

Field Guide to Soil Moisture Sensor Use in Florida



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Program for Resource Efficient Communities

The *Field Guide to Soil Moisture Sensor Use in Florida* was produced for the St. Johns River Water Management District (SJRWMD) by the Program for Resource Efficient Communities (PREC) at the University of Florida (UF).

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DISCLAIMER

The University of Florida does not in any way endorse specific brands of soil moisture sensor control systems. This document only endorses specific best practices for proper installation, calibration, and maintenance of soil moisture sensor control systems. It should be noted that soil moisture sensor (SMS) controllers are most effective when installed in conjunction with efficient irrigation design, installation, and maintenance. SMS controllers will not fix fundamental problems with an irrigation system and proper practices in areas such as component selection, head spacing, equipment location, and hydraulic principles should be addressed first. Additionally, current research has shown that SMS controllers are most effective when the irrigation controller is programmed to water seven days a week. With increasing demand on water resources Florida's water management districts have widely implemented water restrictions, which are in some cases one day per week. At some point it will be necessary to consider whether effective technologies such as SMS controllers should be allowed to operate free from restrictions provided they have been properly installed and are in effective working order.

Published May 2008
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I. Introduction

A. The Role of the Modern Soil Moisture Sensor in Florida

Water is an extremely valuable yet seriously stressed resource in Florida. Nevertheless, in-ground, time-controlled irrigation systems that use potable water are standard in the landscapes of a majority of newly built homes. Ideally, homeowners adjust their irrigation controllers in response to seasonal weather patterns. However, homeowners often make no adjustments, leaving the irrigation timer set at fixed watering levels regardless of plant water requirements. As a result, irrigation systems frequently apply significantly more water than landscapes require.

Conventional irrigation controllers used in residential landscapes allow irrigation at scheduled times for specified periods of time. For example, a controller can be scheduled to initiate a 15-minute irrigation event every Monday and Friday at 6 a.m. These controllers do not account for weather conditions and will irrigate at the scheduled time even if it is raining. To minimize this unnecessary irrigation, *Florida Statute 373.62* requires that all newly installed residential irrigation systems have an add-on rain shutoff device (rain sensor) installed and maintained that bypasses time-scheduled irrigation events during, and for a period after, rain events. While rain sensors improve the water-use efficiency of time-controlled irrigation systems, controllers still use fixed watering schedules, which are historical estimates of landscape water needs. These schedules can neglect seasonal and annual climatic variations and do not reflect actual landscape conditions.

Soil moisture sensor (SMS) controllers measure soil moisture content where it is most vital to plants: in the active root zone. SMS systems connect to irrigation controllers and check soil moisture content prior to scheduled irrigation events. If the SMS controller determines that soil moisture content is above a user-defined set point, the irrigation cycle is bypassed. This allows SMS controllers to function similarly to rain sensors and bypass irrigation during rainy periods, but also to minimize irrigation when plants do not require additional water. Under ideal conditions, a properly working SMS controller does not stress plants or decrease turf grass quality because it allows the irrigation system to apply the amount of water actually needed to meet plant water requirements.

Figure 1 shows the circuit created by an SMS control system. If moisture is above the set point, the circuit in the SMS controller is left open and no irrigation occurs. If the soil moisture is below the set point, the circuit is closed and the scheduled irrigation occurs.

Different SMS technologies are used to measure soil moisture content in landscapes. One is an improved granular matrix sensor (GMS) technology, which has been used in agricultural irrigation systems for decades. Some modern soil moisture sensors use electrical conductivity to measure soil moisture content. Two types of SMS use this technology: a time domain transmissivity (TDT) sensor and a time domain reflectometry (TDR) sensor. All sensor types are discussed in general terms in this field guide.

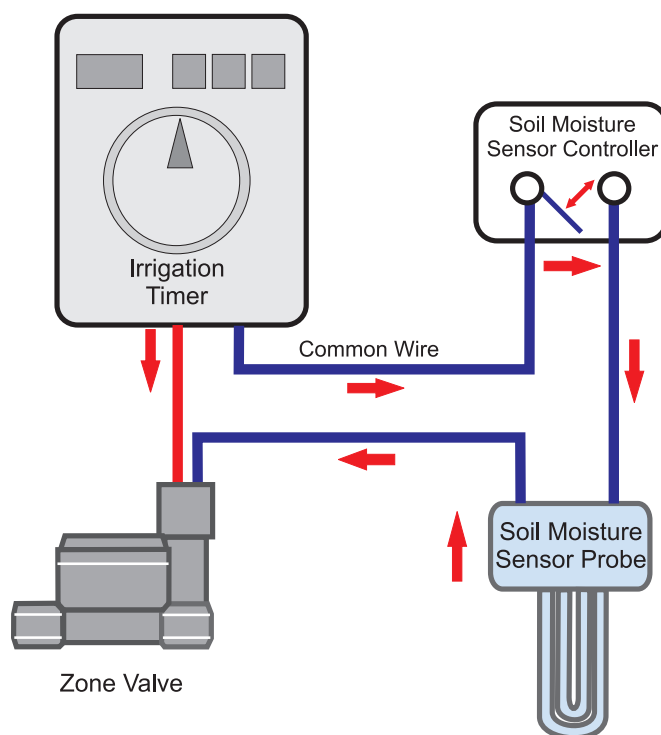


Figure 1. General diagram of an irrigation system with a soil moisture sensor (SMS) control system

Useful Terms

Evapotranspiration (ET) – A combination of water transpiration from vegetation and evaporation from the soil and plant surfaces; also known as consumptive use.

Field capacity – The moisture remaining in the soil following wetting and gravitational drainage until water has ceased drainage.

Irrigation zone – An area in a landscape that is irrigated by a single zone (solenoid) valve; also known as a hydrozone.

Net irrigation requirement – The amount of water needed to replace water lost through evapotranspiration minus the amount of rainfall that contributes water to the plant root zone (i.e., effective rainfall).

Permanent wilt point – Moisture content of the soil after a plant can no longer extract moisture at a sufficient rate for wilted leaves to recover overnight or when placed in a saturated environment.

Plant water requirement – The amount of water needed to replace water lost through evapotranspiration.

Representative area – An area possessing the average qualities of the irrigation zone(s) controlled by the SMS control system.

Soil moisture sensor (SMS) – The soil moisture sensor probe that is installed in the ground within the root zone.

SMS controller – Collective term sometimes used for the entire SMS system.

Transpiration – Movement of water from the soil, into the roots, up the plant stems, and finally out of the plant leaves into the air as vapor.

B. University of Florida Research

Beginning in 2004, a research group in the Agricultural and Biological Engineering Department at the University of Florida (UF) initiated a series of ongoing studies on soil moisture sensors (SMS) in turf grass. These studies have been conducted using one SMS probe per irrigation system in both highly controlled research facilities and in homeowner landscapes. To date, all studies have shown that SMS controllers produce substantial water savings in comparison to conventional controllers and rain sensors while maintaining acceptable turf quality.

Study 1

In the first study, in a controlled research environment in Gainesville, Fla. (2004–2005), four SMS controllers were tested:

- ✦ Acclima RS500
- ✦ RainBird MS-100
- ✦ WaterWatcher DPS-100
- ✦ Irrrometer 200SS-5

Rainfall during this study period was average to above average, resulting in high sensor-based water savings. Treatments were compared to a two-day-a-week, time-based irrigation schedule, based on Dukes and Haman (2002a), using no sensor technology. All four SMS controller treatments applied less irrigation water than the time-based schedule with no sensor (Table 1). Three of the SMS controllers significantly outperformed a rain shutoff device set at ¼ inch (6 mm): the SMS-controlled irrigation application reduction ranged from 70% to 92%, while rain sensors averaged a 34% savings (Cardenas-Lailhacar, in press).

Two other sensors, the BaseLine WaterTec S100 and the Lawn Logic LL-1004, have been added to ongoing research at the UF Gainesville facility.

Table 1: Water Savings in Wet Conditions in a Research Setting	
Treatment	Percentage of Water Saved
2 days/week without sensor	0%
2 days/week with rain sensor	34%
2 days/week SMS average	72%

* SMS = Soil moisture sensor

Study 2

In the second study, at a controlled research environment in Citra, Fla. (2006), two SMS controllers were tested: the Acclima RS500 and the LawnLogic LL-1004. Rainfall during this study was below average, resulting in lower SMS-controlled water savings compared to Study 1 savings. These water savings ranged from 10% to 28% (Table 2). Rain sensors saved 11% to 23% compared to the conservative irrigation schedule (Shedd et al., 2007)

Table 2: Water Savings in Dry Conditions in a Research Setting	
Treatment	Percentage of Water Saved
2 days/week without sensor	0%
2 days/week with rain sensor	10–23%
2 days/week SMS average	10–28%

* SMS = Soil moisture sensor

Study 3

The third study tested one sensor controller, the Acclima RS500, on residential landscapes in the city of Palm Harbor, Fla. Preliminary results show that sensors are successful for irrigation water-use savings at single-family homes. From June 2006 through March 2007, homes with soil moisture sensors demonstrated water savings of 51% compared to homes with an irrigation controller only (Haley and Dukes, 2007).

