrigation cycle is by electronically breaking the common wire.

These SMS controllers do not interrupt irrigation events once they are allowed to begin. To do this, they are either connected to the last irrigation zone or have a time delay so that, once irrigation begins, all irrigation zones will receive water.

Number of Sensors

Many of the SMS systems only include one probe to be buried in the soil. For properties with 8 irrigation zones or less, a single sensor is adequate to control the entire automatic irrigation system, in which case the sensor should be buried in the irrigation zone requiring most frequent irrigation and the runtimes for the other zones should be adjusted to limit over-watering. The zone requiring most frequent irrigation is normally full sun turfgrass.

Location of the Probe; do's and don'ts

The SMS probe(s) should be:

- located in the root zone of full sun turfgrass (Figure 4),
- in undisturbed soil,
- with the center of their sensing section approximately 3 inches deep,

Areas to avoid – general

When establishing the SMS location, certain areas and site conditions should be avoided (see Table 2 and Figure 5).

Table 2. Probe locations to be avoided

<table>
<tr><th>Install the sensor at least 5 feet away from</th><th>To avoid</th></tr>
<tr><td>A property line</td><td>Irrigation overspray from a neighbor’s yard</td></tr>
<tr><td>An impervious surface</td><td>Runoff from impervious surfaces and compacted soil around impervious surfaces</td></tr>
<tr><td>A structure (e.g., house, porch, shed, etc.)</td><td>Compacted soil, shade, and runoff</td></tr>
<tr><td>A depression/swale</td><td>Naturally high soil moisture content areas</td></tr>
<tr><td>On-site treatment and disposal systems (e.g., septic tanks, drain fields)</td><td>High moisture areas</td></tr>
<tr><td>A plant bed</td><td>Higher runoff, shade, and unrepresentative plant roots</td></tr>
<tr><td>A shaded north side of the home (if possible)</td><td>Areas with a lower ET rate and higher moisture content</td></tr>
<tr><td>A downspout</td><td rowspan="4">Areas with higher amounts of inflowing water relative to the rest of the landscape</td></tr>
<tr><td>An overhang</td></tr>
<tr><td>A hose bib</td></tr>
<tr><td>An air-conditioner system condensate line</td></tr>
</table>

Figure 4. Good location for installing the SMS probe

Figure 5. Not a good location for installing a SMS probe

Areas to avoid – disturbed sites and soils

A newly developed landscape will have fill material that must be considered during SMS installation. On other occasions it will be difficult to tell if the soil has been, or will be, compacted. Installers should use their best knowledge of the landscape history and projected use to determine the SMS location. If it is known that the soil has been, or will be, compacted in one area, the SMS should be installed elsewhere. Therefore, the sensor should be installed away from:

- A construction road
- An area with plant debris (e.g., tree stump)
- An area with fill dirt (if fill dirt is unrepresentative of the entire landscape)
- Buried material (e.g., cable, water, or sewer line)

Probe installation

Different types of probes require different installation procedures. However, common to all is the sensor mechanism should be placed within the root zone, with the center of its sensing section at approximately 3 inches deep, in undisturbed soil. Good contact between the probe and the soil (preventing void spaces) is fundamental for proper functionality of any SMS system.

Sensor types

Three types of residential sensor probes are now typically available in Florida: (1) flat, (2) node, and (3) rod. Installation procedures vary by type.

Flat Sensor Probes:

- Encased wave guides: The Baseline WaterTec S100 sensor probe is long, flat, and has a solid surface encasing the wave guides. It should be installed horizontally and with the thin side facing up (Figure 6).

- Exposed wave guides: The Rain Bird SMRT-Y sensor probe is long, flat, and has exposed rounded wave guides (steel rods). It should be installed horizontally and with the wide side facing up (Figure 7).

Figure 6. Sensor probe with encased wave guides been inserted within the root zone

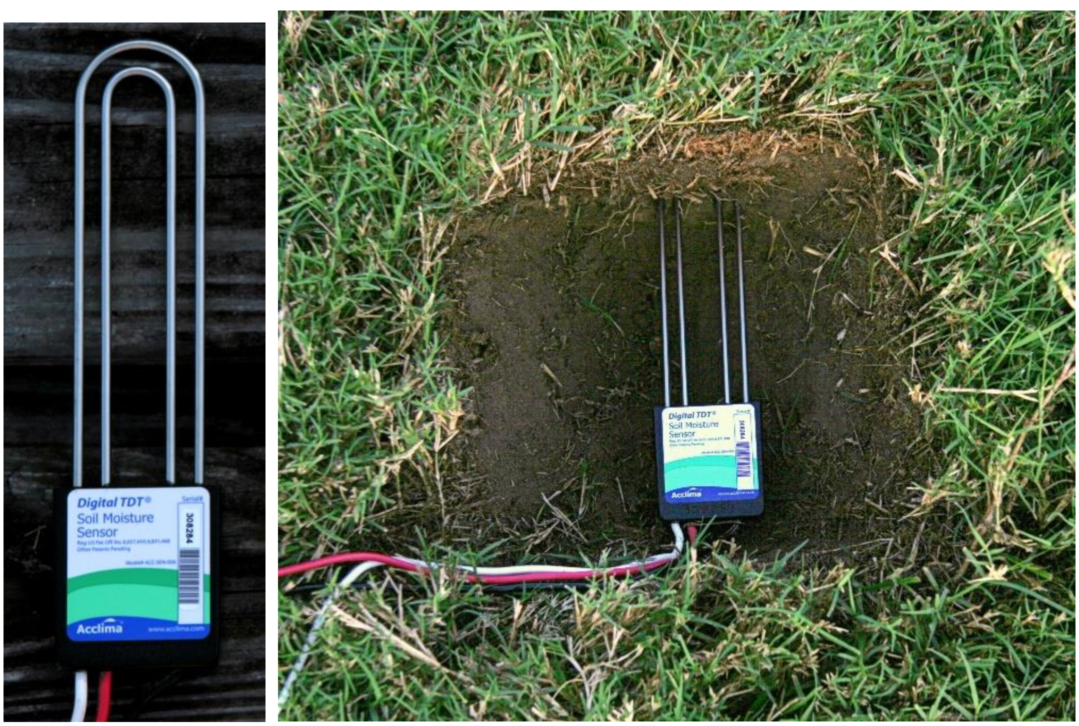

Figure 7. Sensor probe with exposed wave guides been inserted within the root zone

For flat sensor installation in existing turfgrass, an area of sod must be removed to accommodate the probe and a trench must be dug to run the SMS wiring. A square-point shovel is required for proper SMS installation (Figure 8).

Figure 8. Square-point ditching shovel required for SMS installation

Procedure:

1. With the recommended shovel, dig a square hole to a depth of 8 to 10 inches, ideally creating a sod plug that can be pulled out whole, while creating a wall of undisturbed soil where the probe will be inserted (Figures 9 and 10).
2. In established turfgrass, and for an easier insertion of the probe, cut the turfgrass roots to fit the sensor into the wall of the hole, at 3 inches deep, by using a “metal slicing tool” (thinner than the probe) and mallet (Figures 11 and 12).

In new landscapes, the SMS will often be installed prior to installation of the sod. Typically, the sod comes with 1 – 3 inches of soil. Therefore, for these cases, the probe should be installed with the center of its sensing section at 2 inches deep, waiting for the sod to be laid on top.

