WaterSense® Specification for Soil Moisture-Based Irrigation Controllers Supporting Statement

I. Introduction

The U.S. Environmental Protection Agency's (EPA's) WaterSense program released its specification for soil moisture-based irrigation controllers, hereafter referred to as soil moisture sensors (SMSs), to further promote and enhance the market for water-efficient landscape irrigation products.

Residential outdoor water use in the United States accounts for nearly 8 billion gallons[1] of water each day, mainly for landscape irrigation. As much as half of this water is wasted due to evaporation, wind, or runoff often caused by improper irrigation system design, installation, maintenance, or scheduling. The most common method used to schedule irrigation is a manually programmed clock timer that irrigates for a specified amount of time on a preset schedule programmed by the user, often irrespective of landscape water needs. This specification is the culmination of EPA's research and coordination with industry since 2006 to develop performance criteria that can identify products that effectively tailor irrigation schedules to meet landscape water needs based on direct measurements of moisture in the soil. WaterSense labeled SMSs, along with other WaterSense labeled irrigation products, provide consumers with a variety of smart irrigation technology options that can reduce water waste outdoors and improve plant health.

A household with an in-ground irrigation system and average outdoor water use[2] could save more than 15,000 gallons of water per year by installing a WaterSense labeled SMS. Replacing all standard clock timers in residential irrigation systems across the United States with WaterSense labeled SMSs could save more than 390 billion gallons of water nationally each year.[3]

II. Current Status of Soil Moisture-Based Irrigation Controllers

WaterSense estimates there are approximately 28.8 million in-ground irrigation systems installed in residential landscapes across the United States.[4] Less than 10 percent[5] of those

[1] Based on average per capita water use from Dieter, et. al, 2018. *Estimated Use of Water in the United States in 2015*, U.S. Geological Survey Circular 1405. U.S. Department of Interior. Table 6, page 23. Average indoor per capita water use from DeOreo, Mayer, Dziegielewski, and Kiefer, 2016. Residential End Uses of Water, Version 2. Published by the Water Research Foundation. Page 112.
[2] Average outdoor water use per household is 50,500 gallons per year, according to Residential End Uses of Water, Version 2 (DeOreo, Mayer, Dziegielewski and Kiefer, 2016. Residential End Uses of Water, Version 2. Published by the Water Research Foundation. Table 6.32, Page 154.)
[3] Calculations for statistics included in this paragraph are included in Appendix A.
[4] Schein, Letschert, Chan, Chen, Dunham, Fuchs, McNeil, Melody, Stratton, and Williams, 2017. *Methodology for the National Water Savings and Spreadsheet: Indoor Residential and Commercial/Institutional Products, and Outdoor Residential Products*. Lawrence Berkeley National Laboratory. Schein et al. describes the detailed technical approach to WaterSense's stock accounting practice for irrigation products using values available as of the publication date. As it is EPA's practice to continuously update its work as data become available, the values referenced here are for the 2018 analysis, the most recent year available.
[5] Ibid.

systems are controlled by smart irrigation control technologies,[6] leaving a large portion of the market available for transformation.

As mentioned above, improper irrigation scheduling is a major cause of inefficient irrigation and water waste. In a majority of existing and newly installed irrigation systems, the irrigation schedule is controlled by a manual clock timer, where the responsibility of changing the irrigation schedule to meet landscape water needs lies with the end user or an irrigation professional. Clock-timer controllers can be a significant source of wasted water, because irrigation schedules are often set to water at the height of the growing season, and the home or building owner may not adjust the schedule to reflect seasonal changes, precipitation events or changes in plant watering needs. For example, plant water requirements decrease in the fall, but many home or building owners neglect to reset their irrigation schedules to reflect this change (see Figure 1). Therefore, an irrigation system could be watering in October as if it were July.

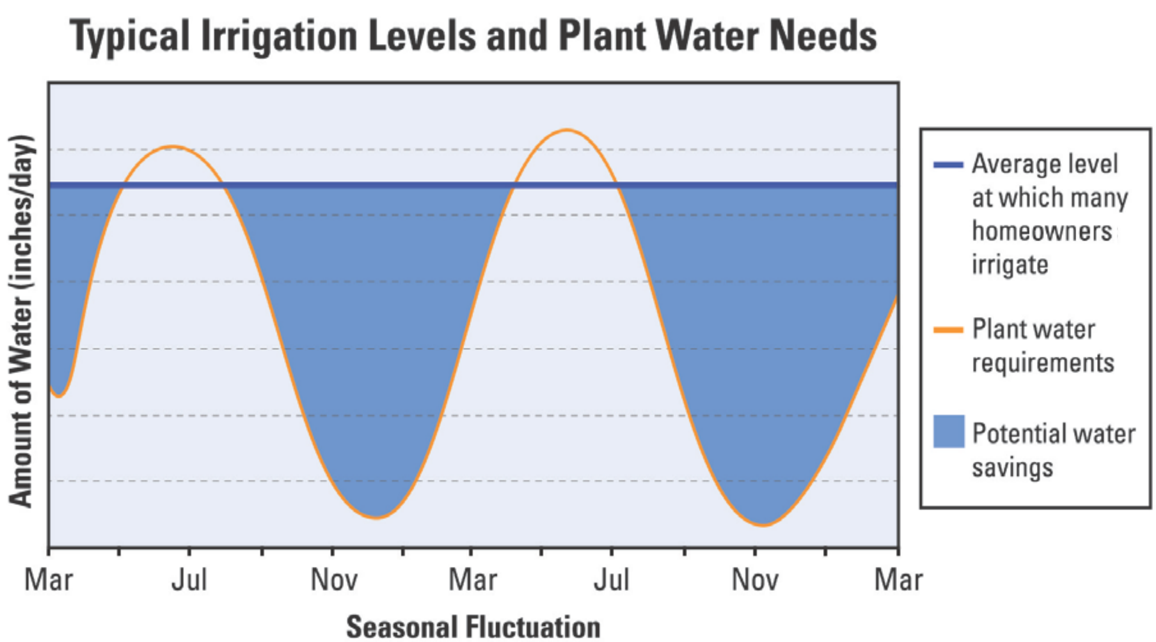

Figure 1. Potential Water Savings From Adjusting Irrigation Scheduling Based on Landscape Water Needs

As an alternative to clock-timer controllers, SMSs make irrigation schedule adjustments by inhibiting an irrigation event[7] based on a soil moisture reading taken in the landscape. This allows irrigation to occur only when plants require water. Not only does this schedule adjustment

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[6] Smart irrigation control technologies include those that dynamically alter irrigation schedules based on real-time weather or soil moisture data, including weather-based irrigation controllers and SMSs.