Disclaimer

Procedures for proper installation, calibration, and maintenance vary by SMS brand. Generally, each manufacturer's installation manual provides adequate instructions for effective installation. Installation manuals should be referenced for specific instructions, especially for wiring, calibration, and troubleshooting. Valuable lessons have been learned during testing conducted by the University of Florida (UF) that can provide additional guidance. This field guide describes these lessons and other information required for general best practices. However, installers and maintenance professionals should always refer to the most current manufacturer's installation manual for model-specific instructions. An SMS cannot make up for a poorly working irrigation system, and sensors should be installed on systems that are in good repair and which have been designed for optimum efficiency.

II. Installation

The four main installation steps are:

1. Establish the sensor location.
2. Install the sensor.
3. Install the controller.
4. Connect the wiring.

Step 1: Establish the Sensor Location

An SMS is most effective when placed in a location representative of the zone(s) that the sensor is controlling. If multiple sensors are being used in a landscape (i.e., one sensor per zone), each sensor should be placed in an area representative of the specific zone it is controlling. If one sensor is being used for the entire landscape (the sensor is controlling multiple zones), the average water requirement of the entire landscape should be considered as the baseline. To gain the most benefit in a multiple SMS probe system, a sensor should be located in each irrigation zone, known as a hydrozone.

When used to control an entire irrigation system with only one sensor, SMS controllers should be installed in an irrigation zone for turf grass. Instructions in this field guide focus on landscapes composed primarily of turf grass. Typically, turf grass will need more frequent irrigation than most other plant types in a landscape. Therefore, if turf grass watering requirements are met, other plants in the landscape will receive sufficient irrigation, presuming that all hydrozones are properly designed and scheduled for the associated plant materials. Care must be taken before using SMS control systems on stress-prone plants, such as annuals. If SMS controllers are being used for landscape plants, trees, or other types of ground cover, installers should refer to the manufacturer's installation manual for location instructions and specifications.

Variations in soil type and condition, adjacent land use, shading, and drainage patterns all can cause a sensor to read an unrepresentative soil moisture content, which can result in too much or too little irrigation. If one area does not represent the average condition of the SMS-controlled area, SMS placement in that location should be avoided.

Location in the landscape – Soil moisture sensors should be placed at the driest location relative to the average of the SMS-controlled zone(s). These driest locations may include

- ✦ Areas with significant sun exposure
- ✦ Lot-specific high elevation points

Depth in the ground – Sensor probes should be placed within the root zone, in contact with relatively undisturbed soil that is representative of the irrigated landscape area. Contact with disturbed soil with a higher (or lower) amount of void space will likely result in unrepresentative soil moisture content readings. However, if the soil in the entire landscape is disturbed (i.e., fill material is used to elevate and level a new construction site), a disturbed area would be representative.

A. Optimal Installation Areas

The following are optimal areas for sensor installation:

- ♦ **In the turf grass root zone** (Figure 2), if turf grass is used as the representative plant type

Purpose: Provide sufficient irrigation to the area with the greatest water requirement. Generally, turf grass will have the highest water requirement relative to other landscape plants. If the turf grass requirements are met, other plant water requirements should also be met, presuming that all irrigation zones are properly designed and scheduled for the associated plant materials.

- ♦ **In a relatively sunny area**, if full sun is representative of the landscape

Purpose: Provide sufficient irrigation to the area with the greatest water requirement. Often, landscapes have turf grass lawns in full sun. These areas have higher evapotranspiration (ET) rates and, therefore, higher water requirements. In new landscapes, these areas may have a poor soil type that does not hold water well.

- ♦ **In the driest representative area possible**, considering all other factors

Purpose: Provide sufficient irrigation to the area with the greatest water requirements. While other areas might receive more water than required, the sensor should not be installed in an area where it will bypass irrigation events necessary to meet the landscape's water requirements as a whole.

- ♦ **In the center of the irrigation zone**, or in an area receiving an average, or slightly less than average, amount of irrigation relative to other irrigated areas in the landscape

Purpose: Ensure that the SMS is not located in an area with a greater than average soil moisture content. In some cases, irrigation distribution may be nonuniform and sensor placement in an area with higher relative irrigation could result in too many bypassed irrigation events, thus preventing plants from receiving their needed irrigation water requirements.

Note: It should be noted that some SMS controllers require the sensor to be located in the area irrigated by the last valve to run, so the sensor is not wetted before all valves have been allowed to irrigate. Sometimes this means the stations on the controller should be re-sequenced so the area where the sensor has been installed is last.



Figure 2. Bermuda grass root zone

B. Areas to Avoid – General

When establishing the SMS location, certain areas and site conditions should be avoided.

INSTALL the sensor at least 5 feet away from:	To avoid:
• A property line.....	irrigation overspray from a neighbor's yard
• An impervious surface.....	runoff from impervious surfaces and compacted soil around impervious surfaces
• A structure (e.g., house, porch, shed, etc.).....	compacted soil, shade, and runoff
• A depression/swale.....	naturally high soil moisture content areas
• On-site treatment and disposal systems (e.g., septic tanks, drain fields)	high moisture areas
INSTALL the sensor at least 3 feet away from:	To avoid:
• A plant bed.....	higher runoff, shade, and unrepresentative plant roots

C. Areas to Avoid – High Moisture

Some areas in the landscape can have a higher moisture content due to increased water inflow or reduced water outflow. For example, directed stormwater runoff can cause an area to have a higher moisture content, while shade can cause the same effect by reducing evapotranspiration. These areas with a higher moisture content relative to the surrounding landscape should be avoided.

INSTALL the sensor at least 5 feet away from:	To avoid:
• A downspout.....	areas with higher amounts of inflowing storm water relative to the rest of the landscape
• An overhang	areas with higher or lower amounts of inflowing storm water relative to the rest of the landscape
• A hose bib.....	areas with higher amounts of inflowing water relative to the rest of the landscape
• An air-conditioner system condensate line.....	areas with higher amounts of inflowing water relative to the rest of the landscape
• The drip line of a tree canopy	areas with a lower ET rate and higher moisture content (unless SMS is specifically used for trees)
• A shaded north side of the home (if possible).....	areas with a lower ET rate and higher moisture content

D. Areas to Avoid – Disturbed Sites and Soils

In some areas it is 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 particular area, the SMS should be installed elsewhere.

INSTALL the sensor at least 4 feet away from:

To avoid:

- ♦ A construction road.....compacted soils and runoff from compacted soils

INSTALL the sensor at least 3 feet away from:

To avoid:

- ♦ An area with plant debris (e.g., tree stump).....compacted soils and materials intermixed with soils that are unrepresentative of the landscape as a whole
- ♦ An area with fill dirt (if fill dirt is unrepresentative of the entire landscape)soils that are unrepresentative of the landscape as a whole
- ♦ Buried material (e.g., cable, water, or sewer line).....soils and materials that will result in a soil moisture reading that is unrepresentative of the landscape as a whole or that may be disturbed in the future due to maintenance or repair

Note: ♦ Check with local building codes before beginning to dig or install an irrigation system.

♦ See Appendix A for a condensed table containing priorities for determining SMS placement.

E. Landscape Examples

To better understand how these rules should be applied, three different landscape installation examples are shown on the following pages. The three depicted conditions are:

1. A typical landscape
2. A Florida Water StarSM landscape
3. A preserved vegetation landscape

In all three examples:

1. Green-dotted areas are **optimal** locations for SMS placement.
2. Blue-striped areas are **secondary** locations that might be appropriate in some cases.
3. Red wavy areas are **not suitable** SMS locations.

Drawings are not to scale, to emphasize landscape features.

Note: Specific site features and conditions could preclude installation in areas that appear to be optimal or secondary installation locations. Always perform a site inspection to determine if any site specific conditions make an area less suitable for sensor probe installation.

In a Typical Landscape

Figure 3 depicts a typical residential landscape characterized by large turf grass areas (greater than 60% of the entire landscape) and very few trees. There are many optimal sensor locations in this landscape, and it should be relatively easy to determine the best location within a short period of time. A newly developed landscape of this type will have fill material that must be considered during SMS installation.