3. Slide the wave guides of the probe completely into the wall of the hole (Figure 13).
4. Gently compact the soil above the sensor to ensure that there is adequate contact between the sensor probe and the soil (Figure 14).
5. Replace the cut square of turfgrass and soil to completely cover the sensor probe. Gently compact the cut square of turfgrass sod, making sure that there are no channels that will allow water to seep in and pool around the SMS probe. Additional soil may be required around the edges of the soil plug to fill in any remaining gaps (Figure 15).
6. Dig the trench to run the wiring, make the connections according to the manufacturer's specifications, and check for proper SMS controller functioning. *Note:* Inadvertent cutting of the wiring is one of the greatest threats to SMS operation. It is highly recommended that all in-ground wiring be encased in conduit to protect it from being severed.

Figure 9. Cutting a square plug of turfgrass

Figure 10. Removing a square plug of grass. Around 80% of the fine/active roots are located above the red line, which is around 3 inches from the surface of the soil

Figure 11. Root cutting procedure preparing soil for SMS installation

Figure 12. Depth recommended to insert the probes (3 inches deep)

Figure 13. Wave guides of the probe completely inserted into the undisturbed wall of the hole

Figure 14. Compaction of soil around sensor to reduce void space and ensure adequate contact between SMS probe and soil

Figure 15. Soil and turfgrass plug replaced, covering SMS probe prior to burying wire

Node Probes

Two models of node probes are currently available: The Hunter Soil-Clik (with one probe) and the Irrometer Watermark (with a pair of probes). These node probes are known as Granular Matrix Sensors (GMS). The installation method for node probes differs from the flat probes.

Procedure:

1. Soak lower two-thirds of probe for 30 minutes before installing. Do not allow water to cover the top cap where wires are connected (Figure 16).
2. With the help of a mallet, insert a ½" PVC pipe to make a vertical hole to the desired depth in the soil (outside diameter 7/8") (Figure 17).
3. In a container, mix a slurry of native soil and water, and pour into the hole (Figure 18 and 19).
4. Place the sensor in a vertical position at bottom of the hole (Figure 20).
5. Pack native soil tightly around probe. Soil must be in full contact with probe (Figure 21).
6. Allow the probe to acclimate for 2 to 3 days and water normally, before proceeding to sensor-based irrigation.

7. Particular attention should be taken when installing Granular Matrix Sensors (Figure 16). Due to their design, the probes of GMSs need to be connected to the last zone to run, so the sensor is not wetted before all valves have been already allowed to irrigate. Sometimes this means the irrigation zones on the controller should be re-sequenced, so the area where the sensor has been installed is the last to run.

Figure 16. Soaking the GMS probes

Figure 17. Making a vertical hole to insert the probe

Figure 18. Mixing a slurry of native soil and water

Figure 19. Pouring the slurry into the hole

Figure 20. Placing the sensor into the soil

Figure 21. Packing native soil around the probe

Rod Probes

Currently, the only model with rods is the Toro Precision Soil Sensor System (Figure 22). This SMS system is currently the only wireless system and requires three size AA alkaline batteries for operation.

Procedure:

1. With the batteries installed, move the sensor probe to the proposed installation site. Signal strength is indicated by the LED color on top of the sensor as follows: green = excellent, yellow = acceptable, red = not acceptable - relocate sensor
2. With a suitable installation site selected, thoroughly irrigate the sensor location and surrounding landscape area.
3. Trim the grass close to ground level where the sensor will be placed. Caution: For close-cut turf varieties, such as Hybrid Bermuda, the top of the sensor must be installed at grade level to prevent damage by mowing equipment.
4. Applying even, downward pressure on top of the sensor, insert the sensor probes and retention spikes completely into the soil.

Figure 22. Sequence of installing a wireless probe with rods

Marking and Measuring the Sensor Location

Documentation of the sensor location can make future maintenance easier. For this, the SMS installer should mark the sensor location. Next, the installer should measure and record the distance from the SMS to two permanent points in the landscape (triangulation). Then, a diagram with the distances and location of these elements should be drawn and displayed adjacent to the irrigation timer. If an as-built irrigation plan exists, the location of the sensor should be marked on it.

In new landscapes, mark the sensor location with a flag to prevent damage during the sod installation.

Connecting the Sensor

A wired SMS requires digging a trench for wire connection. Depending on the circumstances, either mechanical or manual means can be used to dig the trench.

Wiring provided in the installation kit is not always long enough to span the distance between the SMS probe and the irrigation valve or SMS controller. Moreover, additional wiring should be added to allow for SMS probe installation in an optimal location, if necessary.

When connecting the wires from the sensor to the wires coming from the controller or valve, installers should add a small valve-box where the wire connections must have waterproof grease cap wire connectors (Figure 23). If this type of connector is not used during the installation, communication with the sensor will soon fail. In addition to confine the wire connections, the small valve-box will also help finding the sensor location and testing its response, if necessary.

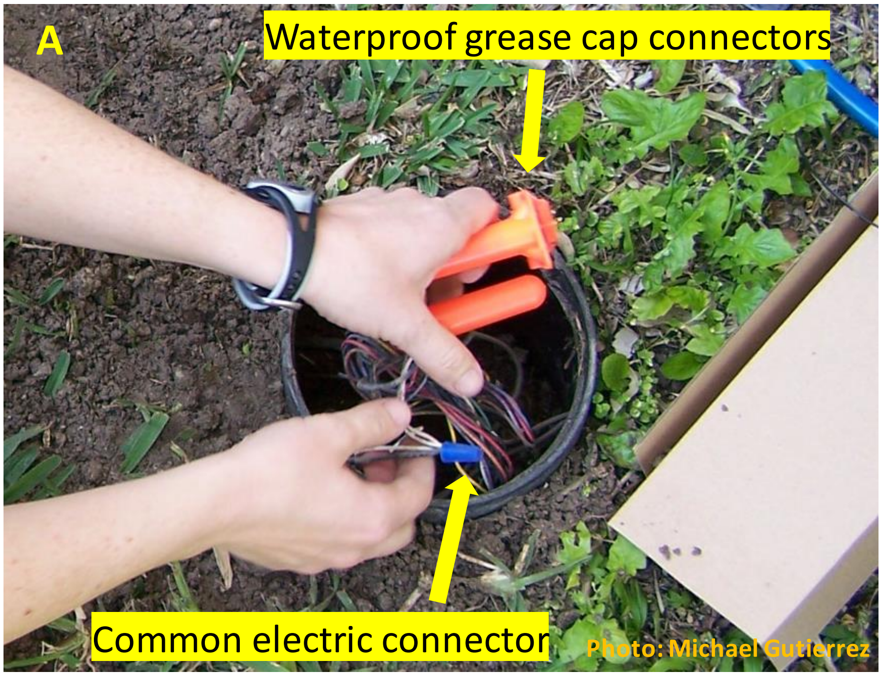

Figure 23. Picture A shows a wire connection, capped with a common electric connector, before inserting it into the waterproof grease cap connector. The waterproof grease caps are used to protect the connection between the probe wires and the extension wires coming from the controller or valve, encased in a valve-box. Picture B shows waterproof grease cap connectors completely submerged in water.

Connecting the Wires

Each brand, with a wired probe, has its own way to connect the probe to a zone valve or to its controller. The same occurs with the sensor controller when connecting it to the timer. Refer to the user's manual for wiring details.