[7] "Irrigation event" is defined within American National Standards Institute (ANSI)/American Society of Agricultural and Biological Engineers (ASABE) S633 *Testing Protocol for Landscape Irrigation Soil Moisture-Based Control Technologies* as landscape watering beginning at a pre-determined start time(s) and run times(s) for one or more watering zones.

prevent irrigation from occurring after sufficient rain has fallen or if the soil is still saturated from a previous irrigation event, but SMSs also account for other environmental factors that impact soil moisture, such as seasonal variation of plant water needs, as well as decreased evaporation from the soil at the beginning and end of a growing season. By measuring soil moisture directly and adjusting the irrigation schedule accordingly, this control allows the irrigation applied to better follow the plant water requirement curve displayed in Figure 1. SMSs and weather-based irrigation controllers together create a suite of smart irrigation control technologies, and while they function differently, they meet the same goal of efficient irrigation scheduling and provide consumers with greater options for saving water in the landscape.

WaterSense has actively participated with industry and other stakeholders in the development of American National Standards Institute (ANSI)/American Society of Agricultural and Biological Engineers (ASABE) S633 *Testing Protocol for Landscape Irrigation Soil Moisture-Based Control Technologies.* This standard provides a test method for examining the performance of SMSs to enable or disable an irrigation event at preset or selected soil water values; in other words, it assesses an SMS's ability to sense moisture in the soil and inhibit an irrigation event when the moisture exceeds an established threshold.

While all SMSs included in the scope of the WaterSense specification enable or disable irrigation based on the soil moisture in the landscape, there are two main differences between products currently on the market. These technologies measure the soil moisture either directly (e.g., soil water content sensors) or indirectly (e.g., matric potential sensors), and they use either wired or wireless connection to the interface device. For detailed definitions of these technologies, please refer to ANSI/ASABE S633. The WaterSense specification accommodates all these variations.

III. *WaterSense Specification for Soil Moisture-Based Irrigation Controllers*

Scope

The specification addresses soil moisture-based irrigation controllers. It applies to products that enable or disable an irrigation event based on reading(s) from soil moisture sensor mechanism(s) (i.e., sensor mechanisms). The specification defines this product category as follows, based on the definitions of the applicable components included in the ANSI/ASABE S633 *Testing Protocol for Landscape Irrigation Soil Moisture-Based Control Technologies:*

- Soil moisture-based irrigation controller—a sensor mechanism and interface device that enables (allows) or disables (prevents/interrupts) an irrigation event at preset or selected soil water values. These products are commonly known as, and for the purpose of this specification shall be referred to as, soil moisture sensors (SMSs). [8]
- Sensor mechanism—the portion of the device that contacts the soil and measures physical properties that are related to the amount of moisture in the soil.
- Interface device—the portion of the device that either enables/disables irrigation events, and/or transmits soil water information to a control system for irrigation decision-making.

[8] More generally, SMSs are technologies that can detect the amount of moisture in the soil and override scheduled irrigation when a moisture threshold is met.

The interface device could be part of an irrigation controller or can be a separate component, either integrated into or separate from the sensor mechanism.

This specification applies to SMSs that are stand-alone controllers, as well as add-on or plug-in devices.

A stand-alone controller is an SMS in which the interface device is integrated into the controller. It includes a single controlling device (i.e., the irrigation controller) and the sensor mechanism(s) that provide the soil moisture data.

An add-on device is an SMS in which the interface device is separate from the controller (either a separate component or part of the sensor mechanism). It communicates the sensor mechanism readings to a base controller.[9] For purposes of this specification, add-on devices are defined as those that are designed to work with multiple brands of base controllers.

A plug-in device is an SMS in which the interface device is separate from the controller (either a separate component or part of the sensor mechanism). It communicates the sensor mechanism readings to a base controller. For purposes of this specification, plug-in devices are defined as those that are designed to work specifically with one brand of controller.

Add-on and plug-in devices are included in this specification because they comprise the majority of the SMS market. In addition, these devices, when paired with a base controller, are anticipated to be capable of meeting the criteria established in the specification.

In providing consistency with the scope and application of the test method to be included in ANSI/ASABE S633, this specification applies to SMSs for use in residential or commercial landscape irrigation applications. The specification does not apply to:

- On-demand SMSs, defined as technologies that initiate irrigation at a lower preset moisture level and terminate irrigation at an upper preset soil moisture level.
- Sensor mechanisms alone (i.e., sold without an interface device).
- SMSs intended for use exclusively within agricultural irrigation systems.

Performance Criteria

With the performance criteria for this product category, EPA aims to label SMSs that can perform their intended function. As indicated by field and plot studies[10], SMSs that can consistently inhibit irrigation events when a preset moisture level is achieved in the soil will save water.

The specification requires SMSs to be tested in accordance with the test method included in ANSI/ASABE S633. A replicate of three SMSs per manufacturer model shall each be tested at three water depletion levels (20 percent, 40 percent, and 60 percent) in engineered soil (i.e.,

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[9] A base controller is the irrigation controller with which the add-on or plug-in device communicates, through a wired or wireless connection, for full operation. Mostly commonly, a base controller is a standard clock-timer controller, but it may also be a weather-based controller that uses weather data as a basis for irrigation scheduling.