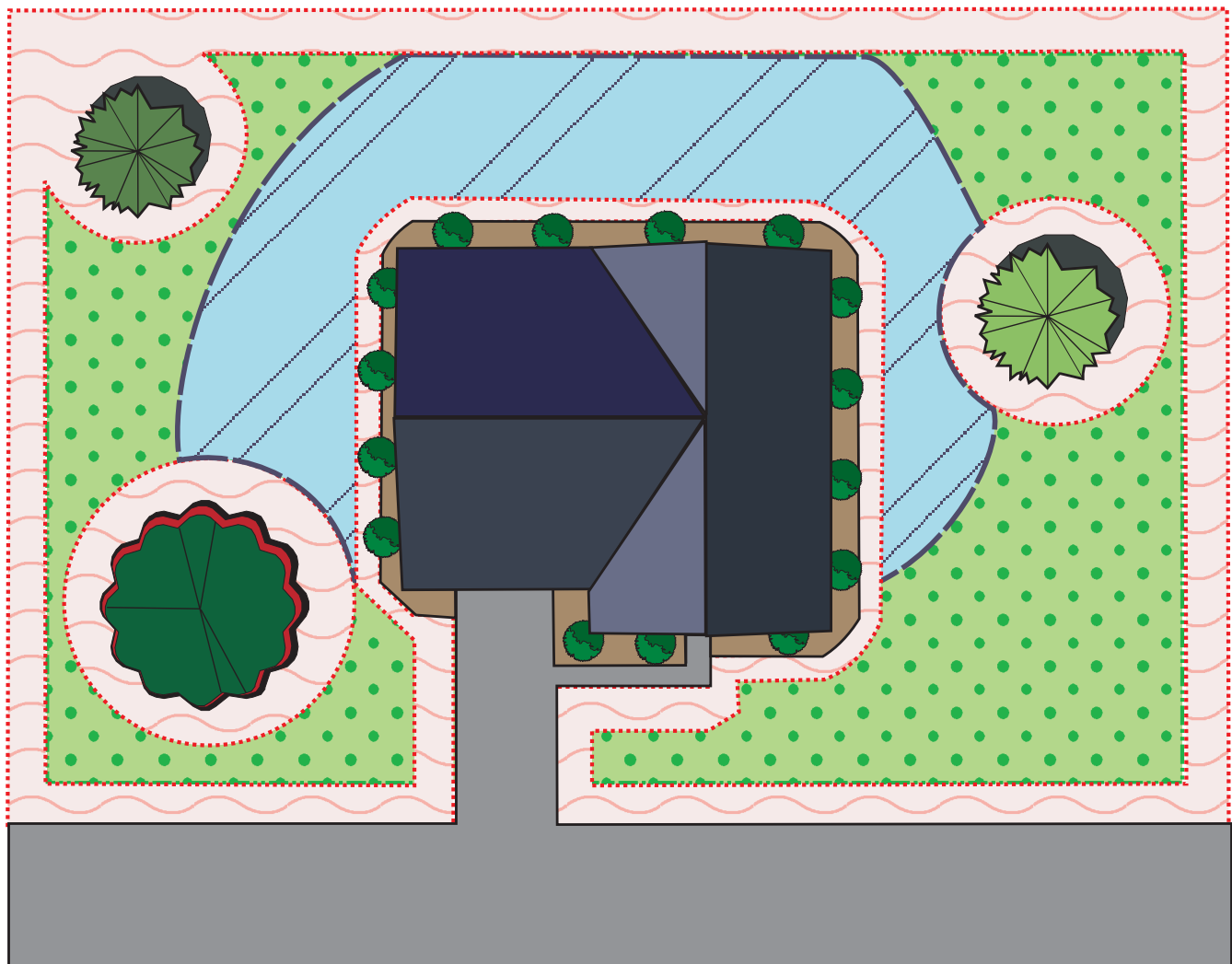


Figure 3. Example of a typical residential landscape

Legend

- | | |
|---------------------|--|
| Green-dotted areas: | Optimal locations for SMS placement. |
| Blue-striped areas: | Secondary locations that might be appropriate in some cases. Areas are more shaded than green in this case. |
| Red wavy areas: | Not suitable SMS locations. |

In a Florida Water StarSM Landscape

Figure 4 depicts a hypothetical Florida Water StarSM (water-efficient) landscape, composed of 60% or less turf grass and 40% or greater planting beds, natural areas, or drought-tolerant ground covers. Reduced turf grass area decreases the number of optimal SMS locations. There are optimal areas in the front yard, but fewer such areas exist throughout the Florida Water StarSM landscape when compared to a typical landscape. Selection of a sensor location in this type of landscape might require more attention than in a typical setting.

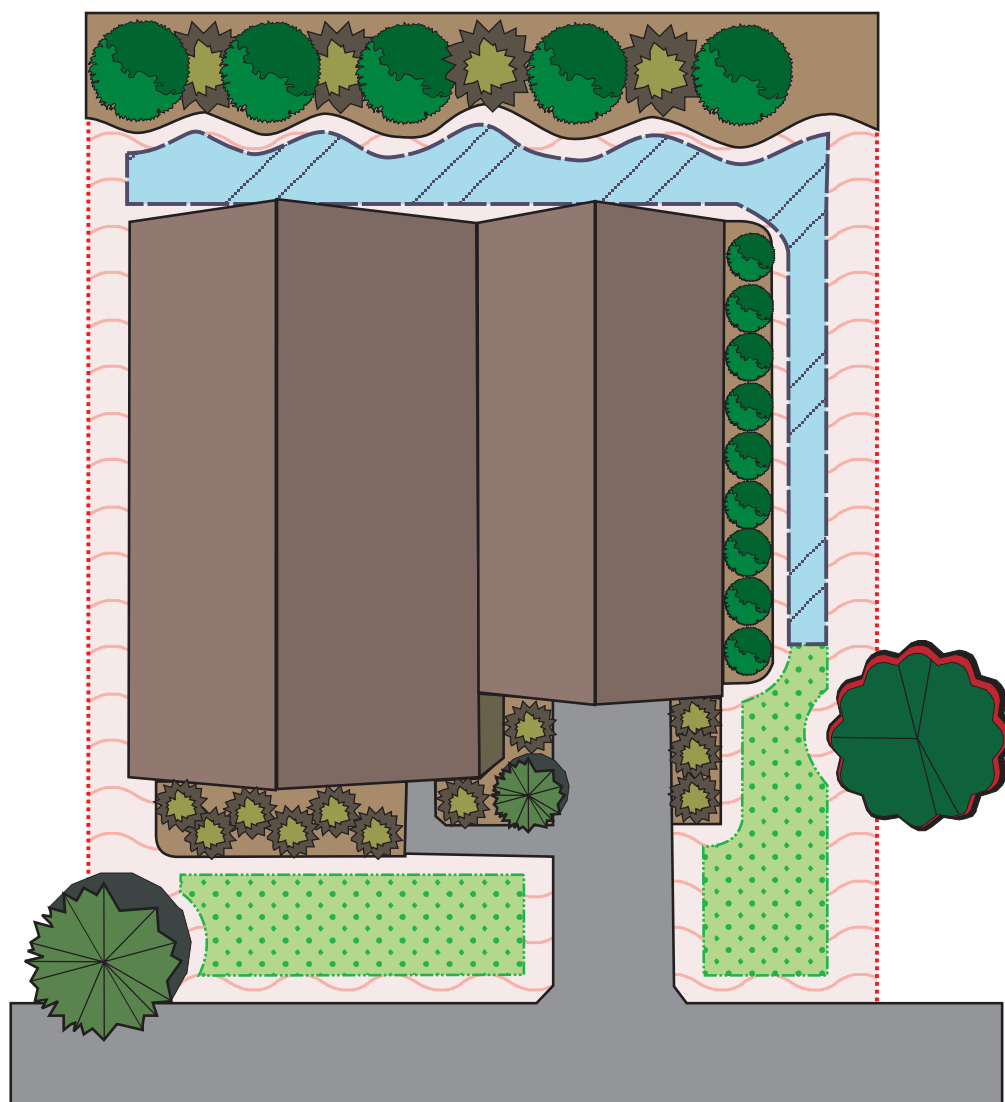


Figure 4. Example of a Florida Water StarSM (water-efficient) landscape

Legend

- | | |
|---------------------|--|
| Green-dotted areas: | Optimal locations for SMS placement. |
| Blue-striped areas: | Secondary locations that might be appropriate in some cases. Areas are more shaded than green in this case. |
| Red wavy areas: | Not suitable SMS locations. |

In a Preserved Vegetation Landscape

Figure 5 depicts a residential landscape with a high percentage of preserved vegetation. This landscape has more shaded areas, less turf grass, and potentially higher soil moisture content. Because of the landscape layout, the optimal areas for SMS installation might be considered secondary areas in other landscapes. However, the goal is to place the SMS in a representative area. If the landscape only has secondary areas, the SMS should be installed in an area that will ensure all areas receive adequate irrigation.