The SMS controller should be installed on an interior wall (i.e. garage) next to the irrigation timer, unless otherwise prepared for through a waterproof/outdoor housing. Each SMS brand contains different color-coded wires to connect the controller to the irrigation timer. User should follow the manufacturer instructions described in the manual.

Calibration

The SMS manufacturers refers to calibration as the process to determine the irrigation threshold—or setpoint—in the controller. This process could be done manually or automatically. The University of Florida recommends the automatic method, since the resulting setpoint would be site-specific. This setpoint can be fine-tuned by the user, afterward.

The first step for the automatic calibration is to saturate the soil with water where the probe was installed. The purpose of this is to establish the field capacity of the soil (i.e., no further water drainage below the root zone). To saturate the soil, pour at least 5 gallons of water directly over the installed and connected SMS. The best way to do this is with a hose or a bucket (Figures 24 and 25).

Note: The soil surrounding the sensor should not receive any water during the 24-hour post-saturation period for all methods identified. If irrigation or rainfall occurs during this period, then the soil will not be at field capacity at the end of 24 hours and the procedure must be repeated once the soil dries.

Figure 24. Hose method

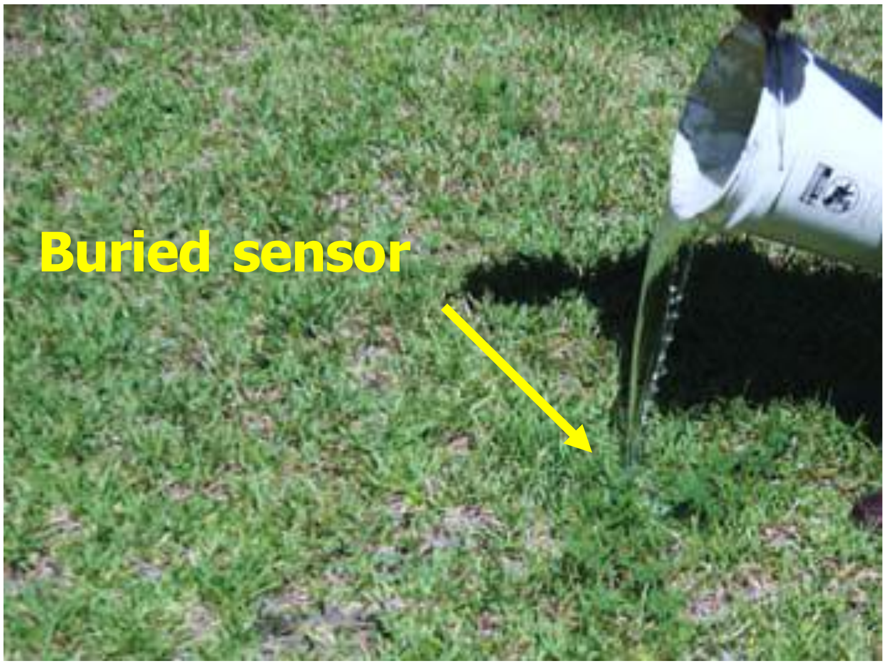

Figure 25. Bucket method

After the saturation is completed, the installer should perform the calibration on the SMS controller. Calibration instructions are brand-specific and, therefore, the user should follow manufacturer's instructions. After 24 hours, the SMS controller will read the soil moisture content, which should be close to field capacity. At that point, the controller will automatically establish the setpoint, which will range between 50% and 75% of the field capacity, depending on the SMS brand.

Note: Timing related to landscape establishment is an important component of proper calibration. Establishment periods typically range from 30-60 days. The controller and sensor should be calibrated post-establishment, because root depth and soil conditions vary from pre- to post-establishment.

Programming the Irrigation Timer

The irrigation timer, not the SMS controller, initiates scheduled irrigation events. It is extremely important that the irrigation controller be set for an irrigation schedule appropriate for the irrigation system, location, plant need, season, and the local watering restrictions.

Generally, a sunny turfgrass area will have the most frequent irrigation need relative to other landscape plants. If the turfgrass requirements are met, other plant water requirements should also be met.

Watering restrictions

As of the printing date of this document, year-round watering schedule and rules have been decreed (Figure 26) in the area of jurisdiction of the Southwest Florida Water Management District's (SWFWMD, 2019).