[10] Dukes. 2019. *Soil Moisture-Based Irrigation Controller Final Test Report*. University of Florida, Institute of Food and Agricultural Sciences, Agricultural and Biological Engineering Department.

media) to examine the SMS' response to changes in soil moisture conditions and ability to consistently enable and disable irrigation events at preset or selected soil water values.

To generate a set of performance data, the University of Florida tested four models of SMSs that comprise the majority of the market in accordance with the ANSI/ASABE S633 test method.[11] Three replicates of each model were tested in two soil media (representing sandy loam and clay loam) and two salinities (representing freshwater and reclaimed or saline water from other sources) at each of the three depletion levels (20, 40, and 60 percent), resulting in four combinations of test conditions per brand for a total of 16 test combinations. WaterSense used these test data to establish the performance criteria included in this specification. From the University of Florida study, WaterSense also identified several modifications that are aimed to simplify and clarify the test for the purpose of the specification.

The performance criteria (discussed in more detail below) included in the specification evaluate:

- **Function**—determines whether the SMS can enable and disable irrigation at all three water depletion levels.
- **Precision**—a measure of the variability between irrigation enable and disable readings from three replicate SMSs installed in the same soil media with the same moisture content. SMS precision is evaluated across the three water depletion levels. Low variability in the soil moisture readings among different SMSs across a variety of soil moisture levels ensures that the product can consistently disable an irrigation event at the same preset moisture threshold.
- **Response to change in soil moisture**—determines whether the SMS can sense a change in soil moisture when moisture levels change.
- **Function following freeze conditions**—evaluates whether the SMS functions after the sensor mechanism is frozen and thawed to ensure the SMS can operate in regions where landscapes freeze in the winter.

In addition, consistent with WaterSense's requirements for weather-based irrigation controllers, the specification requires SMSs (either stand-alone controllers or add-on and plug-in devices paired with a base controller) to be capable of providing supplemental features (e.g., the ability to accommodate watering restrictions) to promote greater long-term water savings.

To comply with the specification's performance requirements, SMSs shall be tested in accordance with the relevant sections of ANSI/ASABE S633, as modified in Section 2.1 of the specification, and shall meet the performance requirements outlined in Section 2.2 of the specification. SMSs shall be sampled and selected for testing in accordance with Section 5.1 of ANSI/ASABE S633 (i.e., each test shall consist of three SMSs per manufacturer model randomly selected from a lot of at least 10 items supplied by the manufacturer).

The subsections below describe the test method modifications and further explain the performance requirements outlined in the specification.

[11] Dukes. 2019. *Soil Moisture-Based Irrigation Controller Final Test Report*. University of Florida, Institute of Food and Agricultural Sciences, Agricultural and Biological Engineering Department.

Test Method Modifications

While EPA fully supports the test method included in ANSI/ASABE S633, the specification includes three modifications that are intended to clarify testing parameters and streamline the test procedures:

- **Power source:** As described in Appendix A of the WaterSense specification, add-on and plug-in devices shall be tested with a base controller specified by the manufacturer for the performance test. The ANSI/ASABE S633 standard does not specify how power shall be supplied to the product. However, the specification requires that these types of products be tested with a base controller to supply power. This addresses potential ambiguity of the power source and provides assurance that the add-on or plug-in devices, when communicating with a representative and compatible base controller, have the ability to meet the supplemental capability requirements included in Section 3.0 of the specification.

- **Engineered soil media and test water:** The ANSI/ASABE S633 test method requires testing within two test media (i.e. engineered soils): moderately coarse media (representing sandy loam), and moderately fine media (representing clay loam). It also requires testing in two salinities in each media: freshwater and saline water with an electrical conductivity of 3 deciSiemens/meter (dS/m) (representing reclaimed water or saline water from other sources). This combination of soils and water salinities results in testing under four scenarios at each of the three water depletion levels.

  EPA examined test data generated by the University of Florida (see Figure 2) and found that SMS performance was not statistically different depending upon the soil media composition (i.e., coarse vs. fine) or water salinity (i.e., freshwater vs. saline water).[12] Therefore, to reduce the number of tests (from 12 to four) and associated testing time and costs, the specification requires testing only in the moderately coarse media (representing sandy loam) with a salinity of 3 dS/m. EPA selected sandy loam because it is the more common soil type across the United States.[13] EPA selected saline water (3 dS/m) instead of freshwater because users in the past have expressed concern over product performance under saline conditions.

- **Freeze test conditions:** ANSI/ASABE S633 requires the freeze test to be conducted on a specific depletion level, soil medium and salinity. Because of the test modifications, the WaterSense specification requires the freeze test to be conducted on the 40 percent water depletion container using the moderately coarse media after the initial test is complete. This avoids testing in a new set of soil conditions solely for

[12] The p-value between coarse and fine media was 0.50 and the p-value between freshwater and saline water (i.e., test water) was 0.42. Based on comments received on the draft specification, EPA compared several combinations of test results via additional t-tests. No p-values were less than 0.05, indicating no statistical difference between soil or salinity results. For detailed statistical results, see the *Response to Public Comments Received on the WaterSense Draft Specification for Soil Moisture-Based Irrigation Control Technologies.*

[13] Rodell. 3.3 NCA-LDAS, 2019: NLDAS Soil Texture Types Dataset. NASA/GSFC, Greenbelt, Maryland, NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) Accessed: 25 July 2019 at https://ldas.gsfc.nasa.gov/nldas/soils.

the purpose of the freeze test, which would otherwise add undue burden and cost to the performance testing. As indicated in the University of Florida performance testing,[14] neither media type nor salinity (added via water) had an impact on results, so selecting this combination should provide representative results for the freeze test.

Performance Criteria

To comply with WaterSense performance criteria, the specification requires SMSs to be tested in accordance with ANSI/ASABE S633, as modified in Section 2.1 of the specification (as described above) and meet the requirements related to the following:

1. **Function**: Each SMS evaluated shall enable and disable irrigation at each of the three depletion levels.

