WaterSense® Draft Specification for Soil Moisture-Based Irrigation Control Technologies Supporting Statement

I. Introduction

The U.S. Environmental Protection Agency's (EPA's) WaterSense program released its draft specification for soil moisture-based irrigation control technologies, 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 draft specification is the culmination of the EPA's research and coordination with industry since 2006 to develop performance criteria that can effectively identify products that effectively tailor irrigation schedules to meet landscape water needs based on direct measurements of moisture in the soil. Once labeled, SMSs, along with other WaterSense labeled irrigation products, will 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[2] use 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.

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.[3] Less than 10 percent[4] 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 the 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] Schein, Letschert, Chan, Chen, Dunham, Fuchs, McNeil, Melody, Strattron, and Williams. 2017. Methodology for the National Water Savings and Spreadsheet: Indoor Residential and Commercial/Institutional Products, and Outdoor Residential Products. Lawrence Berkley 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 the 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.
[4] Ibid.

systems are controlled by smart irrigation control technologies,[5] 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.

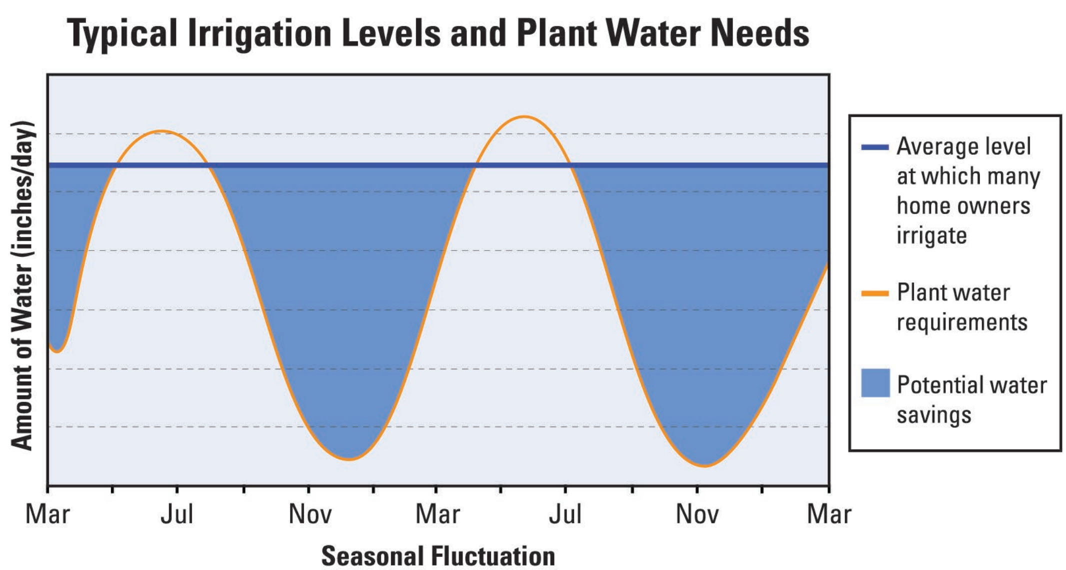

Figure 1. Potential Water Savings From Adjusting Irrigation Scheduling Based on Landscape Water Needs

As an alternative to clock-timer controllers, SMSs make irrigation schedule adjustments by inhibiting an irrigation event 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 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

[5] 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.

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 the recently published American Society for Agricultural and Biological Engineers (ASABE) draft standard ASABE X633 *Testing Protocol for Landscape 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. The draft standard forms the basis for the testing requirements included in this draft specification. WaterSense intends to reference the standard in its final specification once the final standard is published, anticipated in early 2020.

While all SMSs enable or disable irrigation based on the soil moisture in the landscape, there are two main differences between products currently on the market. The first difference relates to the technology used by an SMS to detect soil moisture. Some SMSs use soil water *content* to detect soil moisture. These technologies measure a property of the soil (e.g., electrical) that is related to soil water content. Alternatively, some SMSs detect soil water *potential*, indirectly measuring soil moisture. For detailed definitions of these two technologies, please refer to the *ASABE X633* draft standard. The second difference relates to the SMS's connection to the interface device. SMSs can either be wired to the interface device or wirelessly communicate with the interface device.