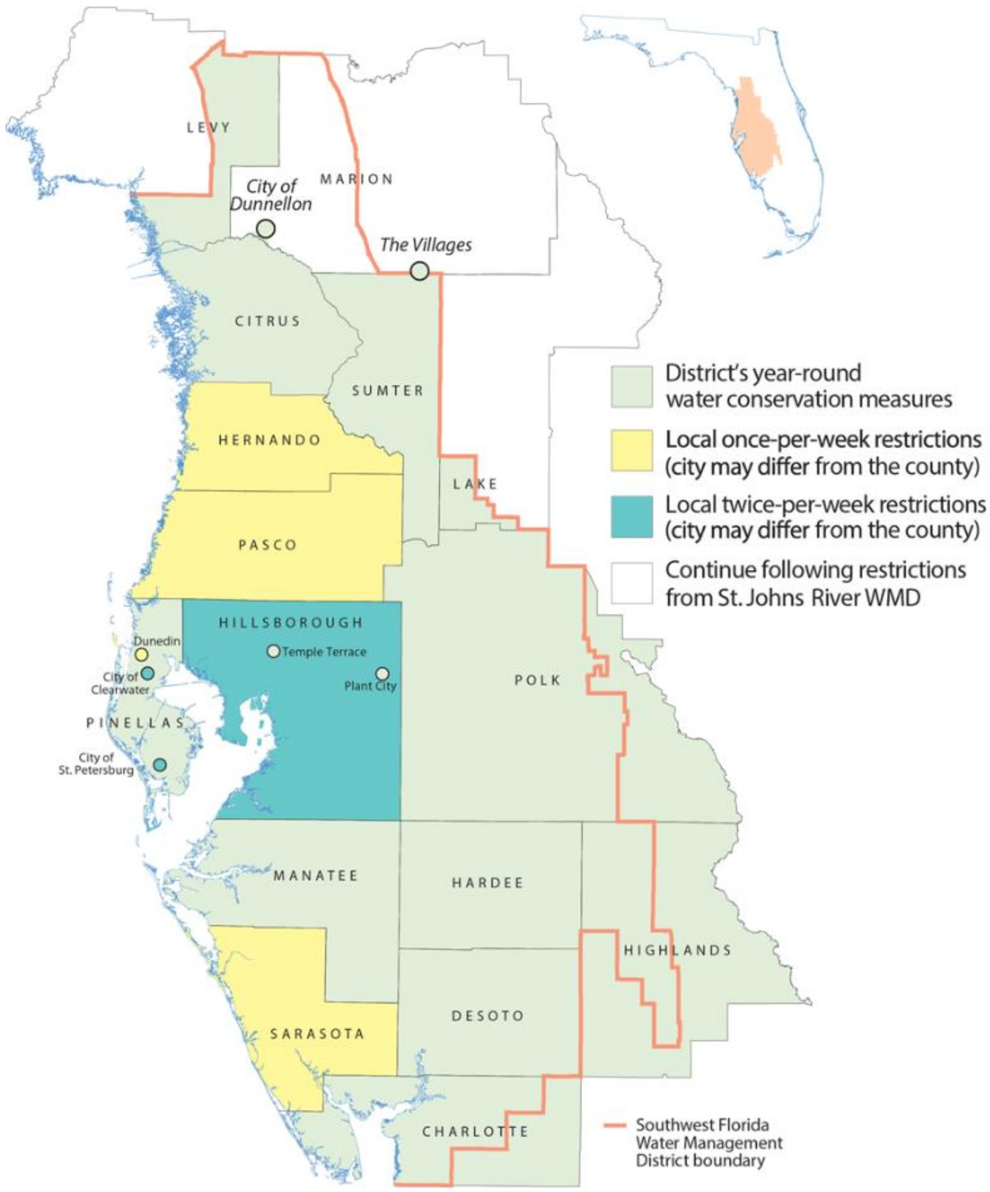

Figure 26. Map displaying the watering restrictions in the SWFWMD area

Effective Date and Areas

- The District's year-round water conservation measures are in effect except where stricter measures have been imposed by local governments.
- The measures shown below currently apply to all of Charlotte, Citrus, DeSoto, Hardee, Highlands, Manatee, Pinellas, Polk, Sumter, Lake and Levy counties; the City of Dunnellon and The Villages in Marion County; and the cities of Temple Terrace, Plant City and North Port.

- Some local governments such as unincorporated Hillsborough County and the cities of Clearwater, St. Petersburg and Tampa have local ordinances with differing twice-per-week schedules.
- Some local governments such as unincorporated Hernando, Pasco and Sarasota counties, and the cities of Dunedin, Longboat Key, Sarasota and Venice, have local ordinances that remain on one-day-per-week schedules.

Lawn Watering Days and Times

- Lawn watering is limited to no more than twice per week.
- Lawn watering days and times are as follows unless your city or county has a different schedule or stricter hours in effect:
    - Even addresses may water on Thursday and/or Sunday before 10 a.m. or after 4 p.m.
    - Odd addresses may water on Wednesday and/or Saturday before 10 a.m. or after 4 p.m.
    - Locations without a discernable address, such as rights-of-way and common areas inside a subdivision, may water on Tuesday and/or Friday before 10 a.m. or after 4 p.m.
- Hand watering and micro-irrigation of plants (other than lawns) can be done on any day and any time.

New Lawns and Plants

- New lawns and plants have a "30-30" establishment period.
- On the day of installation, watering is allowed on any day at any time.
- During the first 30 days, watering is allowed on any day during the allowable hours.
- During the second 30 days, watering is allowed three days per week: even-numbered addresses may water on Tuesday, Thursday and Sunday; odd-numbered addresses may water Monday, Wednesday and Saturday; and locations without a discernable address may water on Tuesday, Friday and Sunday.

Reclaimed Water

- Reclaimed water is only subject to voluntary watering hours, unless restricted by the local government or utility.

Fountains, Car Washing and Pressure Washing

- There are no specific restrictions on fountains, car washing and pressure washing.

- These and other water uses should be conducted as efficiently as possible, such as using a shutoff nozzle on each hose to adhere to the general restriction prohibiting wasteful water use.

Additional watering restrictions may be imposed by local governments if conditions warrant it. Always refer to your city or county regulations first. For the SWFWMD area, a Water Restrictions Hotline is currently available: 1-800-848-0499 (FL only).

A petition for variance from year-round water conservation measures or water shortage restrictions is available if an alternative irrigation plan is proposed. Petitions should be directed to SWFWMD: during normal business hours at 1-800-848-0499 (FL only) or email Water.Restrictions@WaterMatters.org.

Runtimes

When an in-ground irrigation system is provided with a smart irrigation controller (SMS or ET controller), the runtime of each zone should be scheduled to fulfil the maximum irrigation requirement during the year (normally between May and August). After the runtime is established, the smart irrigation controller would adjust this schedule, depending on the agroclimatic conditions of the site.

Different methods could be used for establishing the maximum runtime of each zone.

From online tables:

Different online tables are available for setting the runtime of each irrigation zone, for turfgrass in Florida. A simplified summary of the recommended irrigation runtimes—based on the irrigation scheduling developed by Dukes and Haman (2016)—is presented in Table 3. This table assumes application rates for residential sprinklers are ~0.5 inch/hour for rotors and ~1.5 inches/hour for spray heads. (For details on how to estimate the actual application rate, see the "Application rate" subheading.)

For example, from Table 3, for an irrigation zone located in the Tampa Bay Area (Central Florida), the maximum requirement is during the summer season. If the zone has spray heads, the runtime would be 30 minutes for full replacement of the historical evapotranspiration. These runtimes, in minutes, are for each of two irrigation events programmed per week. If irrigation is allowed only at one day per week, then increase the runtime in Table 3 30%. Longer runtimes will result in wasted water.

Table 3. Irrigation scheduling (minutes) per irrigation event for Florida turfgrasses, considering two irrigation cycles per week. If irrigation is allowed only at one day per week, then first cycle should be programmed to run early in the morning (before 6 AM) and the other cycle to run in the night of the same day (between 6 PM and 11 PM).

		North Florida			Central Florida			South Florida		
		Replacement of evapotranspiration								
		Reduced	Medium	Full	Reduced	Medium	Full	Reduced	Medium	Full
ROTORS	Winter	5	5	5	5	15	20	30	40	50
	Spring	25	35	45	40	55	65	45	55	70
	Summer	40	55	70	55	70	90	55	70	90
	Fall	35	45	55	40	55	70	30	40	50
SPRAYS	Winter	5	5	5	5	5	5	5	15	20
	Spring	5	10	15	10	15	20	15	20	25
	Summer	15	20	25	20	25	30	20	25	30
	Fall	10	15	20	15	20	25	10	10	15

Adapted from: Dukes, M.D. and Haman, D.Z. 2016. Runtimes calculated from historical evapotranspiration and effective rainfall, estimating 60% system efficiency. Numbers were rounded for convenience.

Note: This table is based on historical evapotranspiration, and might not represent necessary runtimes under atypical conditions (e.g., drought, wet conditions). Current conditions should be considered when setting the timer.

From a specific depth of water:

Sometimes a specific irrigation depth is recommended or desired. To transform a specific depth of water to runtime in the timer, first, is necessary to know the application rate of the zone (see the "Application rate" subheading), and then apply the formula below:

$$Runtime\ [minutes] = \frac{Irrigation\ depth\ [inches]\ x\ 60\ [minutes]}{Application\ rate\ [inches/hour]}$$

For example, a typical recommendation is applying ¾" (or 0.75") of water to the turfgrass per irrigation cycle, and let's say that the irrigation zone has an application rate of 1.5 inches/hour. Then the formula will be:

$$Runtime\ [minutes] = \frac{0.75\ [inches]\ x\ 60\ [minutes]}{1.5\ [inches/hour]}$$

$$Runtime = 30\ minutes$$

Once the runtimes are determined, program the specific runtime into the irrigation timer for each zone.

Maintenance

Most of the Rain Bird and Baseline SMSs tested at UF have worked properly for many years, without any maintenance. The wireless Toro SMSs operate around two years, until the batteries expire and need to be replaced. If a note of where the probe was located was not done—or not done properly—it would be very difficult to find. In that case, the whole system (controller and probe) would need to be replaced. Long term duration/maintenance of the Hunter SMSs has not been assessed by UF.