   This criterion ensures a baseline level of function. Each SMS must be capable of enabling and disabling irrigation around a soil moisture threshold, as part of the performance test described in Section 6 of the ANSI/ASABE S633 standard. If any of the replicate SMSs do not meet this criterion under any of the test conditions, the test shall be stopped, and the products do not pass.

2. **Precision**: The relative average deviation (RAD) of the readings at which the replicate SMSs enable and disable irrigation, when averaged across all three water depletion levels, shall be less than or equal to 10 percent.

   Because the products are installed and calibrated in the field to enable and disable irrigation around a threshold moisture level set by the user, precision—not accuracy—determines whether the products perform and will save water. Therefore, EPA is specifying RAD as a performance metric, which assesses whether the three sensors are precise in their irrigation enable/disable readings under each set of conditions (i.e., combination of soil and salinity at each depletion level). SMSs with a small RAD have high precision and can consistently disable an irrigation event across a variety of conditions at the same preset moisture threshold. The RAD also provides a percentage based on the average deviation and mean of the readings to normalize the performance metric regardless of the specific scale a particular brand might use. This allows the precision metric to be compared among products and to a uniform threshold requirement.

   RAD is calculated according to the following equations:

$$\text{Equation (1)} \quad Average\ Deviation_x = \frac{[|\bar{x}-x_1|+|\bar{x}-x_2|+|\bar{x}-x_3|]}{3}$$

Where: $Average\ Deviation_x$ is the average of the absolute value of the deviation for enable readings at a given depletion level (20, 40, or 60 percent) and disable readings at a given depletion level (20, 40, or 60

[14] Dukes. 2019. *Soil Moisture-Based Irrigation Controller Final Test Report*. University of Florida, Institute of Food and Agricultural Sciences, Agricultural and Biological Engineering Department.

percent). In total, there are six average deviations calculated.

$$\bar{x} = \frac{(x_1 + x_2 + x_3)}{3}$$

x_1 is the first observation
x_2 is the second observation
x_3 is the third observation

Equation (2) $RAD_x = \frac{Average\ \ Deviation_x}{\bar{x}}$

Where: RAD_x is the relative average deviation for the enable readings at a given depletion level (20, 40, or 60 percent) and disable readings at a given depletion level (20, 40, or 60 percent). In total, there are six RADs calculated.

$Average\ \ Deviation_x$ is taken from Equation 1 for the given enable or disable reading and given depletion level.

$$\bar{x} = \frac{(x_1 + x_2 + x_3)}{3}$$

x_1 is the first observation
x_2 is the second observation
x_3 is the third observation

Equation (3) $RAD_{avg} = \frac{RAD_{en20}+RAD_{en40}+RAD_{en60}+ RAD_{dis20}+RAD_{dis40}+RAD_{dis60}}{6}$

Where: RAD_x is taken from Equation 2 RAD_x results, as follows:

RAD_{en20} is the RAD for enable readings at 20 percent water depletion
RAD_{en40} is the RAD for enable readings at 40 percent water depletion
RAD_{en60} is the RAD for enable readings at 60 percent water depletion
RAD_{dis20} is the RAD for disable readings at 20 percent water depletion
RAD_{dis40} is the RAD for disable readings at 40 percent water depletion
RAD_{dis60} is the RAD for disable readings at 60 percent water depletion

EPA selected an average RAD of less than 10 percent (RADs averaged across irrigation enable and disable readings and across all three water depletion levels) to reflect the range of product performance from the University of Florida study.[15] Figure 2 shows the average RAD across all depletion levels and irrigation enable and disable readings for the four models of SMSs tested by the University of Florida. This figure displays the entire suite of tests conducted (i.e., two soil media and two salinities), but identifies the one set of conditions selected by EPA for this specification. EPA notes that one product did not pass the initial irrigation enable/disable test, as it was not capable of disabling irrigation and was therefore not carried through the suite of performance tests.

While Figure 2 demonstrates that there was a range of RADs observed in the University of Florida performance testing, field and plot studies that assessed water savings for each of the three models that functioned properly indicate water savings of at least 30 percent.[16] Therefore, the WaterSense specification's performance criterion threshold is set to be inclusive of the products that functioned properly in the University of Florida performance testing.