III. WaterSense Draft Specification for Soil-Moisture Based Irrigation Control Technologies

Scope

This draft specification addresses soil moisture-based irrigation control technologies. 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 EPA is defining this product category as follows, based on the definitions of the applicable components included in the ASABE X633 *Testing Protocol for Landscape Soil Moisture-Based Control Technologies* (currently in draft form):[6]

- Soil moisture-based irrigation control technology—a sensor mechanism and interface device that enables or disables 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).
- Sensor mechanism—the portion of the device that contacts the soil and measures physical properties that are related to water content or potential.

[6] WaterSense intends to require soil moisture-based irrigation technologies to be tested in accordance with ASABE X633 *Testing Protocol for Landscape Soil Moisture-Based Control Technologies* upon the standard's final publication. That standard is currently undergoing public comment and final review.

- 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. 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 draft 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 (typically a standard clock-timer controller). 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 (typically a standard clock-timer 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 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 *ASABE X633*, this specification is intended to apply to SMSs for use in residential or commercial landscape irrigation applications. The specification does not apply to:

- On-demand SMSs, defined as technologies that enable irrigation at a lower preset soil moisture level and disable 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, the EPA aims to label SMSs that can perform their intended function. As indicated by field and plot studies[7], SMSs that can consistently inhibit irrigation events when a preset moisture level is achieved in the soil save water.

[7] 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.

The EPA intends to require SMSs to be tested in accordance with the test method included in *ASABE X633,* upon its release. As currently drafted, a replicate of three SMSs per manufacturer model are each tested at three water depletion levels (20 percent, 40 percent and 60 percent) in engineered soil (i.e., media) to examine the SMS's 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 draft *ASABE X633* test method.[8] Three replicates of each brand were tested in two soil media and two salinities at each of the three depletion levels, 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 draft 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 are intended to evaluate:

- **Function**—determines whether the SMS has the ability to enable and disable irrigation at all three 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 EPA intends to require 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 EPA's performance requirements, SMSs shall be tested in accordance with the relevant sections of *ASABE X633*, as modified in Section 2.1 of the draft specification, and shall meet the performance requirements outlined in Section 2.2 of the draft specification. SMSs shall be sampled and selected for testing in accordance with Section 5.1 of *ASABE X633* (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).

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

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

Test Method Modifications

While the EPA fully supports the test method included in *ASABE X633*, the draft 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 draft specification, add-on and plug-in devices shall be connected to a base controller specified by the manufacturer for the performance test. The draft *ASABE X633* standard does not currently specify how power shall be supplied to the product. However, the EPA is specifying that these types of products shall be connected to a base controller to supply power. This addresses potential ambiguity of the power source and also provides assurance that the add-on or plug-in devices, when connected to a representative and compatible base controller, have the ability to meet the supplemental capability requirements included in Section 3.0 of the draft specification.

- **Engineered soil media and test water:** The *ASABE X633* test method, as currently drafted, 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 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.

  The 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., course vs. fine) or water salinity (i.e., freshwater vs. saline water).[9] Therefore, to reduce the number of tests (from 12 to four) and associated testing time and costs, the EPA intends to require testing only in the moderately coarse media (representing sandy loam) with a salinity of 3 dS/m. The EPA selected sandy loam because it is the more common soil type across the United States.[10] The 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:** *ASABE X633* requires the freeze test to be conducted on a specific depletion level, soil medium and salinity. However, the conditions are different from the modified test conditions WaterSense is specifying for the

[9] The p-value between course and fine media was 0.50 and the p-value between freshwater and saline water (i.e., test water) was 0.42. P-values can be used to determine whether one group of data are statistically different from another group of data. Typically, p-values exceeding 0.05 indicate there is no statistical difference between the two groups of data.
[10] Rodell. 3.3 NCA-LDAS, 2019: NLDAS Soil Texture Types Dataset. NASA/GSFC, Greenbelt, MD, USA, NASA Goddard Earth Sciences Data and Information Services Center (GES DISC) Accessed: 25 July 2019 at https://ldas.gsfc.nasa.gov/nldas/soils

performance test. Therefore, the freeze test shall 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 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,[11] 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 draft performance criteria, the EPA intends for SMSs to be tested in accordance with *ASABE X633*, as modified in Section 2.1 of the draft specification (modifications are described above) and meet the following four requirements:

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 as described in Section 6 of the draft *ASABE X633* 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, the 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 Equations 1 and 2 below.

   Equation (1) $$RAD = \frac{Average\ Deviation}{\bar{x}}$$

   Where: $\bar{x}$ is the mean

[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.