ET CONTROLLERS

Climatologically based controllers are also known as evapotranspiration controllers, ET controllers, or "WBICs" (acronym for weather-based irrigation controllers). In this document we will refer to them as ET controllers (Figure 27).

The United States Environmental Protection Agency (EPA), through its WaterSense program, has labeled some ET controllers which are certified to use at least 20 percent less water, save energy, and perform as well as or better than regular models (EPA, 2019). A list of WaterSense-labeled ET controllers can be found at: https://www.epa.gov/watersense/product-search

Note: If an ET controller is installed on a property that was not previously over-irrigating its landscape, studies have demonstrated that their historical irrigation water use might increase. Therefore, ET controllers are only recommended for water users using more than required.

Types of ET controllers

There are generally three types of ET controllers:

a. **Signal based**: Meteorological data are either collected from publicly available sources or from agreements with weather station networks. The ET value is calculated for a hypothetical grass surface for that site. Then, ET data are sent to surrounding controllers via wireless communication. In some cases, the ET values are adjusted to account for controllers that are not near the weather data collection site. The ET controller adjusts the irrigation runtimes or watering days according to climate throughout the year.

b. **Historical ET**: This approach for ET controllers uses a pre-programmed crop water use curve for different regions. The curve may be modified by a sensor such as a temperature or solar radiation sensor that measures on-site weather conditions.

c. **On-site weather measurement**: This approach uses measured weather data at the controller to calculate ET continuously and adjust the irrigation times according to weather conditions.

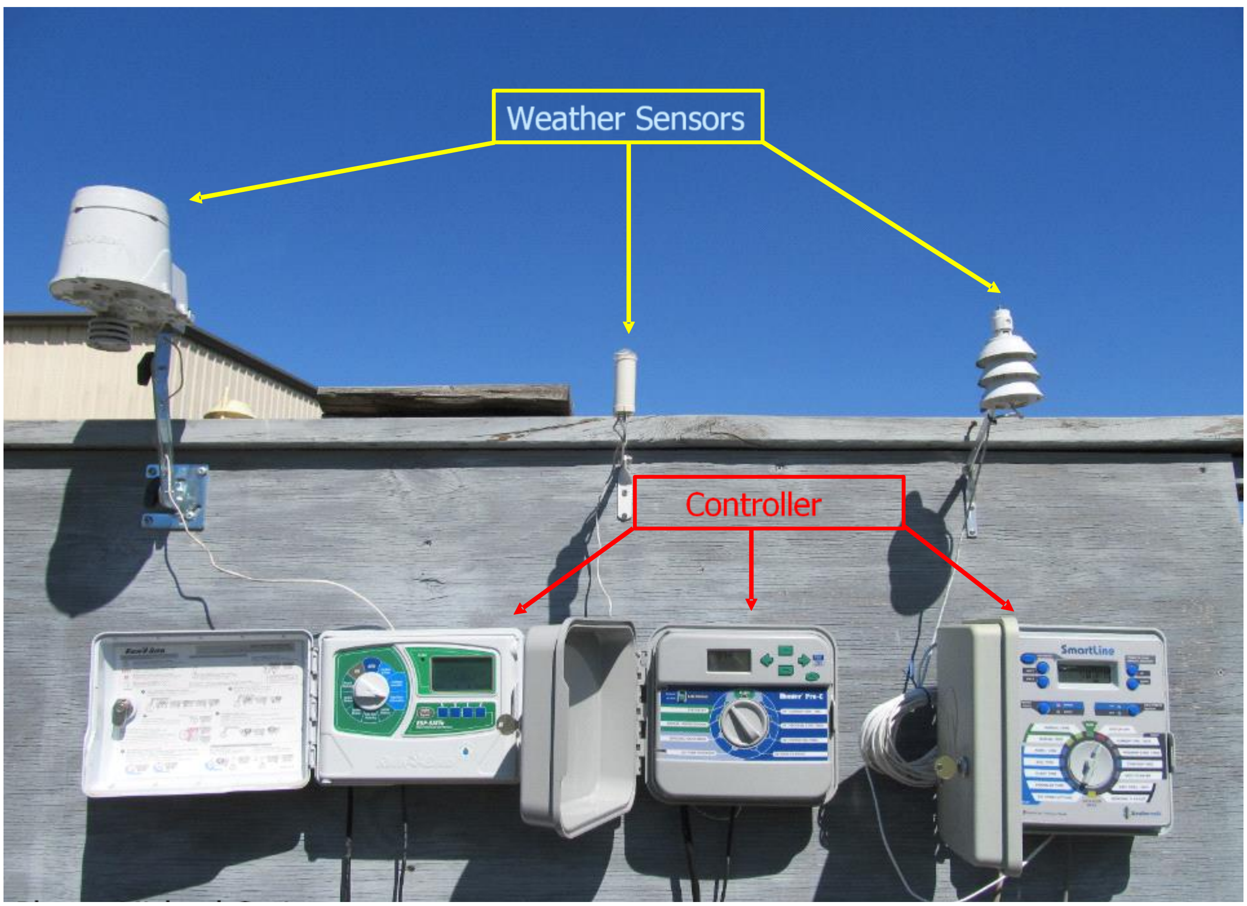

Figure 27. Different ET controllers with wired weather sensors

Sensors

Most current ET controller kits include one or more sensors for gathering local weather conditions.

Rain sensor

A rain sensor is the most common sensor included by the different ET controller brands. Rain sensors bypass irrigation events when a specific amount of rainfall has occurred. Some ET controllers will refill the soil to field capacity after a rain event is sensed, whereas other controllers will only pause irrigation until the rain sensor is dry. Unless a controller measures rainfall on site, a supplemental rain sensor should be added due to frequent and site-specific rainfall experienced in Florida. It is important that the rain sensor be connected to a “sensor” port if available on the ET controller so that irrigation bypass events are accounted for properly in the controller. If the rain sensor has optional setting points, the sensor should be set to ¼ inch (Figure 28).