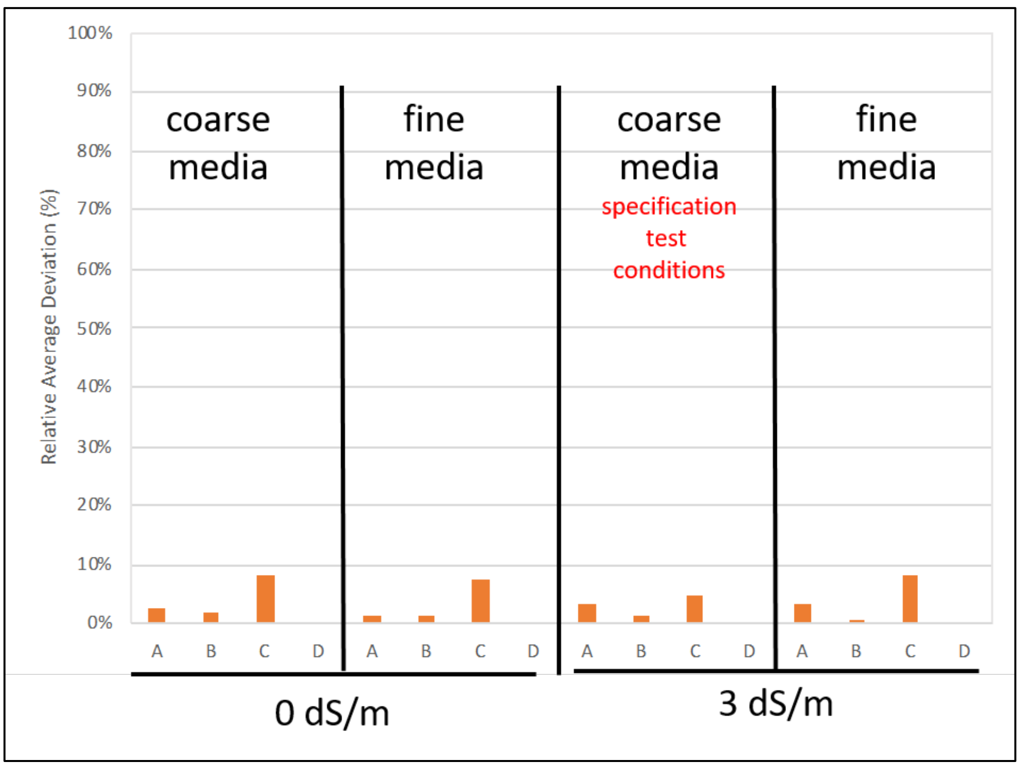

Figure 2. RAD for Four Brands Included in the University of Florida Performance Tests
(averaged across irrigation enable and irrigation disable readings and across depletion levels)

[15] Dukes. 2019. *Soil Moisture-Based Irrigation Controller Final Test Report*. University of Florida, Institute of Food and Agricultural and Biological Engineering Department.
[16] Cardenas and Dukes, Part I, 2016; Cardenas and Dukes, Part II, 2016; Dukes, 2019; The Metropolitan Council, 2019; Torbert et al., 2016; Nautiyal et al., 2014; Grabow et al., 2013; Haley and Dukes, 2012; Cardenas-Lailhacar et al. 2010; Cardenas-Lailhacar and Dukes, 2010.

3. **Response to change in soil moisture**: The absolute value of the slope across three depletion levels of the line generated using a least square regression plot of irrigation *enable* readings (expressed as a percent of full scale) for each replicate shall be greater than zero when rounded to two significant digits (i.e., ≥ 0.01). In addition, the absolute value of the slope across three depletion levels of the line generated using a least square regression plot of irrigation *disable* readings (expressed as a percent of full scale) for each replicate shall be greater than zero when rounded to two significant digits (i.e., ≥ 0.01).

   This criterion ensures the SMS' ability to respond to a change in soil moisture. Figure 3 shows an example test result for one model of SMS tested in one soil medium, and one salinity for irrigation enable readings at all three depletion levels. The y-axis represents the SMS reading for irrigation enable, and the x-axis represents depletion level (one container for each depletion level at 20, 40, and 60 percent). The three data points at each depletion level indicate the irrigation enable readings of the three replicate sensors in that container. This particular example indicates that the sensor reading decreases as depletion increases (i.e., as the moisture level in the soil decreases). Note that it is possible for a product to have a positive or negative slope as depletion levels increase, depending on the technology (soil water potential vs. soil water content, as defined in ANSI/ASABE S633) and how the SMS reports its reading. Therefore, the WaterSense specification requires that the absolute value of the slope must be greater than zero. A slope of zero would indicate that the product did not adjust its sensor readings when it was tested in soils with decreased moisture, and that would result in a horizontal line when the readings are plotted on a graph. These products could still be precise in their readings, but might not adequately adjust their readings when the soil moisture changes. This could affect the point at which the product actually enables/disables irrigation, depending on the soil moisture content.

   The University of Florida test results showed that the absolute values of the slopes of the tested products ranged from 0.04 to 0.26. Field and plot studies indicate achievable water savings greater than 30 percent associated with several products that underwent the testing.[17] Therefore, EPA has determined that, where the absolute value of the slope is greater than zero in the laboratory test, products should be able to provide water savings in the field.

[17] Cardenas and Dukes, Part I, 2016; Cardenas and Dukes, Part II, 2016; Dukes, 2019; The Metropolitan Council, 2019; Torbert et al., 2016; Nautiyal et al., 2014; Grabow et al., 2013; Haley and Dukes, 2012; Cardenas-Lailhacar et al. 2010; Cardenas-Lailhacar and Dukes, 2010.