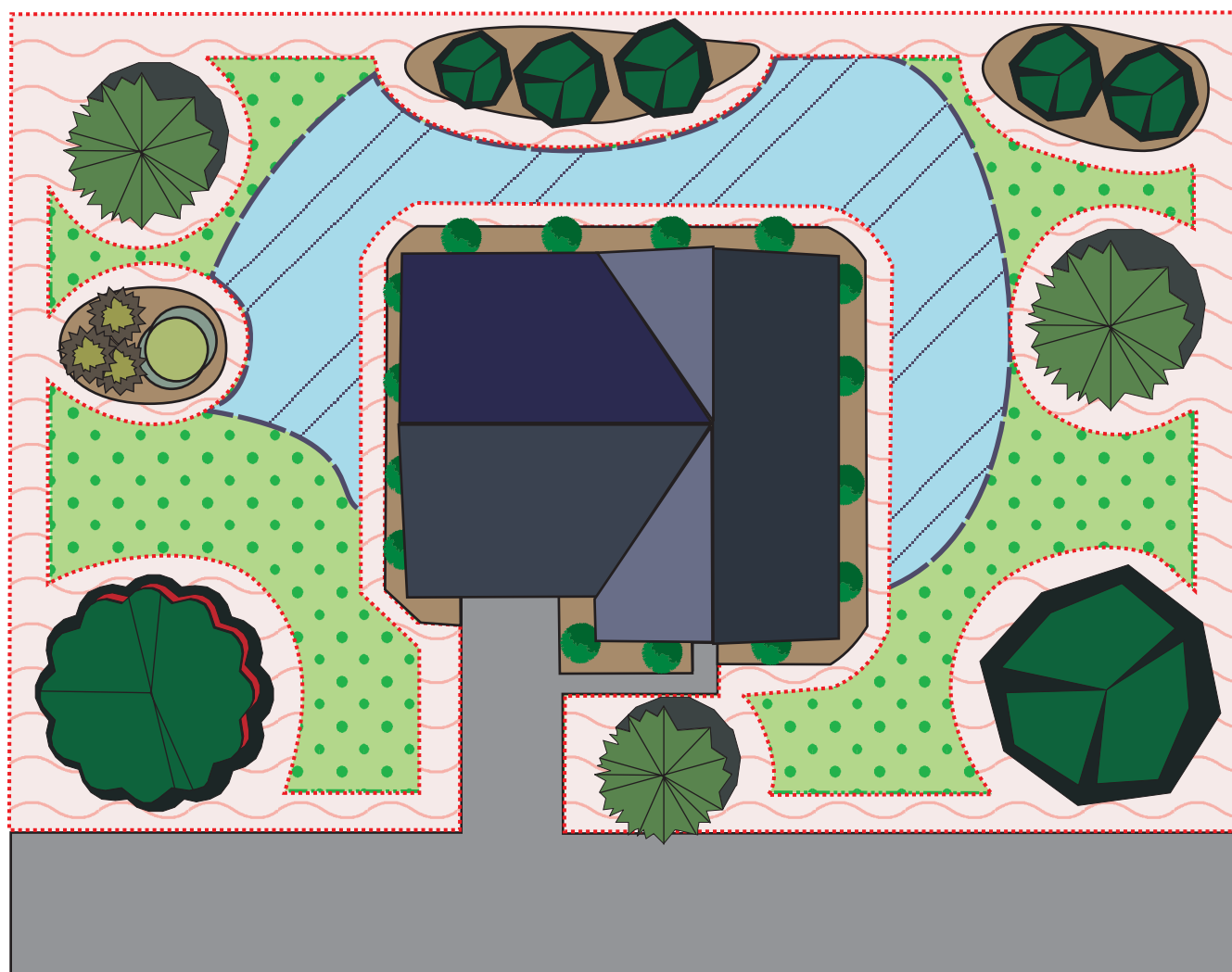


Figure 5. Example of a landscape with preserved vegetation

Legend

Green-dotted areas:	Optimal locations for SMS placement.
Blue-striped areas:	Secondary locations that might be appropriate in some cases. Areas are more shaded than green in this case.
Red wavy areas:	Not suitable SMS locations.

F. Include SMS Location in New Landscape Plans

Specifying the SMS location in the landscape and irrigation design plan prior to installation can help to simplify the installation process and reduce human error in the field. If the location is predefined, the installer will spend less time surveying the landscape to determine an optimal sensor location. Nevertheless, the predefined location should be checked according to instructions provided in step 1, Establish the Sensor Location, to ensure that unforeseeable factors do not make the area a poor choice for an SMS location.

G. Mark and Measure the Sensor Location

Documentation of the sensor location can make future maintenance easier by providing a record of the SMS location for future homeowners, irrigation contractors, and maintenance professionals. Foremost, the SMS installer should specifically mark the sensor location on a copy of the as-built irrigation plan and display the plan adjacent to the irrigation timer. Next, installers should measure and record the distance and approximate angle from the SMS to two permanent points in the landscape (triangulation) and note this also on the as-built plan. Finally, installers should consider adding tracer wire for future SMS probe location.

Step 2: Install the Sensor

A sensor's installation orientation depends upon its type, size, and shape. Installers should always refer to the manufacturer's installation manual for specific installation instructions. Until more information regarding sensor installation becomes available, the sensor should be installed in the turf grass root zone. In new landscapes, the SMS will often be installed prior to installation of the turf grass sod. In this case, the sensor probe should be buried in the soil at the midpoint of the maximum plant root density (typically < 6 inches) and the turf grass sod laid on top. For sensor installation in existing turf grass, an area of sod must be removed to accommodate the sensor probe and a trench must be dug to run the SMS wiring. The following installation instructions suggest that a wiring trench be dug after SMS installation. It is perfectly reasonable to dig the hole for the SMS probe and the trench at the same time and then install the sensor and wiring.

Note: ♦ Always use a square-point ditching shovel for SMS installation (Figure 6).

- ♦ Always check for proper system operation before burying the sensor probe and wiring.
- ♦ Bury the sensor probe within the midpoint of the maximum plant root density
- ♦ In new landscapes where there is no existing root zone, the installer should consider the root depth of any potential plantings in the landscape design, then estimate the midpoint necessary for correct sensor probe depth.



Figure 6. Square-point ditching shovel required for SMS installation

A. 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 and are described individually in the sections below.

1. Flat Sensor Probes

Two types of long, flat sensor probes are commonly found. Sensors with this type of probe often use time domain transmissivity (TDT) to measure soil moisture content. Orientation should occur as follows:

Exposed wave guides – If the 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).

Encased wave guides – If the 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 8).

Flat Probes in New Landscapes

In landscapes with new turf grass sod being installed, the sensor should be buried approximately 3 inches below the soil surface, with the turf grass sod placed on top of the soil as follows:

1. Dig an 8-inch by 8-inch hole to a depth of 3 inches.
2. Insert the sensor into the bottom of the hole according to the sensor orientation specifications (Figure 9).
3. Dig the trench for the wiring connection (See section B); connect the wiring according to the manufacturer's instructions; and check for proper SMS controller functioning.
4. Fill in the hole and trench, completely covering the sensor and wiring.
5. Mark the sensor location with a flag to prevent damage during the sod installation.
6. Install the turf grass sod, pressing firmly over the sensor.



Figure 7. Probe with exposed wave guides



Figure 8. Probe with encased wave guides
(Photo courtesy of Base Line)



Figure 9. Installation of flat probe SMS in new landscape (bare soil)

Flat Probes in Existing Landscapes

Two methods can be used to install flat sensors in existing landscapes.

Option 1: Bury the SMS probe in a shallow hole by rolling back a square of cut turf grass.

1. Using a square-point ditching shovel, cut a square piece of turf grass sod to the midpoint of the maximum plant root density and just large enough to cover the entire probe (Figure 10).
2. Remove the cut square of turf grass sod by rolling it back to expose the soil below (Figure 11).



Figure 10. Cutting a square of turf grass large enough to cover entire probe



Figure 11. Turf grass square rolled back

3. Place the sensor on top of the soil and gently press it into the soil (Figure 12).
4. Dig the trench to run wiring (see section B), make the connections according to the manufacturer's specifications, and check for proper SMS controller functioning.
5. Roll back the cut square of turf grass sod to completely cover the sensor probe (Figure 13).