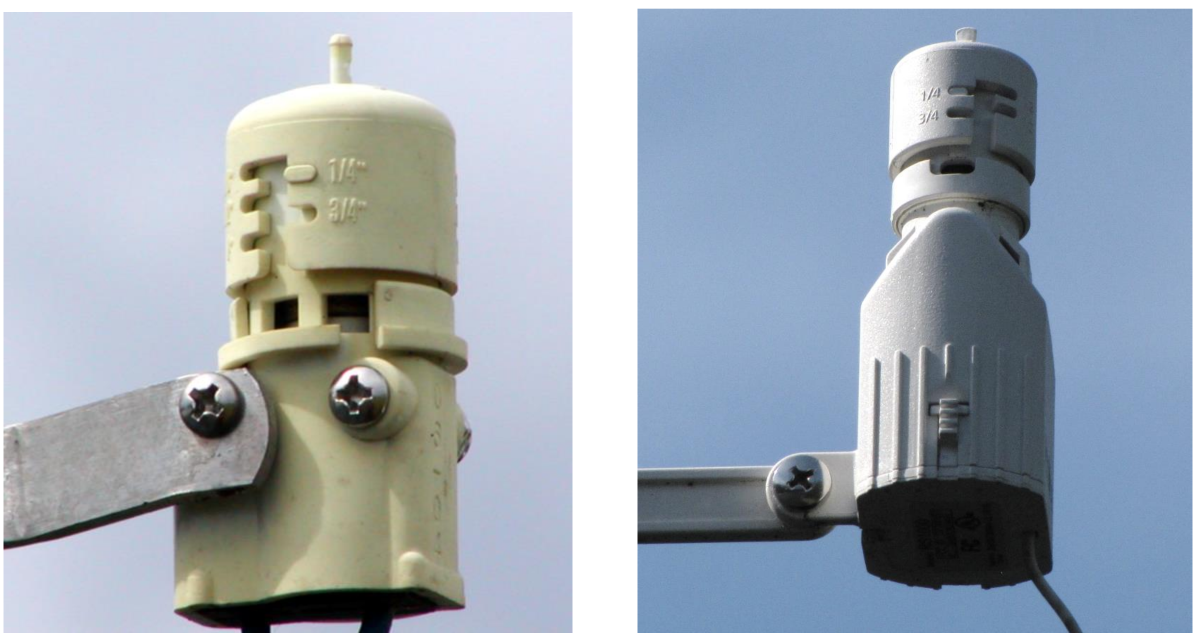

Figure 28. Rain sensors with optional set points, set at ¼” or 6 mm

Other sensors

Some ET controllers might include other sensors for measuring weather data. These data are used by their algorithms for calculating the amount of water that will be delivered to the different irrigation zones. These sensors usually measure temperature, solar radiation, and/or wind speed (Figure 29).

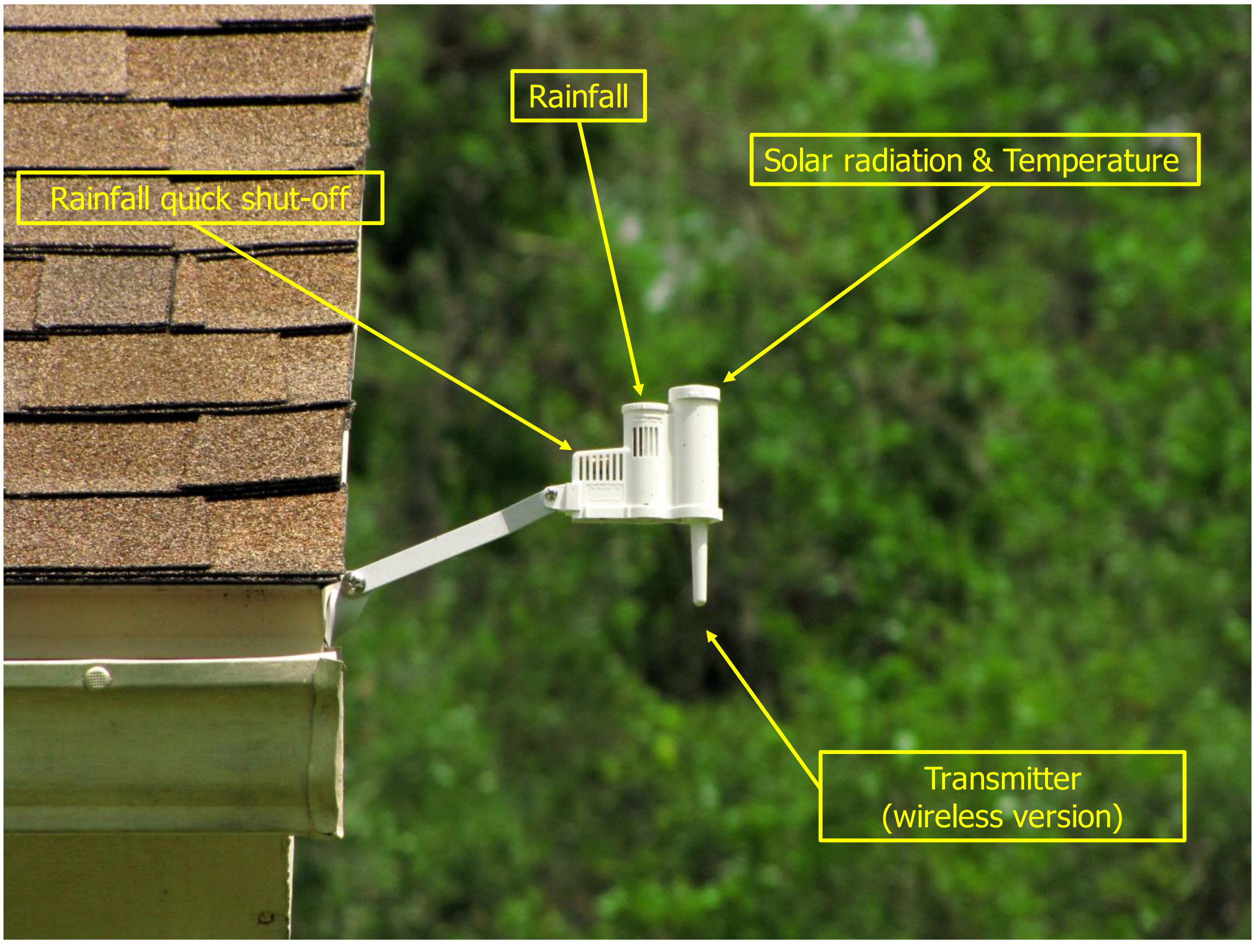

Figure 29. Wireless weather sensors for an ET controller

Location of sensors

Sensors should be installed in a place open to the sky, away from obstructions. A good location is the roofline of the house. Sensors should not be under a tree or other structure (Figures 30 and 31).

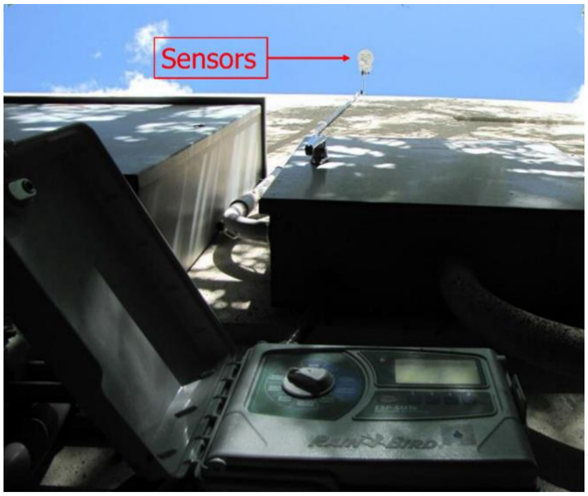

Figure 30. Adequate placement of sensors

Figure 31. Inadequate placement of sensors

Programming

Confusion may arise with these controllers when dealing with the programming aspect. The various commercially available ET controllers have different programming terms, inputs, and procedures; there is no standardized model. Table 4 shows common settings that should be programed in the ET controller. Manufacturers design the controllers to be installed by knowledgeable contractors who understand the various inputs. Programming the controller correctly for each unique landscape is critical to the ability of the controller to reduce water use and maintain good landscape aesthetics.