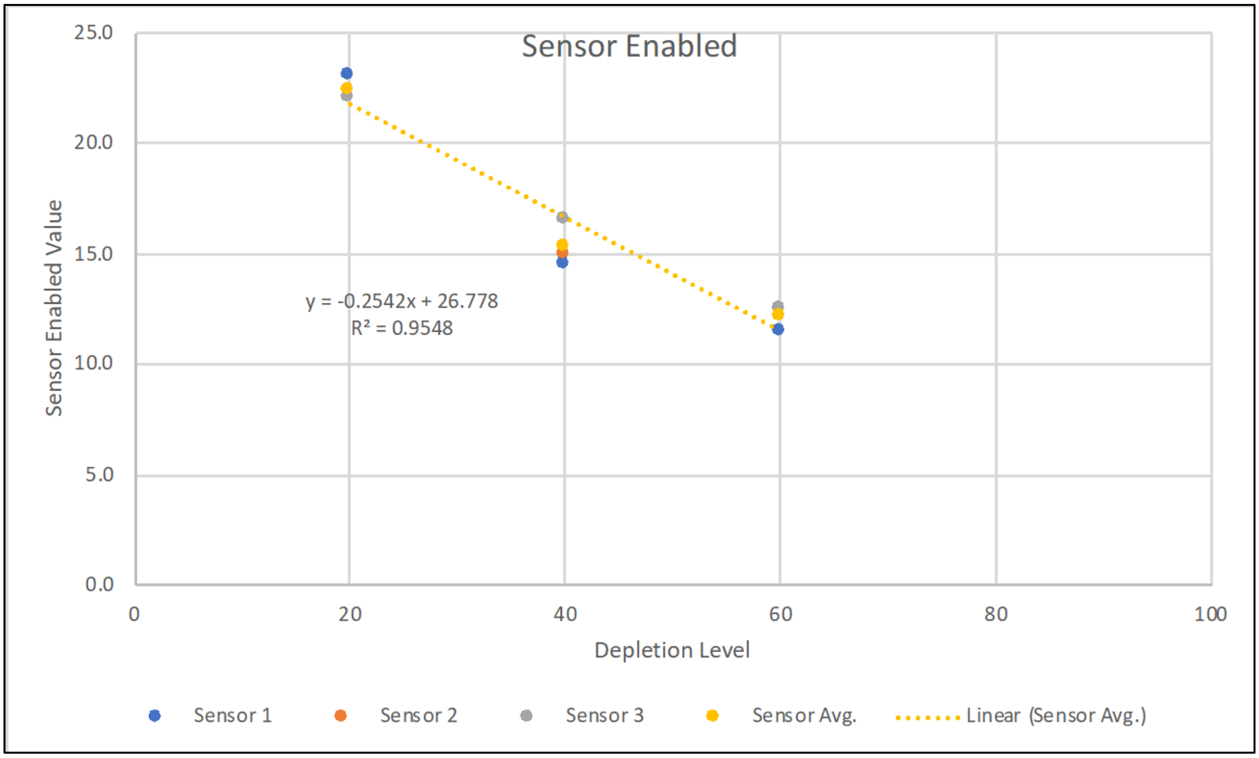

Figure 3. Sample Test Data Demonstrating a Sloped Line in Response to Changes in Water Depletion Level (Slope = -0.2542)

4. **Function following freeze conditions:** Each SMS evaluated shall enable and disable irrigation after the sensor mechanism is placed in a freezer for three days and thawed to pre-freeze temperature.

   EPA included testing functionality of each SMS after the freeze test to ensure the products function after one freeze-thaw cycle, as specified in Section 7.2 of ANSI/ASABE S633 (with the specification's required modification to test in the 40 percent water depletion container using the moderately coarse medium after the initial test is complete). The WaterSense specification requires that the products continue to enable/disable irrigation after the freeze test. It is not specifying that products meet a specific RAD threshold. Products are recommended to be reconditioned every field season; therefore, measuring RAD directly after a freeze would not necessarily translate to actual field conditions.

Supplemental Capability Requirements

To ensure high performing SMSs and to remain consistent with the *WaterSense Specification for Weather-Based Irrigation Controllers*, this specification includes supplemental capability requirements for SMSs. The list of supplemental capability requirements was initially developed for the *WaterSense Specification for Weather-Based Irrigation Controllers* at the request of water utility stakeholders who indicated that weather-based controllers should have certain features (in addition to meeting performance criteria) to promote greater long-term water savings. EPA developed the list of supplemental capability requirements that are currently included in Section 4.0 of the *WaterSense Specification for Weather-Based Irrigation Controllers* in coordination with a working group consisting of utility and manufacturer representatives. In 2019, EPA reviewed the *WaterSense Specification for Weather-Based Irrigation Controllers* for possible revision and, as part of that process, gathered public comments on that specification. Stakeholders were generally very positive about the supplemental capability requirements and did not request any changes.

Though weather-based irrigation controllers and SMSs function differently, both product types aim to address irrigation scheduling inefficiencies. As such, EPA is promoting the products together as "WaterSense labeled irrigation controllers." Therefore, EPA has retained all the supplemental features, as appropriate for SMSs, to ensure an equal level of performance for this product category.

Specifically, stand-alone SMSs and add-on or plug-in devices paired with a compatible base controller (as described in Appendix A of the WaterSense specification) shall meet the following requirements in both soil moisture mode and standard mode:

- Be capable of preserving the contents of the programmed irrigation settings and sensor mechanism settings when the power source is lost and without relying on an external battery backup. This ensures that information regarding the irrigation program and settings are retained when the power source is lost, and no backup battery is available.

- Be capable of independent, zone-specific programming to successfully manage landscapes that have multiple areas with various watering requirements that need to be managed separately.

- Be capable of indicating to the user when it is not receiving sensor mechanism input and is not adjusting irrigation based on soil moisture content in the landscape (e.g., if there is a problem with the sensor mechanism that is prohibiting it from enabling or disabling irrigation).

- Be capable of interfacing with a rainfall device. Rainfall devices are an important component of an efficient irrigation system in many climate regions. Multiple states have mandated the inclusion of these devices by law. However, if a rainfall device and soil moisture sensor are both connected to the same port, the devices must be wired in series so that either device may interrupt or bypass scheduled irrigation events. If incorrectly connected in parallel, both devices must disable irrigation for an irrigation event to be bypassed.

- Be capable of accommodating watering restrictions. With the existence of utility-imposed watering restrictions, it is important that SMSs, along with their base controllers, if applicable, are capable of watering efficiently, while complying with these restrictions.

- Include a percent adjust (water budget) feature. This feature allows end users to adjust water applied to the landscape without changing the detailed settings in the controller's program.

- Be capable of reverting to a conservative watering schedule (i.e., percent adjust or water budget feature) if the interface device loses input from the sensor mechanism.

- Be capable of automatically returning to soil-moisture mode after a manual troubleshooting test cycle is run. Often products are turned to manual mode for troubleshooting or other reasons and not returned to soil-moisture mode. This requirement ensures the product will automatically return to soil-moisture mode within a specified time period as designated by the manufacturer.

It is important to note that, for add-on and plug-in devices, the majority of these requirements are likely features of the base controller with which the SMS device will communicate. Since most of the products currently on the market are add-on devices, EPA has determined that it is critical to require manufacturers to identify compatible base controllers that the SMS can be paired with to meet the supplemental requirements. As described in Appendix A of the specification and further explained in Section IV of this supporting statement, the specification does not require that a WaterSense labeled add-on or plug-in device be tested with every compatible base controller.

Packaging and Product Documentation Requirements

To ensure that SMSs, as sold, have the capability to provide water efficiency and performance, EPA is specifying packaging and product documentation requirements as part of the criteria for products to earn the WaterSense label.