Figure 12. SMS installed in root zone by rolling back the sod



Figure 13. Turf grass rolled back over sensor

6. Gently compact the turf grass sod, making sure that there are no channels that will allow water to seep in and pool around the SMS probe (Figure 14). Additional soil can be added on top of the sensor location so that it may wash into any remaining gaps.



Figure 14. Gently compacting the turf grass area

Option 2: Slide the SMS into the sidewall of a hole by cutting the turf grass roots.

1. Dig an 8-inch by 8-inch hole to a depth of 6 to 8 inches, ideally creating a sod plug that can be pulled out whole (Figure 15).
2. Horizontally, cut the turf grass roots in an area large enough to fit the sensor into the wall of the hole within the midpoint of the maximum root density by using a “metal slicing tool” and mallet (Figure 16).



Figure 15. Removal of turf grass and soil plug



Figure 16. Root cutting procedure preparing soil for SMS installation

Installation

3. Using the manufacturer's specified orientation, slide the sensor probe into cut area at the midpoint of the maximum turf grass root density (Figure 17).
4. Gently compact the soil above the sensor to ensure that there is sufficient contact between the sensor probes and the soil (Figure 18).



Figure 17. SMS probe installed within root zone



Figure 18. Compaction of soil around sensor to reduce void space and ensure adequate connection between SMS probe and soil

5. Dig the trench to run the wiring (see section B); make the connections according to the manufacturer's specifications; and check for proper SMS controller functioning.
6. Replace the cut square of turf grass and soil to completely cover the sensor probe (Figure 19).



Figure 19. Soil and turf grass plug replaced, covering SMS probe prior to burying wire

7. Gently compact the cut square of turf grass 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 added on top of the sensor location to fill in any remaining gaps.

2. Node Probes

An SMS with node probes should be installed vertically or at a 45-degree angle within the root zone. Sensors with this type of probe typically use granular matrix technology to measure soil moisture. Because this type of sensor might have additional specifications, always refer to the manufacturer's installation manual. Figure 20 shows a granular matrix sensor (GMS) being installed in a new landscape.



Figure 20. SMS node probes in a new landscape installation



Figure 21. SMS node probes installed in turf root zone

Node Probes in New Landscapes

In landscapes with new turf grass sod, the sensor probes should be inserted just below where the sod roots join the native soil.

1. Soak the sensor in water prior to installation.
2. Cut a small V-trench in the soil.
3. Insert the sensor into the side of the trench at a 45-degree angle (see Figure 21).
4. Dig the trench to run the wiring (see section B); make the connections according to the manufacturer's specifications; and check for proper SMS controller functioning.
5. Replace the plug of soil cut out, completely covering the sensor and keeping the wires at the bottom of the trench. Be sure it is compacted similarly to the surrounding soil.
6. Mark the sensor location with a flag to prevent damage during the sod installation.
7. Install the turf grass sod.

Node Probes in Existing Landscapes

In landscapes with established turf grass, the sensor probes should be inserted into the side of a shallow cut out section of turf and then the turf plug replaced.

1. Soak the sensor in water prior to installation.
2. Cut a small V-trench to expose the turf roots.

3. Insert the sensor into the side of the trench at a 45-degree angle (see Figure 21).
4. Dig the trench to run the wiring (see section B); make the connections according to the manufacturer's specifications; and check for proper SMS controller functioning.
5. Replace the plug of turf cut out, completely covering the sensor and keeping the wires at the bottom of the trench.
6. Tamp the replaced turf plug down firmly.

3. Rod Probes

If a sensor has rod probes, it should be installed with all probes positioned toward the ground at an approximate 45-degree angle. This allows the probes to read soil moisture content in the most active portion of the root zone. Sensors with these types of probes typically use time domain reflectometry (TDR) to measure soil moisture content.

Rod Probes in New Landscapes

In landscapes with new turf grass sod, the sensor probes should be inserted into a shallow hole and the turf grass laid on top.

1. Dig a 4-inch by 4-inch hole to a depth of 2 inches.
2. Insert the sensor into the bottom of the hole at a 45-degree angle.
3. Dig the trench to run the wiring (see section B); make the connections according to the manufacturer's specifications; and check for proper SMS controller functioning.
4. Fill in the hole, completely covering the sensor.
5. Mark the sensor location with a flag to prevent damage during the sod installation.
6. Install the turf grass sod.

Rod Probes in Existing Landscapes

In a landscape with existing turf grass, the SMS should be inserted in the turf grass root zone in the sidewall of a hole.

Dig an 8-inch by 8-inch hole to a depth of 6 inches, ideally creating a sod plug that can be pulled out whole.

1. Insert the sensor probes to penetrate the root zone in the soil of the hole's sidewall at a 45-degree angle (Figure 22), using a depth in the midpoint of the maximum turf grass root density of approximately 2 to 3 inches. (If the rods are inserted at a 2-inch depth they would reach to a depth of approximately 4 inches.)
2. Gently compact the turf grass and soil above the SMS to ensure that the probes are in sufficient contact with the soil.



Figure 22. SMS rod probes partially inserted into the turf grass root zone of undisturbed soil

3. Dig the trench to run wiring (see section B); make the connections according to the manufacturer's specifications; and check for proper SMS controller functioning.
4. Replace the cut square of turf grass sod.
5. Gently compact the turf grass and soil plug, making sure that there are no channels that will allow water to seep in and pool around the SMS probe. Additional soil can be added on top of the sensor location to fill in any remaining gaps.

B. Run Sensor Cable to Zone Valve

SMS wire connection requires digging a trench that may vary in length depending upon the installation distance. Wiring provided in the installation kit is typically long enough to span the distance between the SMS probe and the irrigation valve or SMS controller. If necessary, additional wiring should be added to allow for SMS probe installation in an optimal location. Depending on the circumstances, either mechanical or manual means can be used to dig the trench. For simplicity, instructions here discuss wiring the SMS probe to an irrigation valve.

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.

Mechanical Digging in New Landscapes

If the SMS is being installed in a newly developed landscape, it commonly will be installed prior to turf grass installation. In this case, a mechanical device, such as an earth saw trencher, chain trencher, or vibratory plow, can be used to dig the wiring trench. A mechanical trencher creates a deeper trench (8 to 12 inches) that will further protect the wiring from being cut by aerators, edgers, shovels, and other landscape maintenance devices. While the trench might be deeper in this case, the soil moisture sensor probe should still be installed in the root zone at the midpoint of the maximum density (typically < 6 inches).

1. After establishing the sensor location, mark the location with a flag.
2. Determine where the connection between the SMS probe and the valve will be made and mark it with a flag.
3. Dig the trench between the two flags to a depth of 8 to 12 inches.
4. Install the SMS probe at the end of the newly dug trench in the midpoint of the maximum density of the root zone.
5. Insert the wiring into the bottom of the trench until it reaches the point where the connection to the irrigation valve will be made.
6. Make the proper wiring connections according to the manufacturer's specifications and check for proper SMS controller functioning.
7. Fill in the trench completely.

Note: If the irrigation system is being installed at the same time as the SMS system, the irrigation trench can be used for running the SMS wiring. Additionally, wiring should be placed underneath the irrigation pipes for further protection. Not all sensors are wired the same and connections should be made according to the manufacturer's specifications.

Manual Digging In Existing Landscapes

Two manual digging methods, lift trench and slit trench, can be used for running wiring in existing landscapes.

a. Lift Trench Method

A lift trench is made by inserting a square ditching shovel at a 45-degree angle to the ground surface and while the soil is lifted, inserting the wiring underneath. This method is appropriate when no conduit is being used and there is little risk of cutting the wire. It is relatively simple and reduces the chances of killing turf grass above the trench.

1. Insert square ditching shovel into the soil at a 45-degree angle to a depth of 6 inches (Figure 23).
2. Lift the shovel to a 90-degree angle or to where there is enough room to insert the SMS wiring at a depth of 6 inches in the bottom of the trench (Figure 24).
3. While the shovel is still in the trench, insert the wiring into the trench to a depth of 6 inches, only running the wire halfway across the shovel head (Figure 25).
4. Repeat steps 1 to 3 until the wiring reaches the irrigation valve.
5. Make the wiring connections according to manufacturer's specifications and check for proper SMS controller functioning.
6. Gently compact the lifted trench on the top and the edge of the turf grass and soil to close the trench. Continue to compact the entire length of the trench until it is completely closed (Figure 26).



Figure 23. Beginning lift trench



Figure 24. Lifting shovel within the lift trench to create room for SMS wiring



Figure 25. Closing the lift trench



Figure 26. Placing sensor wires while continuing to lift the trench

b. Slit Trench Method

A slit trench is a wedge made in the ground. This method can be slightly more time-consuming than the lift trench method, while also leaving a line of dead turf after installation. However, this method should be used when running wiring through conduit for additional protection (Figure 27). When manually digging a trench, the slit trench method including conduit is recommended.