Equation (2) $$Average\ Deviation = \frac{\sum_{i=1}^{n}|\bar{x}-x_i|}{n}$$

Where: $\bar{x}$ is the mean
x_i is the observation
n is the number of observations

The EPA selected an average RAD of less than 10 percent (RADs averaged across irrigation enable and disable readings and across all three depletion levels) to reflect the range of product performance from the University of Florida study.[12] 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 graph displays the entire suite of tests conducted (i.e., two soil media and two salinities), but identifies the one set of conditions selected by the EPA for this specification. The EPA notes that one product did not pass the initial irrigation enable/disable test.

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.[13] Therefore, WaterSense is proposing in the draft specification a performance criterion threshold that includes all products that functioned properly in the University of Florida performance testing.

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

[13] 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.

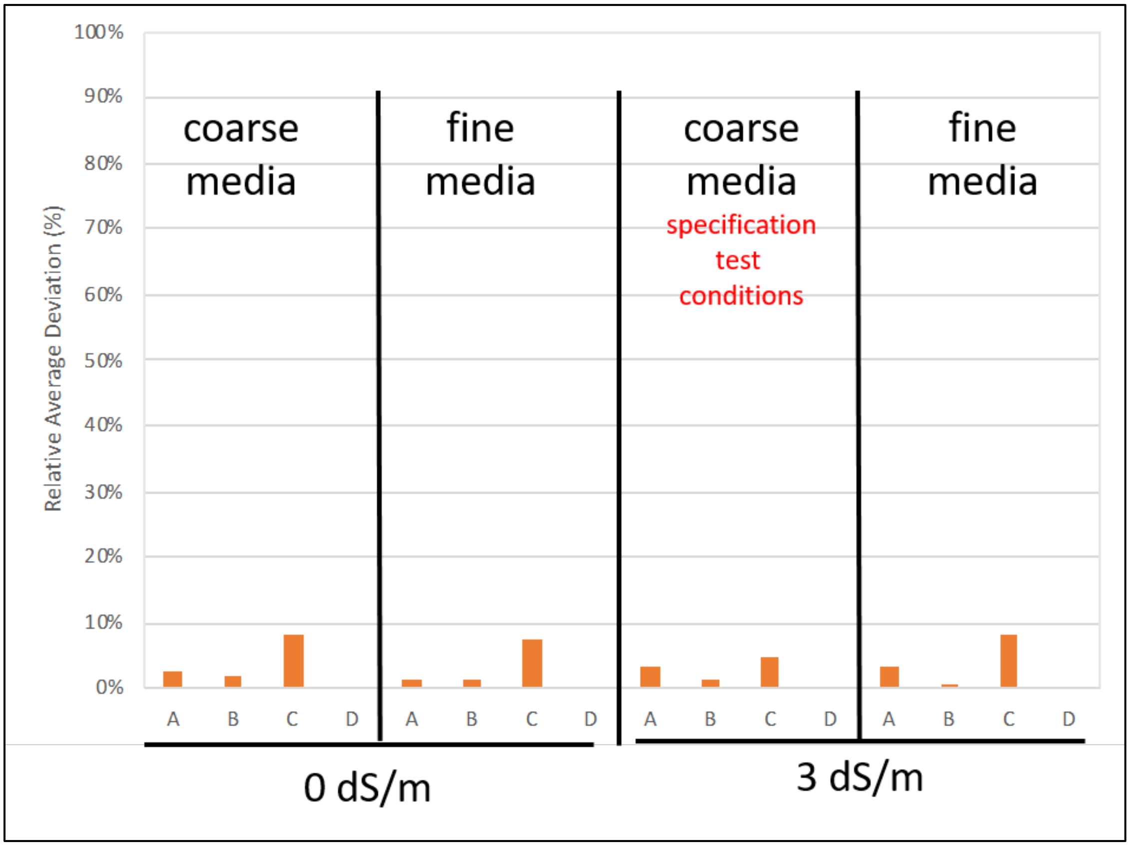

Figure 2. RAD for Four Brands Included in the University of Florida Performance Tests
(averaged across irrigation enable and irrigation disable readings and across depletion levels)

3. **Response to change in soil moisture**: The absolute value of the slope of the line generated by plotting irrigation enable readings for all three replicates across all three depletion levels and the absolute value of the slope of the line generated by plotting irrigation disable readings for all three replicates across all three depletion levels shall both be greater than zero when rounded to two significant digits (i.e., $\geq$ 0.01).

   This criterion ensures the SMS's 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 *ASABE X633*) and how the SMS reports its reading. Therefore, the EPA is specifying 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.[14] Therefore, the 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.