Like the requirements for weather-based irrigation controllers, stand-alone SMS controllers shall not be packaged or marked to encourage operation of the controller in non-soil-moisture mode (i.e., standard mode). Any instruction related to the maintenance of the product shall direct the user on how to return the controller to soil-moisture mode. The intent of this requirement is to encourage and ensure the use of the controller in soil-moisture mode.

Add-on and plug-in devices shall not be required to be packaged with the base controller(s) with which they were tested or have been determined compatible, as specified in Appendix A of the specification. However, the product documentation (e.g., product packaging, user manual, website, specification sheet) for add-on and plug-in devices shall list (or provide access to a list of) each compatible base controller model. The documentation shall also contain a statement to the effect that the device is only WaterSense labeled when used in combination with a base controller on the provided compatibility list. This requirement ensures all supplemental capability requirements are met when the two products (add-on or plug-in device and base controller) are working together.

IV. Testing Configuration and Compatible Base Controller Determination for Add-on and Plug-in Devices

The WaterSense specification requires that the manufacturer specify a single base controller model with which an add-on or plug in device shall be tested. Together, the unit shall be capable of meeting the requirements of the specification, including the supplemental capability requirements specified in Section 3.0. This requirement allows for the specification of a power source, as well as consistency with the weather-based irrigation controller specification and serves as the basis for determining base controller compatibility, which allows for the retention of all supplemental capability requirements.

If desired, the manufacturer can work with their licensed certifying body (LCB) to specify and list additional base controller models with which the add-on or plug-in device is compatible if, together as a unit, the add-on or plug-in device and base controller meet the requirements of the specification, including the supplemental capability requirements specified in Section 3.0 of the specification.

It is at the discretion of the LCB to determine whether the add-on or plug-in device is required to be tested with any additional base controllers the manufacturer wishes to specify and list in product documentation as compatible. Similar to weather-based irrigation controllers, EPA maintains a list of compatible base controllers for each add-on or plug-in device on its WaterSense labeled product registry. This information helps purchasers and utilities offering labeled product rebates ensure that the specific combination of an add-on or plug-in device and base controller will provide the expected water savings and long-term performance. For more information, manufacturers can review the *Supplemental Guidance for WaterSense Certification and Labeling of Irrigation Controllers* and the *WaterSense Product Certification System*.

V. Certification and Labeling

EPA has established an independent product certification process, described in the *WaterSense Product Certification System*. Under this process, products are certified to meet or exceed applicable WaterSense specifications by accredited LCBs. Manufacturers are authorized by LCBs to use the WaterSense label in conjunction with certified products. To aid irrigation controller manufacturers in the certification and labeling of their products, EPA also developed the *Supplemental Guidance for WaterSense Certification and Labeling of Irrigation Controllers.*

For add-on and plug-in devices, only the devices certified to meet the requirements of this specification may bear the WaterSense label. Base controllers with which the add-on or plug-in devices are tested and/or determined to be compatible shall not bear the WaterSense label on their own. Product documentation shall indicate that the add-on or plug-in device is only WaterSense labeled when used in combination with the base controller(s) listed in product documentation, as described in Section 4.0 of the specification.

Base controllers that are tested, or determined to be compatible, with an add-on or plug-in device may bear the WaterSense promotional label and include language similar to “Look for the WaterSense labeled [plug-in or add-on device] to improve the water efficiency capabilities of this controller.” This requirement aims to avoid base controllers from baring the WaterSense label and confusing consumers.

Products (i.e., stand-alone controllers, plug-in and add-on devices) that are packaged and sold as a single unit and integrate soil moisture-based scheduling (i.e., an allowance or prevention of an irrigation event based on a reading(s) from a soil moisture mechanism) and weather-based scheduling (i.e., the use of current weather data as the basis for scheduling irrigation) shall be certified to meet the requirements of the *WaterSense Specification for Soil Moisture-Based Irrigation Controllers* and the *WaterSense Specification for Weather-Based Irrigation Controllers* in order for the product to bear the WaterSense label.

VI. Other Issues

SMSs have been demonstrated to save significant amounts of water, upwards of 60 percent in certain applications.[18] However, there are numerous outside factors that must be considered and addressed in order to achieve the intended savings. First, it is important to acknowledge that the SMS is part of the irrigation system and can only perform as intended if the system is properly designed, installed, and maintained. Second, the controller must be programmed properly. Third, the end user must monitor water use after SMS installation to determine whether settings are appropriate or if they can be changed to decrease the amount of irrigation applied, while still maintaining a healthy landscape.

WaterSense plans to address these issues with marketing and outreach to stakeholders, including a national network of irrigation professionals certified through WaterSense labeled programs. Marketing and outreach strategies will be used to help consumers and utilities make informed purchasing decisions and necessary irrigation system improvements before installing these technologies. EPA also recommends that purchasers of these products use the services of irrigation professionals who have been certified through a WaterSense labeled program that focuses on water-efficient techniques and technologies.

VII. Potential Water Savings and Cost-Effectiveness

Note: Appendix A of this supporting statement provides the assumptions and calculations used to derive these estimates.

Potential Water Savings

SMSs have the potential to save significant amounts of water. WaterSense estimates that 90 percent of the approximate 28.8 million irrigation systems installed in the United States are controlled by standard, inefficient clock-timer controllers and are candidates for replacement with smart irrigation control technologies. EPA estimates that the average household with an in-ground irrigation system and average-sized residential landscape could save more than 15,000 gallons of water per year by installing WaterSense labeled SMSs. WaterSense estimates that installing labeled SMSs in residential landscapes across the United States could save more than 390 billion gallons of water and more than $4.5 billion in water supply and wastewater costs annually.