1. Insert a square ditching shovel into the ground at a 90-degree angle.
2. While standing on both sides of the shovel head, rock the shovel, spreading the soil to a depth of approximately 6 inches.
3. Continue steps 1 and 2 until the trench reaches from the SMS probe to the irrigation valve.
4. Insert the wiring through a section of conduit long enough (in total) to protect the entire length of the wiring.
5. Insert the wiring and conduit into the bottom of the trench, making sure that the wiring reaches from the SMS probe to the irrigation valve or SMS controller.
6. Make the wiring connections according to manufacturer's specifications and check for proper SMS functioning. Gently compact the trench by stepping on both sides of the opening in order to completely close the entire trench.



Figure 27. A conventional slit trench should only be used when placing wiring in conduit

Step 3: Install the Controller

There are two recommended locations for an SMS controller:

- Adjacent to the irrigation timer on an interior wall (e.g., garage)
- Adjacent to the irrigation timer in a weatherproof housing on the exterior of the home

Note: Do not install the SMS controller outside without a weatherproof housing and ultraviolet (UV) protection from the sun.

After determining the SMS controller location, install it on the wall adjacent to the timer. Make sure it is not blocked when the timer door is open. Installers should always refer to the manufacturer's specifications when installing the SMS controller.

Step 4: Connect the Wiring

Figure 28 shows a general wiring configuration of the SMS probe, the irrigation valve, the SMS controller, and the irrigation timer. This illustration does not depict the wiring configuration for all sensors, and installers should always refer to the manufacturer's illustration manual for specific instructions to make wiring connections.

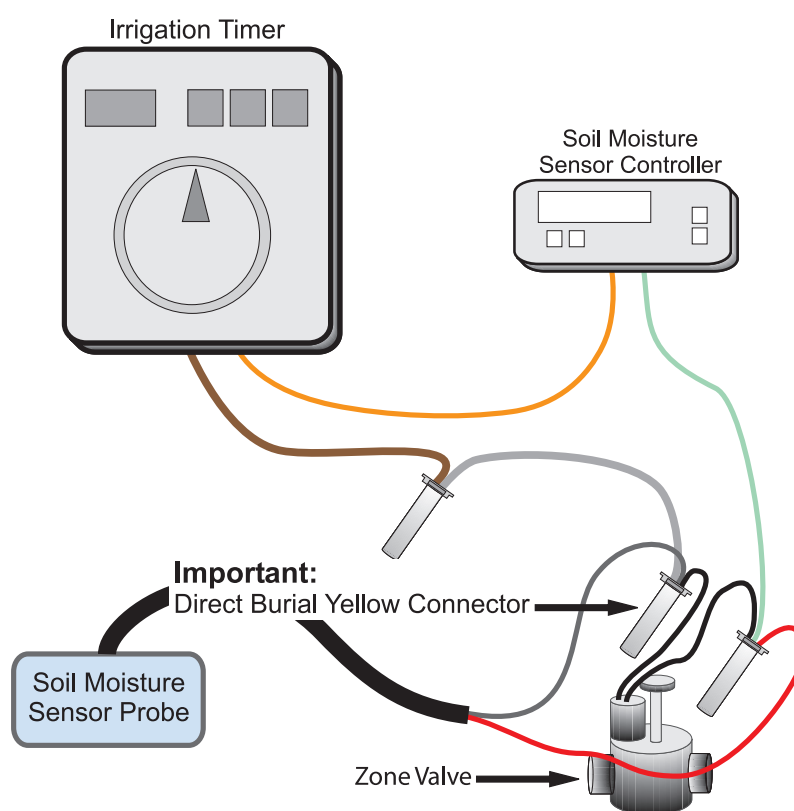


Figure 28. Example of a general wiring configuration for an SMS-controlled irrigation system

A. Connect Sensor to the Zone Valve

Generally, sensors can be wired either to an irrigation valve or directly to the SMS controller. It is recommended that the SMS be wired to the nearest zone valve, if possible, to facilitate sensor installation in the most representative area. Some sensors must be wired to the last zone valve for the entire system to be controlled by the SMS controller.

Wiring configurations vary among brands. Installers should always refer to specific wiring diagrams in the manufacturer's installation manual. Figures 29 through 34 show a connection being made between a sensor and a zone valve.

Note: Direct burial yellow or red (DBY or DBR) connectors should be used on all connections between the sensor and the zone valve to prevent moisture intrusion and to provide a secure connection.

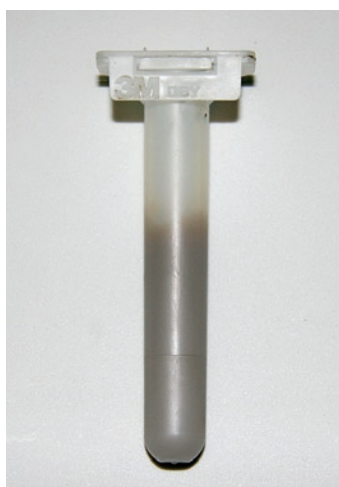


Figure 29. Direct burial yellow (DBY) connector



Figure 30. Uncover the irrigation zone valve box



Figure 31. Disconnect the existing wiring connection between the irrigation timer and zone valve



Figure 32. Prepare the soil moisture sensor and zone valve for connection



Figure 33. Connect the wires from the soil moisture sensor to the zone valve



Figure 34. Enclose all wire nuts in direct burial connectors

B. Connect SMS Controller to the Irrigation Timer

The connections from the SMS controller to the irrigation timer also vary by brand and should always be done according to specifications in the manufacturer's installation manual. Figures 35 through 38 show a controller being wired to an irrigation controller.

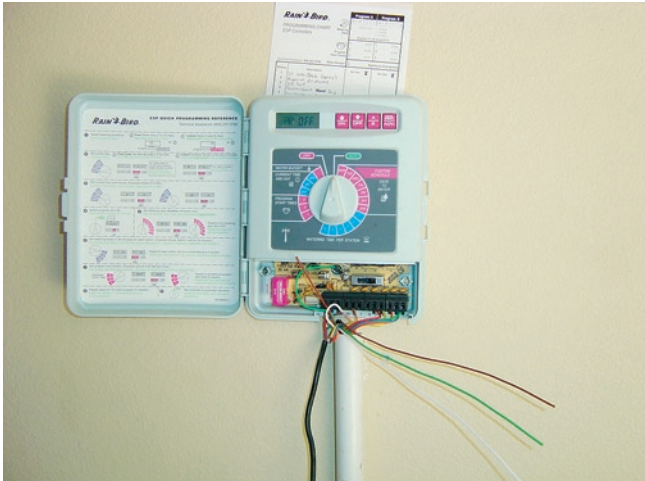


Figure 35. Open irrigation timer, exposing wires to be connected to SMS controller

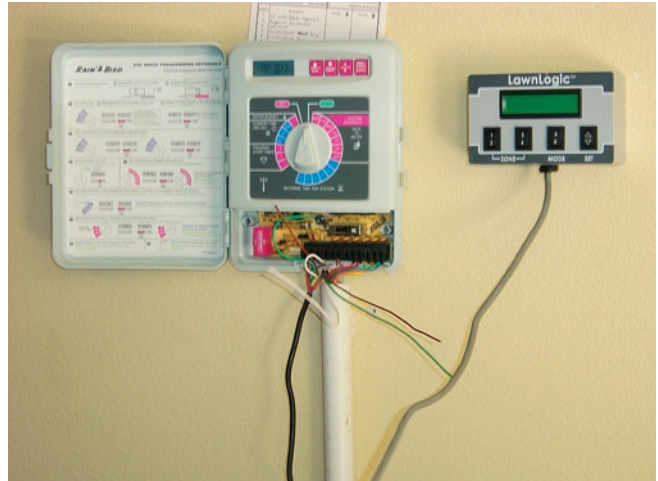


Figure 36. Install SMS controller adjacent to the irrigation timer on the side opposite the timer door hinges