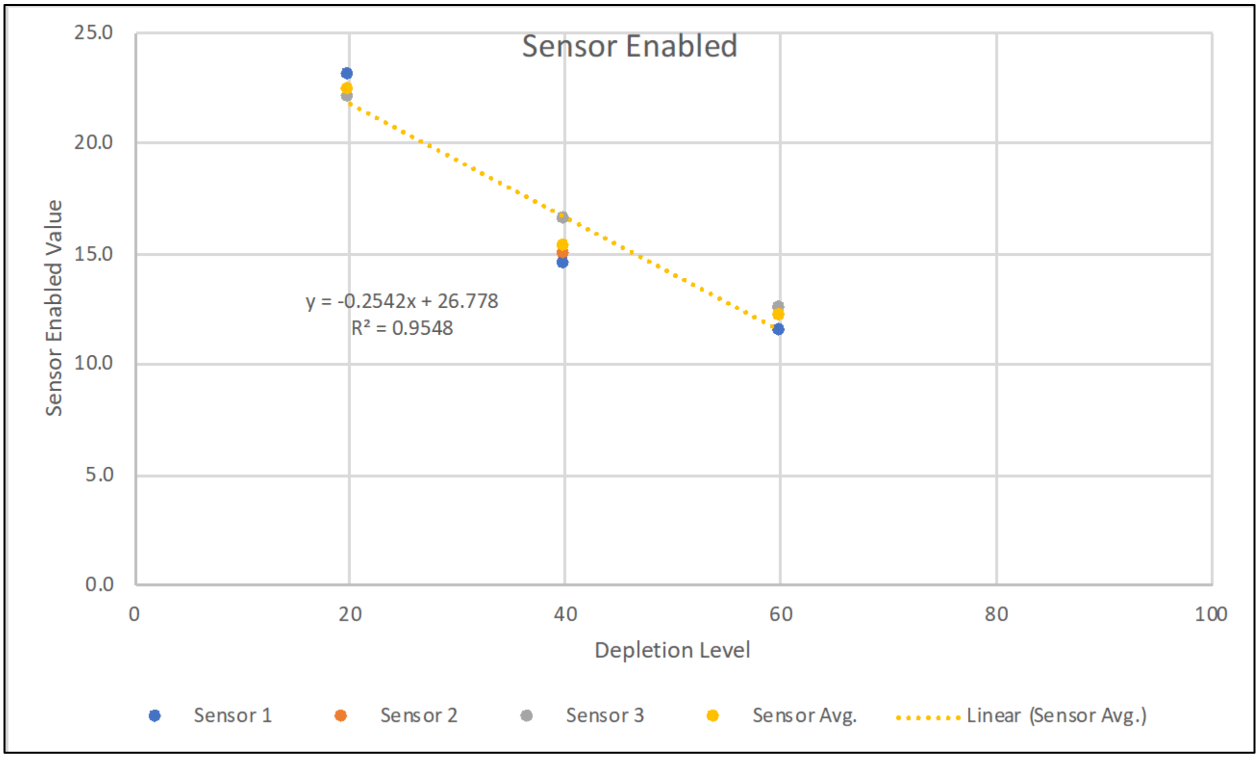

Figure 3. Sample Test Data Demonstrating a Sloped Line in Response to Changes in Water Depletion Level (Slope = -0.2542)

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.

   The 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 (with modification) of *ASABE X633*. WaterSense is only requiring that the products continue to enable/disable irrigation after the freeze test. It is not specifying that products meet a specific RAD

[14] 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.

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 draft 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* by 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. The 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. The EPA recently reviewed the *WaterSense Specification for Weather-Based Irrigation Controllers* for possible revision. During that process, WaterSense 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, the EPA intends to promote the products together as "smart irrigation control technologies." Therefore, the EPA has retained all of 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 draft specification) shall meet the following requirements in both soil moisture mode and standard mode:

- Be capable of preserving the contents of the irrigation program 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.

- 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 if switched to manual mode. 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 to which the device will be connected. Since most of the products currently on the market are add-on devices, the 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 Section IV of this supporting statement, WaterSense is not requiring 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, the EPA intends to specify packaging and product documentation requirements as part of the criteria for products to earn the WaterSense label.

Similar to 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 draft specification. However, the product documentation (e.g., product packaging, user manual, website, specification sheet) for add-on and plug-in devices shall list 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 EPA intends to require that the manufacturer specify a single base controller model with which an add-on or plug in device shall be connected and tested. Together, the unit shall be capable of meeting the requirements of the draft specification, including the supplemental capability requirements specified in Section 3.0. This requirement allows for 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 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; and
- The compatible base controller communicates with the interface device in the same way as the base controller with which the add-on or plug-in device was tested (e.g., common wire interrupt).