Table 4. Common settings that are programmable in ET controllers to properly schedule irrigation

Category	Common Settings	Parameter Affected by Setting	Common Florida Inputs
Irrigation Type	Spray head	Application Rate Uniformity/ Efficiency	Spray Rotor
	Rotor		
	Impact Bubblers		
	Drip emitters		
Soil Type	Sandy	Infiltration Rate Water Holding Capacity	Sandy Sandy Loam
	Sandy Loam		
	Loam		
	Clay Loam		
	Clay		
Plant Type	Warm Season Grass	Crop Coefficient (Kc)	Warm Season Grass Grass Mixed Shrubs
	Cool Season Grass		
	Combined Grass		
	Flowers		
	Trees		
	Shrubs		
	Mixed		
	Trees		
	Native Grasses		
Microclimate	Sunny all day	ET Adjustments	Site Specific
	Sunny most of the day		
	Shady most of the day		
	Shady all day		
Slope	0-5%	Cycle/Soak	Site Specific
	6-8%		
	9-12%		
	13-20%		
	>20%		

Application rate

One of the settings for some ET controllers is the application rate. Rates of water application vary depending on the brand, type, and installation details of sprinklers. Typically, the application rates of rotors are lower than spray nozzles. This rate has units of depth per time (such as inches/hour) and can be used to calculate the irrigation runtime.

The application rate can be obtained by different ways. The easiest is to find the manufacturer's specifications of the sprinklers of each zone (typical application rates for residential sprinklers are ~0.5 inches/hour for rotors and ~1.5 inches/hour for spray heads). Another way is to calculate it through the depth using a soil water balance (see Dukes et al., 2019). A third way of obtaining the application rate is by performing a distribution uniformity test (see Trenholm et al., 2009).

The recommended way to obtain the application rate is: Run each zone for 2 minutes, take a reading of the flowmeter before and after running each zone, and measure the area of each irrigation zone. After this is done, apply the calculations as shown in the following example:

A	Run time (minutes)	= 2
B	Meter reading before (Gal)	= 1000
C	Meter reading after (Gal)	= 1020
D = C - B	Gallons applied	= 1020 – 1000 = 20
E = D / A	Application rate (gpm)	= 20/2 = 10
F	Irrigation zone area (ft^2)	= 1000
G = (E/ F) * 96.3	Application rate (in/hr)	= (10/1000) * 96.3 = 0.01 * 96.3 = 0.96

Note: the factor 96.3 is used to convert gpm/ft^2 to in/hr

Efficiency

Many landscape sprinkler systems are inefficient. For scheduling purposes in the ET controller instead of using low quarter distribution uniformity (DUlq), it is recommended that the low half distribution uniformity (DUlh) be used. In absence of uniformity testing information, the following efficiencies may be used as an estimate: rotary or impact sprinklers: 70-80%; spray heads: 60-80%; drip or other microirrigation emitters: 80-90%. The lower the efficiency number input to the controller, the more water that will be applied because the controller will compensate for lower efficiency (i.e. more losses) by applying more water. It is best to use as high an efficiency value as possible to limit over-watering.

Landscape Inputs

Landscape conditions typically included as inputs to the controllers are soil type, plant type, slope, sun, and shade. The controllers generally have options available for each condition, which are self-explanatory.

Runtime setting

Set station runtimes for peak summer watering with seasonal adjustment set at 100%. For specific runtimes, see "Runtimes" heading, under soil moisture sensors

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Trenholm, L.E., Unruh, J.B., and Cisar, J.L. 2009. How to Calibrate Your Sprinkler System. ENH61, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL. Available at: http://ufdc.ufl.edu/IR00003389/00001 (accessed May 14, 2019).

APPENDIX I

IRRIGATION SYSTEM EVALUATION
Smart Controller Edition

Address: ______________________________

Date: ______________________________

Controller Location: Garage ☐ Outside wall ☐

Common Issues						
Leaks	Heads ☐	Pipes ☐	Valves ☐	Meter box ☐	Other ☐	
Heads	Clogged ☐	Broken ☐	Sunken ☐	Misaligned ☐	Low pressure ☐	
	High pressure ☐	Blocked by vegetation ☐		Unmatched precipitation rate ☐		

Problems Detected/Solved:

Zone	Description

Flow Test / Zone number		1	2	3	4	5	6	7	8
A	Run Time (min)	______	______	______	______	______	______	______	______
B	Meter Reading Before	______	______	______	______	______	______	______	______
C	Meter Reading After	______	______	______	______	______	______	______	______
D = C-B	Water Applied (gal)	______	______	______	______	______	______	______	______
E = D/A	Application Rate (gpm)	______	______	______	______	______	______	______	______
F	Irrigated Area (ft^2)	______	______	______	______	______	______	______	______
G=(E/F)*96.3	Precipitation Rate (in/hr)	______	______	______	______	______	______	______	______

Soil Moisture Sensor

Zone Number		1	2	3	4	5	6	7	8
Pgm A	Schedule	Sun ☐	Mon ☐	Tue ☐	Wed ☐	Thu ☐	Fri ☐	Sat ☐	___AM___PM
Pgm A	Run Time	______	______	______	______	______	______	______	______
Pgm B	Schedule	Sun ☐	Mon ☐	Tue ☐	Wed ☐	Thu ☐	Fri ☐	Sat ☐	___AM___PM
Pgm B	Run Time	______	______	______	______	______	______	______	______

Threshold: ______ Current Reading: ______

Sensor Location (zone) ______ ______ ______ ______ ______ ______ ______ ______

Sensor Location Notes ______________________________

Valve Box Notes ______________________________

ET Controller

Setting	1	2	3	4	5	6	7	8
Sprinkler Type	______	______	______	______	______	______	______	______
Plant Type	______	______	______	______	______	______	______	______
Sun/Microclimate	______	______	______	______	______	______	______	______
Soil Type	______	______	______	______	______	______	______	______
Slope	______	______	______	______	______	______	______	______
Weather Sensor	Location:							

Evaluator: ______________________________

APPENDIX II

CHECK LIST FOR SOIL MOISTURE SENSORS (SMS)

IRRIGATION SYSTEM EVALUATION:

- ☐ No leaks detected
- ☐ Irrigation heads working properly based on evaluation
- ☐ Irrigation system in good condition for SMS installation

SITE SELECTION FOR PROBE:

- ☐ In the location needing most frequent irrigation
- ☐ 5 feet away from (check all):
    - ☐ A property line
    - ☐ An impervious surface
    - ☐ A structure (e.g., house, porch, shed, etc.)
    - ☐ A depression/swale
    - ☐ On-site treatment and disposal systems (e.g., septic tanks, drain fields)
    - ☐ A plant bed
    - ☐ A shaded north side of the home (if possible)
    - ☐ A downspout
    - ☐ An overhang
    - ☐ A hose bib
    - ☐ An air-conditioner system condensate line
    - ☐ A construction road
    - ☐ An area with plant debris (e.g., tree stump)
    - ☐ An area with fill dirt (if fill dirt is unrepresentative of the entire landscape)
    - ☐ Buried material (e.g., cable, water, or sewer line)

INSTALATION OF THE PROBE:

- ☐ In the root zone of turfgrass
- ☐ In undisturbed soil
- ☐ With the center of their sensing section approximately 3 inches deep
- ☐ If probe has (choose one):
    - ☐ Exposed wave guides: installed horizontally, with the wide side facing up
    - ☐ Encased wave guides: installed horizontally, with the thin side facing up
    - ☐ Rods: installed vertically, with the top leveled with the ground
    - ☐ Node probe/s: installed vertically in a slurry of soil and water
- ☐ A picture was taken, showing probe installation depth and orientation

MAP OF THE PROBE'S LOCATION:

- ☐ Measured distance between the probe and two permanent points in the landscape
- ☐ Map drawn with the distance between the probe and two permanent points in the landscape
- ☐ Map with the probe location adhered to or beside the irrigation timer

WIRING:

- ☐ Outdoor wire connections protected with waterproof grease caps

CONNECTION TO THE TIMER:

- ☐ SMS controller installed next to the irrigation timer (choose one):
  - ☐ On an interior wall
  - ☐ Outdoor with a waterproof housing
- ☐ If probe is not a GMS type: SMS wired to the zone needing most frequent irrigation
- ☐ If probe is a GMS type:
  - ☐ SMS wired to the zone needing most frequent irrigation
  - ☐ Zone wired to SMS (choose one):
    - ☐ Was the last zone in the irrigation timer
    - ☐ Swapped zones, such that the SMS is now wired to the last zone

CALIBRATION:

- ☐ Saturated soil around the probe
- ☐ Initiated automatic calibration
- ☐ No rain for 24 hours after initiated automatic calibration

TIMER:

- ☐ Programed following local watering restrictions (day/s of the week, start time/s)
- ☐ Runtimes scheduled to fulfil the maximum irrigation requirement during the year

APPENDIX III

CHECK LIST FOR ET CONTROLLERS

IRRIGATION SYSTEM EVALUATION:

- ☐ No leaks detected
- ☐ Irrigation heads working properly based on evaluation
- ☐ Irrigation system in good condition for ET controller installation

SENSORS:

- ☐ Located on a place open to the sky, away from obstructions
- ☐ If the ET Controller did not include a rain sensor, a rain sensor was added and connected to the sensor port
- ☐ If the rain sensor had optional setting points, set it to ¼”

PROGRAMING:

- ☐ Programed following local watering restrictions (day/s of the week, start time/s)
- ☐ Application rate of each zone measured on-site
- ☐ Runtimes scheduled to fulfil the maximum irrigation requirement during the year
- ☐ If the model has predictive watering, selected not watering when 80%+ chance of rain
- ☐ Programed all the settings according to the model installed

APPENDIX IV

CHECK LIST FOR SOIL MOISTURE SENSOR (SMS) INSTALLATION

(Evaluator will receive copy of installation check list along with all documents required for submittal by installers)

Property Owner Name:____

Property Address:____

Property Water Bill Account #:____

Name of Installer Firm:____

Date of Installation:____

IRRIGATION SYSTEM EVALUATION

Turn on system to determine:

__ No leaks detected

__ Irrigation heads working properly based on irrigation evaluation (provided)

__ Irrigation system meets the requirements for installation of a SMS system

If one of these is not verified provide details below:

____

____

____

The installed soil moisture sensor is one of the approved models allowed for this program

____ Yes ____ No

SMS EVALUATION

Based on the photo of the installed soil moisture sensor provided by the installer, was the probe installed correctly prior to being covered?

___Yes ___No

(Note: If the answer is "NO" the installation will be deemed unacceptable, and the contractor will be required to reinstall the probe correctly, providing documentation. The evaluator shall continue the evaluation regardless.)

Identify why the probe was not installed correctly:

____
____
____

Is there a diagram of the probe's location adhered to or beside the irrigation timer?
__Yes ___No

Did the installer indicate the measurements required to properly locate the probe?
___Yes ___No

Is the probe location sited by the installer's diagram accurate?
___ Yes ___No ___Could not be verified

If no, mark the location on the diagram where the actual location of the probe resides.

Is the probe located in the zone needing most frequent irrigation?
___Yes ___No

If no, does reinstallation need to occur due to poor or improper location installation?
___Yes ___No

Is the valve box location consistent with the location sited in the installer's diagram?
___Yes ___ No ___Not required (wireless SMS)

If no, mark the location on the diagram where the actual location of the valve box resides.

WIRING

Are wire connections from the SMS probe properly encased in a valve-box?
___Yes ___ No ___N/A

Are outdoor wire connections protected with waterproof grease caps?
___Yes ___No ___N/A

SMS CONTROLLER CONNECTION

Is the SMS controller connected to the timer?
___ Yes ___ No

If controller is located outdoors, is it protected from weather appropriately?
___ Yes ___ No

Dependent on the SMS model installed, are the appropriate requirements met for SMS zone placement?
___Yes ___No

(Note: The zone where a Granular Matrix Sensor (GMS) probe was installed should be the last zone to run. The original last zone in the irrigation timer might need to be swapped with the zone where the GMS probe was installed. Refer to the UF IFAS Recommendations for Optimizing Use of Smart Irrigation Controllers document for guidance.)

CALIBRATION

Is the SMS controller displaying an Error Code?
___Yes ___No

If yes, refer to the manufacturer's manual for troubleshooting. If the error cannot be fixed, the installation will be deemed unacceptable and the contractor will be required to resolve the issue. (The evaluator shall continue the evaluation regardless.)

Typical threshold values for the different SMSs

Brand	Model	Display	
		Type	Value
Baseline	WaterTec S100	VMC	7-20
Hunter	Soil-Clik	Step bars	5-8
Rain Bird	SMRTY	VMC	7-17
Toro	Precision Sensor	#	50

What is the brand, current reading, and threshold value?
Brand ______________ Current reading _____ Threshold ______

Is the SMS controller in allowing irrigation mode?
___Yes ___No

If yes, in the irrigation timer, manually start an irrigation cycle. Irrigation should start. Stop irrigation immediately after verifying functionality. Reset the timer to automatic irrigation control.

If no, in the irrigation timer, manually start an irrigation cycle. Irrigation should not start. Reset the timer to automatic irrigation control.

Is the irrigation timer programed following local watering restrictions (day/s of the week, start time/s)?

___Yes ___No

Maximum run times per zone are typically 30 minutes for sprays and 90 minutes for rotors (see Table 3 in the Guide). Are the run times per zone at or below these values?

___Yes ___No

If they are above, adjust each zone to these maximum values.

Notes:

____
____
____
____
____
____
____

Name of Evaluator: ____

Signature of Evaluator: ____

Date of Evaluation: ____

APPENDIX V

CHECK LIST FOR ET CONTROLLER INSTALLATION

(Evaluator will receive copy of installation check list along with all documents required for submittal by installers)

Property Owner Name:____

Property Address:____

Property Water Bill Account #:____

Name of Installer Firm:____

Date of Installation:____

IRRIGATION SYSTEM EVALUATION

Turn on system to verify the following:

__ No leaks detected

__ Irrigation heads working properly based on evaluation

__ Irrigation system meets the requirements for installation of an ET system

If, one of these is not verified provide details below:

____

____

____

SENSORS:

Is the ET Controller sensor(s) located on a place open to the sky and away from obstructions and any potential obstruction?

___Yes ___No

Is there a rain sensor included with the ET Controller system?

___Yes ___No

If the rain sensor has optional setting points, is the sensor set to ¼ inch, if possible? (See Figure 28 in the Guide.)

___Yes ___No

PROGRAMING:

Is the ET Controller model programmed specifically based on FFL BMPs and recommendations based on the UF/IFAS document? (See Table 4 in the Guide.)

___ Yes ___No

Is the ET Controller programed to follow local watering restrictions (day/s of the week, start time/s)?

___Yes ___No

Notes:

____

____

____

____

____

____

____

Name of Evaluator: ____

Signature of Evaluator: ____

Date of Evaluation: ____