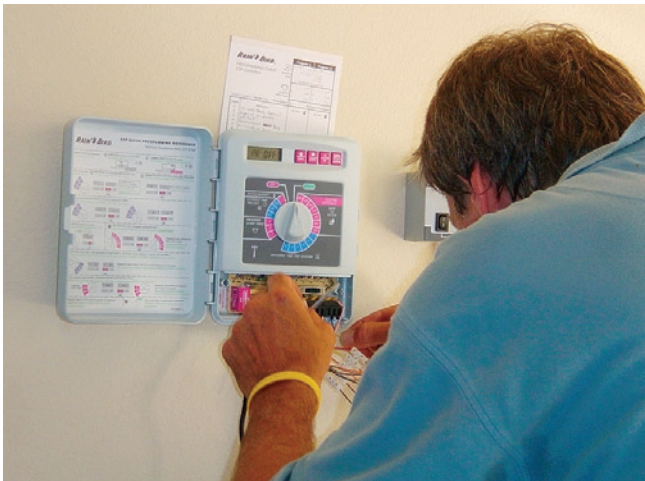


Figure 37. Connect SMS controller wiring to the irrigation timer wiring

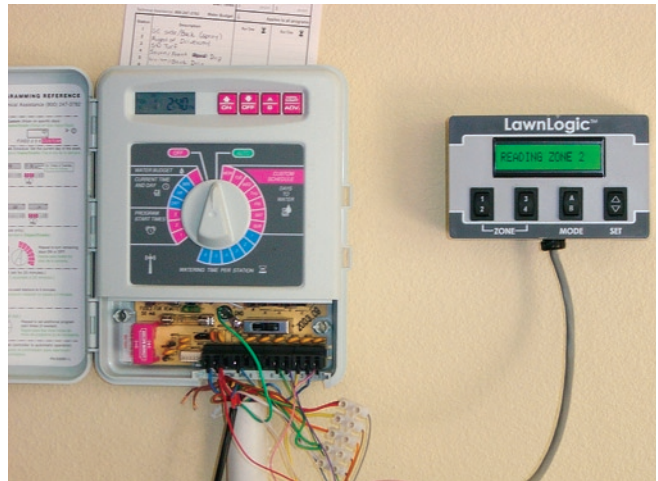


Figure 38. Power the SMS controller and the irrigation timer and check for proper functioning

III. Calibration

Step 1: Establish the Controller Set Point

Prior to calibration and set point establishment, it is necessary to determine how much water can be held in the root zone where the SMS is located. To achieve this, the installer should saturate the area immediately around the SMS location. Within 24 hours of saturation, the controller will read the soil moisture content, which should be close to field capacity (i.e., no further water drainage below the root zone). Generally, the recommended soil moisture set point is 75% of the field capacity. Two primary methods for establishing field capacity, bucket and irrigation, are recommended. A third method, calibration after a significant rainfall, can be used in situations where rainfall occurs shortly after sensor installation.

Option 1. Bucket method

1. Pour a 5 gallon bucket of water directly over the installed and connected SMS (Figure 39).
2. Wait 24 hours.
3. Perform the calibration according to the manufacturer's specifications.

Option 2. Irrigation method

1. Specify a watering cycle period, according to Appendix B, that will apply 1 inch of water to the zone where the sensor is installed.
2. Using the manual start button, start the irrigation system for the zone where the SMS is located (Figure 40).
3. Wait 24 hours from the end of the irrigation cycle.
4. Perform the calibration according to the manufacturer's specifications.

Option 3. Post rainfall method

1. Wait 24 hours from the end of a significant rainfall event (1 inch or more).
2. Perform the calibration according to the manufacturer's specifications.

Note: The soil surrounding the sensor should not receive any water during the 24-hour post-saturation period. If 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 39. Establishing the controller set point—bucket method (arrow points to sensor location)



Figure 40. Manual start of the irrigation timer to saturate area around SMS for calibration

Step 2: Calibration

Always refer to the manufacturer's specifications for detailed SMS controller calibration procedures. Calibration instructions are brand-specific and cannot be adequately addressed for all systems here in this field guide.

Timing With Plant Establishment

In new landscapes, plants (including turf grass) are often installed at about the same time as irrigation systems. During root establishment, new plants have their highest water needs. Water management districts and local governments specify rules that typically allow for 30 to 60 days for the establishment of new plantings. However, these rules vary by location and should be appropriately referenced for accuracy in all cases.

Two SMS calibration issues arise during a plant establishment period. First, the irrigation system will be set to meet the water requirements of newly installed plants and the SMS controller will be turned off during this period. Second, plant root depth and soil qualities in the root zone will change significantly during establishment. As a result, the controller should be calibrated post-establishment when the irrigation timer is reset for normal operation.

Recommended Set Points

Always refer to the manufacturer's installation manual for specific set point recommendations. Generally, an SMS controller should be set at an initial soil moisture set point equivalent to 75% of field capacity. Table 3 shows volumetric moisture content (VMC) settings for several field capacity VMCs. The VMC setting varies by SMS controller brand (see the manufacturer's installation manual).

Table 3: Recommended SMS Controller Set Points				
Field Capacity	10%	15%	20%	25%
Moisture Setting (threshold)	8%	11%	15%	19%

Irrigation Controller Scheduling

The irrigation controller, 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 your water management district's requirements. Appendix B contains recommended irrigation scheduling for Florida turf grasses. To establish the run-time for a particular zone, use the following procedure:

1. Determine your region (e.g., central Florida).
2. Determine the season (e.g., autumn).
3. For each zone, determine the appropriate application rate (e.g., 0.5 inches/hour for typical rotors, 1.5 inches/hour for typical spray heads; see Dukes and Haman, 2002a).
4. Determine the appropriate run-time for each zone according to Appendix B (e.g., 85 minutes for a zone with an application rate of 0.50 inches/hour during autumn months).
5. Program the specific run-time into the irrigation timer for each zone.
6. Repeat for each zone until all zones have been programmed appropriately.

Note: For additional assistance in setting the irrigation controller, see the Florida Automated Weather Network (FAWN) Urban Irrigation Scheduler at http://fawn.ifas.ufl.edu/tools/urban_irrigation/.

IV. Maintenance

SMS control system manufacturers do not specify routine maintenance procedures. A properly working SMS controller should not result in excessive irrigation application. If the system is applying excessive amounts of irrigation, it needs to be inspected by an irrigation contractor. The principle maintenance task described here is monitoring of the irrigation system's functioning.

Note: As previously mentioned, to improve monitoring and maintenance of an SMS, the sensor location should be marked on an as-built design plan and the plan displayed next to the irrigation timer.

A. Evaluate Soil Moisture Sensor Functioning

Step 1: Review Water Bill/Meter

The water bill should be reviewed to estimate how much water is being used for irrigation. For new homes, initial irrigation is likely to be higher for plant establishment and water consumption should be compared with water use for a similarly existing landscape. After extended occupancy, it will be possible to compare current water use with past water use. In existing homes, it is fairly straightforward to compare irrigation between pre-and post-SMS installation conditions.

For a complete evaluation tool, the following should be known:

1. Amount of water used for irrigation as reported in the monthly utility bill
2. Irrigated landscape area taken either from an irrigation plan or estimated based on the lot and house size

a. Estimate Monthly Outdoor Water Use

Single Meter

If one meter combines monitoring of domestic indoor water use and outdoor irrigation water use, the two uses should be separated. Two methods can be used for this calculation.

Method 1. Assume the average Floridian uses 53 gallons per day indoors (Marella, 2004, p. 15). Multiply this by the number of people in the household to calculate indoor domestic water use.

Formula: 53 gallons /day × ____ people in household × ____ days in month
 = ____ monthly indoor water use

Method 2. Calculate the monthly domestic indoor use based on the water bill during a period of low, net irrigation requirement (winter months). If the irrigation timer is set properly, irrigation during those winter months should be near zero and total consumption can act as a baseline for monthly domestic indoor water consumption throughout the year. To determine monthly outdoor water use, subtract the monthly indoor use from the monthly total water use.

Formula: ____ total monthly water use – ____ monthly indoor use = ____ monthly outdoor use

Dual Meter

If an independent water meter is installed to record irrigation consumption, calculating SMS performance is relatively straightforward. The only required calculation is estimation of the irrigated landscape area (square feet).

b. Compare to Appendix C

Appendix C contains monthly recommended net irrigation volume in gallons by region. Net irrigation is calculated by subtracting average historical rainfall from historical evapotranspiration (ET). To compare your monthly irrigation application to the net irrigation requirements in Appendix C, take the following steps:

1. Determine your region (e.g., central Florida).
2. Determine the season (e.g., autumn).
3. Estimate your irrigated landscape area in square feet (e.g., 2,000 square feet).
4. Find the recommended net irrigation volume in gallons (e.g., 4,300 gallons) from Appendix C. (Use the steps found on page 29 to help you calculate the volume.)
5. Compare this recommendation to the amount of monthly outdoor water use from your utility bill (e.g., 4,000 gallons). When comparing, be sure that the amount of water from your bill is for one month, as some utilities have a bimonthly billing cycle.
6. If you are applying excessive amounts of irrigation volume compared to the recommended net irrigation volume, the SMS controller system should be inspected by an irrigation contractor. (In this example, the irrigation volume is reasonable. Check again the following month.)