The add-on or plug in device is not required to be tested with any additional base controllers determined to be compatible. As long as the communication mechanism used between compatible base controllers is the same as the base controller with which the device was tested, the product should perform well, regardless of the base controller to which it is connected. Similar to weather-based irrigation controllers, the EPA intends to maintain a list of compatible base controllers for each add-on or plug-in device on its product registry. This information will help purchasers and utilities offering 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.

V. Certification and Labeling

The 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 licensed certifying bodies. Manufacturers are authorized by licensed certifying bodies to use the WaterSense label in conjunction with labeled products.

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. 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 described in Section 4.0 of the draft specification.

Base controllers that are tested, or determined to be compatible, with an add-on or plug-in device may bear the 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."

VI. Other Issues

SMSs have been demonstrated to save significant amounts of water, upwards of 60 percent in certain applications.[15] However, there are numerous outside factors that must be considered and addressed in order to achieve the intend 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 a two-pronged approach consisting of marketing and outreach with stakeholders, including a national network of certified irrigation professionals. 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. For example, the EPA intends to publish a technical guide to SMSs along with the final specification. The 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 efficiency and innovative technologies.

VII. Potential Savings and Cost-Effectiveness

Note: Appendix A 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. The 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 $4.3 billion in water supply and wastewater costs annually.

[15] 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.

Cost-Effectiveness

For the purposes of cost savings estimates, the 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, the 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, the EPA determined the cost-effectiveness for an upgrade of an existing clock-timer controller, as WaterSense recognizes that add-on or plug-in devices might be connected to an existing clock-timer controller as an upgrade.

The 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. The EPA determined the cost of add-on or plug-in devices only (in the case of an upgrade of an existing clock-timer controller) to be approximately $180. The 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 $167 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.[16]
- 90 percent of the 28.82 million irrigation systems are candidates for installation of SMSs.[17]
- Average outdoor water use per household is 50,500 gallons per year.[18]
- 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).[19] 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 seeing overall water savings of at least 30 percent after installation of SMSs.
- The cost of water for irrigation is $11.02 per 1,000 gallons.[20] 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 water supply costs for water used for irrigation.

Equation 1. Annual Individual Irrigation Water Savings From Installing WaterSense labeled SMS
(50,500 gallons/year) x (30 percent savings factor) = 15,150 gallons/year

Equation 2. Candidates for Installation of Labeled SMSs
(28,820,000 irrigation systems) x (90 percent candidates for installation) = 25,900,000 irrigation systems

[16] Schein, Letschert, Chan, Chen, Dunham, Fuchs, McNeil, Melody, Strattron, and Williams. 2017. Methodology for the National Water Savings and Spreadsheet: Indoor Residential and Commercial/Institutional Products, and Outdoor Residential Products. Lawrence Berkley 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 the 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.
[17] Ibid
[18] DeOreo, Mayer, Dziegielewski and Kiefer, 2016. Residential End Uses of Water, Version 2. Published by the Water Research Foundation. Table 6.32, Page 154.
[19] 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.
[20] Raftelis Financial Consulting. Water and Wastewater Rate Survey. American Water Works Association. 2016.

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 ($11.02/1,000 gallons) = $4.3 billion

Cost-Effectiveness Calculations

Assumptions:

- $253 is the average retail price for an SMS as a full replacement of a clock-timer controller or installation in a new irrigation system (either a stand-alone SMS controller or an add-on or plug-in device plus a base controller).[21]
- $183 is the average retail price for an SMS upgrade to an existing clock-timer controller (an add-on or plug-in device only).[22]

Equation 6. Estimated Annual Water Cost Savings From Installing an SMS

*(15,150 gallons per year) x ($11.02/*1,000 gallons*) = $167 savings per year*

Equation 7. Estimated Payback Period for the Average Cost of a SMS (full replacement or new installation)

($253 product cost ÷ $167 savings per year) = 1.5 years

Equation 8. Estimated Payback Period for the Average Cost of a SMS (upgrade)

($183 product cost ÷ $167 savings per year) = 1.1 years

[21] Market research based on residential or light commercial models available at the time the draft 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.
[22] Market research based on residential or light commercial models available at the time the draft specification was released. This includes the price of an add-on or plug-in device only.