Cost-Effectiveness

For the purposes of cost savings estimates, EPA has determined cost-effectiveness in two ways. First, for a full replacement of an existing clock-timer controller or installation as part of a new irrigation system, EPA assumes that the purchase of an SMS consists of either 1) a sensor mechanism and an irrigation controller for stand-alone products; or 2) in the case of plug-in or add-on devices, one sensor mechanism, an associated interface device, and a compatible base controller. Second, EPA determined the cost-effectiveness for an upgrade of an existing clock-

[18] Cardenas and Dukes, Part I, 2016; Cardenas and Dukes, Part II, 2016; Dukes, 2019; The Metropolitan Council, 2019; Torbert et al., 2016; Nautiyal et al., 2014; Grabow et al., 2013; Haley and Dukes, 2012; Cardenas-Lilhacar et al. 2010; Cardenas-Lilhacar and Dukes, 2010.

timer controller, as WaterSense recognizes that add-on or plug-in devices might communicate with an existing clock-timer controller as an upgrade.

EPA reviewed the retail prices of SMSs in the marketplace and found the average cost for full replacement or new installations (i.e., stand-alone controllers or add-on and plug-in SMSs plus a base controller) to be approximately $250. EPA determined the cost of add-on or plug-in devices only (in the case of upgrading an existing clock-timer controller) to be approximately $180. EPA limited its evaluation of retail prices to SMSs appropriate for residential or light commercial landscapes, as this corresponds with the assumptions made for its water savings estimates.

Installing an SMS in conjunction with a residential landscape could save more than $170 annually for the average irrigation system, with a payback period of 1.5 years for full replacement or new systems, or 1.1 years if upgrading an existing clock-timer controller.

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Appendix A: Calculations and Key Assumptions

Potential Water Savings Calculations

Assumptions:

- 28.82 million detached single-family homes have automatic irrigation systems.[19]
- 90 percent of the 28.82 million irrigation systems are candidates for installation of SMSs.[20]
- Average outdoor water use per household is 50,500 gallons per year.[21]
- WaterSense has gathered the best available data regarding water savings from SMSs in field or plot studies, including numerous studies that include SMS brands currently on the market. Results from these studies indicate a range of water savings from 30 to 83 percent, with an average of 49 percent (weighted by the number of landscapes or plots from the studies).[22] Individual site savings can vary beyond these overall numbers, depending on the watering habits prior to installing the SMS and local climate. For example, the majority of these savings studies took place in Florida, where rainfall is frequent, providing the opportunity for significant water savings. Further, several of the studies were conducted in controlled plot conditions, and likely inflate water savings higher than what can be expected in the field. In full consideration of the findings of these numerous studies, WaterSense estimates that customers will see overall water savings of at least 30 percent after installing SMSs.
- The cost of water for irrigation is $11.48 per 1,000 gallons.[23] This rate includes the costs of both water supply and wastewater treatment. It is possible, although uncommon, that a homeowner could be billed separately for these utility service connections and would only incur the costs for water used for irrigation.

Equation 1. Annual Individual Irrigation Water Savings From Installing a WaterSense Labeled SMS

(50,500 gallons/year) x (30 percent savings factor) = 15,150 gallons/year

Equation 2. Candidates for Installation of WaterSense Labeled SMSs

(28,820,000 irrigation systems) x (90 percent candidates for installation) = 25,900,000 irrigation systems

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[19] Schein, Letschert, Chan, Chen, Dunham, Fuchs, McNeil, Melody, Stratton, and Williams, 2017. *Methodology for the National Water Savings and Spreadsheet: Indoor Residential and Commercial/Institutional Products, and Outdoor Residential Products*. Lawrence Berkeley National Laboratory. Table A-4. Schein et al. describes the detailed technical approach to WaterSense's stock accounting practice for irrigation products using values available as of the publication date. As it is EPA's practice to continuously update its work as data become available, the values referenced here are for the 2018 analysis, the most recent year available.

[20] Ibid.

[21] DeOreo, Mayer, Dziegielewski, and Kiefer, 2016. Residential End Uses of Water, Version 2. Published by the Water Research Foundation. Table 6.32, Page 154.

[22] Cardenas and Dukes, Part I, 2016; Cardenas and Dukes, Part II, 2016; Dukes, 2019; The Metropolitan Council, 2019; Torbert et al., 2016; Nautiyal et al., 2014; Grabow et al., 2013; Haley and Dukes, 2012; Cardenas-Lilhacar et al. 2010; Cardenas-Lilhacar and Dukes, 2010.

[23] WaterSense estimate for 2019 based on Raftelis Financial Consulting. Water and Wastewater Rate Survey. American Water Works Association, 2016. WaterSense adjusted rate data using the Gross Domestic Product (GDP) deflator for water from the U.S. Department of Commerce Bureau of Economic Analysis.

Equation 3. Annual National Water Savings From Installing WaterSense Labeled SMSs
(25,900,000 candidate irrigation systems) x (15,150 gallons/year) = 393 billion gallons/year

Equation 4. Annual National Cost Savings From Installing WaterSense Labeled SMSs
(393 billion gallons/year) x ($11.48/1,000 gallons) = $4.5 billion

Cost-Effectiveness Calculations

Assumptions:

- $253 is the average retail price for an SMS when installed as a full replacement of a clock-timer controller or installed in a new irrigation system (either a stand-alone SMS controller or an add-on or plug-in device plus a base controller).[24]
- $183 is the average retail price for an SMS upgrade to an existing clock-timer controller (an add-on or plug-in device only).[25]

Equation 6. Estimated Annual Water Cost Savings From Installing an SMS
(15,150 gallons per year) x ($11.48/1,000 gallons) = $174 savings per year

Equation 7. Estimated Payback Period for the Average Cost of an SMS (full replacement or new installation)
($253 product cost ÷ $174 savings per year) = 1.5 years

Equation 8. Estimated Payback Period for the Average Cost of a SMS (upgrade)
($183 product cost ÷ $174 savings per year) = 1.1 years

[24] Market research based on residential or light commercial models available at the time the specification was released. This includes the price of a stand-alone controller, or for add-on or plug-in devices, the additional cost of a typical base controller for use in residential irrigation systems.
[25] Market research based on residential or light commercial models available at the time the specification was released. This includes the price of an add-on or plug-in device only.