Step 2: Manual Start

Another method for monitoring the SMS controller function is a manual start of the irrigation controller. This is done by pressing the irrigation controller's manual start button (the SMS controller is activated). When the manual start is pressed, the irrigation system should not come on. If a watering cycle is activated under these conditions, there is a problem with the system's functioning and an irrigation contractor should be contacted (Figure 41).



Figure 41. Manual start of irrigation timer while SMS controller is “on hold” to test proper operation

Step 3: Observation

In some instances, observation of plant health can indicate whether the SMS control system is functioning properly. Visual evidence can tell you if the landscape is getting either too much or too little water. Certain conditions, as shown in Table 4, are caused by too much or too little irrigation. Too much irrigation can mean that the SMS is not working properly or that the set point is too wet. Too little irrigation typically indicates that the set point is too dry. Also, it is important to remember that over- or under irrigation can result from improper scheduling.

B. Other Information

Periodic Recalibration

SMS controller set points can be increased or decreased periodically to achieve a homeowner's desired irrigation results. Reasons for this periodic recalibration could be seasonal weather variation, water table variation, improper sensor location, or site alteration. If the system is installed properly and the landscape has not been altered, recalibration is only recommended once a year as part of a routine annual irrigation system maintenance program. Annual recalibration should be done beginning with step 1 in the Calibration section of this field guide.

Table 4. Methods for Testing Soil Moisture Sensor Functioning

Method	Possible Causes of Failure		
	Malfunction	Threshold	Schedule
1. Review of water bill/meter	X	X	X
2. Manual system activation	X		X
3. Check for wet/dry areas			
→Wet	X	X	X
Fungus	X	X	X
Dollar weed	X	X	X
→Dry		X	X
Chinch bugs		X	X

Other Considerations

Fertilization companies often activate a watering cycle after fertilizer application. An SMS controller might be turned off at this time to prevent it from bypassing the irrigation system. The SMS controller must be turned back on. Instructions for these and other professionals (e.g., pest control) should be included in the design plan displayed next to the irrigation timer.

Sensor and Controller Replacement

Contact your distributor for replacement components. If they are unable to meet your needs, contact the manufacturer directly.

V. Troubleshooting

SMS control systems have troubleshooting procedures that are typically model-specific, and operators should always refer to the manufacturer's installation manual for troubleshooting guidance.

Important Reminders

- ♦ Be certain the sensor is connected to the valve that controls irrigation in the sensor's location.
- ♦ Make sure the correct wire is connected to the sensor zone terminal on the irrigation timer.
- ♦ Make sure all in-ground wiring connections are enclosed within a direct burial connector.
- ♦ Make sure the circuit that connects the sensor, zone valve, SMS controller, and controller is properly connected (i.e., no short circuit)

VI. References and Resources

A. Irrigation Scheduling

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C. UF Soil Moisture Sensor Research

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D. Water Efficiency

- Florida Water Star. http://sjr.state.fl.us/programs/outreach/conservation/water_star/water_star.html.
- Marella, R.L. (2004). Water withdrawals, use, discharge, and trends in Florida, 2000. *U.S. Geological Survey Scientific Investigations Report* 2004-5151.

VII. Appendixes

Appendix A: Where to Install a Soil Moisture Sensor (SMS)

Prerequisites for Placement

- Within the root zone of turf grass
- In sunniest area possible
- Within the driest area possible considering all other factors
- Within the center of an irrigation zone

Main Areas to Avoid

Minimum Distance Away

Away from structures (house, garage, shed, etc.)

5 feet

- Away from a property line
- Away from depressions/swales
- Away from impervious surfaces
- Away from septic tanks/drainfields
- Away from plant beds

5 feet
5 feet
5 feet
5 feet
3 feet

High Moisture Areas to Avoid

- Away from an overhang
- Away from an air-conditioner system condensate line
- Away from a hose bib
- Away from north (shaded) side of the home
- Away from tree canopy
- Away from a downspout

5 feet
5 feet
5 feet
5 feet
5 feet
5 feet

Disturbed Areas to Avoid

- Away from construction roads
- Away from areas with plant debris (i.e., tree stump)
- Away from areas with fill dirt
- Away from buried materials

4 feet
3 feet
3 feet
2 feet

Appendix B: Irrigation Scheduling per Irrigation Event for Florida Turf Grasses (minimum)

Season	North	Central	South	Season	North	Central	South
0.50 inches/hour				1.50 inches/hour			
Winter	5	25	50	Winter	0	10	15
Spring	75	110	80	Spring	25	35	25
Summer	80	95	100	Summer	25	30	35
Autumn	55	85	65	Autumn	20	30	20
0.75 inches/hour				1.75 inches/hour			
Winter	0	15	35	Winter	0	5	15
Spring	50	70	55	Spring	20	30	25
Summer	55	65	65	Summer	25	25	30
Autumn	40	55	45	Autumn	15	25	20
1.00 inches/hour				2.00 inches/hour			
Winter	0	15	25	Winter	0	5	15
Spring	40	55	40	Spring	20	25	20
Summer	40	45	50	Summer	20	25	25
Autumn	30	45	35	Autumn	15	20	15
1.25 inches/hour				Season = Month with highest net requirement			
Winter	0	10	20				
Spring	30	44	30				
Summer	35	40	40				
Autumn	25	35	25				

- Events occur twice per week
- 60% system efficiency
- Calculated from historical evapotranspiration (ET) and effective rainfall
- Numbers rounded for convenience

Adapted from: Augustin, 2000; and Dukes and Haman, 2002a

Note: Appendix B is based on historical rainfall and might not represent necessary run times under atypical conditions (e.g., drought, wet conditions). Current conditions should be taken into account when setting the timer.

Appendix C: Monthly Net Irrigation Requirements for Florida

Table 1: Monthly Net Irrigation Requirements for North Florida

Net Irrigation Requirement (Historical ET – Rainfall)						
	Volume (gallons) of Irrigation per Irrigated Area (square feet)					
Season	Maximum Application (inches) ¹	Irrigated Area (square feet)				
		2,000	4,000	6,000	8,000	10,000
Spring	3.70	4,600	9,200	13,800	18,500	23,000
Summer	3.21	4,000	8,000	12,000	16,000	20,000
Autumn	3.51	4,400	8,800	13,100	17,500	21,900
Winter	1.44	1,800	3,600	5,400	7,200	9,000
Annual Total	11.86	14,800	29,600	43,300	59,200	73,900

¹Under normal rainfall conditions

- Requirements are for Gainesville, Fla.
- Seasons are the months with the highest irrigation requirement.
- Spring = May
- Summer = June
- Autumn = September
- Winter = December

Adapted from Augustin, 2000

Table 2: Monthly Net Irrigation Requirements for Central Florida

Net Irrigation Requirement (Historical ET – Rainfall)						
		Volume (gallons) of Irrigation per Irrigated Area (square feet)				
Season	Maximum Application (inches) ¹	Irrigated Area (square feet)				
		2,000	4,000	6,000	8,000	10,000
Spring	4.73	5,900	11,800	17,700	23,600	29,500
Summer	4.68	5,800	11,700	17,500	23,300	29,200
Autumn	3.41	4,300	8,500	12,800	17,000	21,300
Winter	1.19	1,500	3,000	4,500	6,000	7,400
Annual Total	14.01	17,500	35,000	52,500	69,900	87,400

¹Under normal rainfall conditions

- Requirements are for Orlando, Fla.
- Seasons are the months with the highest net irrigation requirement.
- Spring = May
- Summer = August
- Autumn = September
- Winter = November

Adapted from Augustin, 2000

Table 3: Monthly Net Irrigation Requirements for South Florida

Net Irrigation Requirement (Historical ET – Rainfall)						
	Volume (gallons) of Irrigation per Irrigated Area (square feet)					
Season	Maximum Application (inches) ¹	Irrigated Area (square feet)				
		2,000	4,000	6,000	8,000	10,000
Spring	4.12	5,100	10,300	15,400	20,500	25,700
Summer	4.06	5,100	10,100	15,200	20,200	25,300
Autumn	2.96	3,700	7,400	11,100	14,800	18,500
Winter	2.07	2,600	5,200	7,700	10,300	12,900
Annual Total	13.21	16,500	33,000	49,400	65,800	82,400

¹Under normal rainfall conditions

- Requirements are for Ft. Myers, Fla.
- Seasons are the months with the highest irrigation requirement.
- Spring = May
- Summer = August
- Autumn = November
- Winter = December

Adapted from Augustin, 2000