Water when you need it!

Watering With Soil Moisture Sensors
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Watering with Soil Moisture Sensors

Studies have shown that a properly configured soil moisture sensor can reduce outdoor water use by up to 62 percent or more over traditional irrigation methods. By watering your plants when needed, you can increase landscape health, promote deeper root growth, and make your plants more disease resistant.

If something as simple as a soil moisture sensor delivers all these benefits, then why isn’t this valuable tool used on every irrigation system? Unfortunately, professional irrigators are often familiar with inferior soil moisture sensors that do not deliver expected results, and this experience has discredited the value of all soil moisture sensors. Additionally, when deciding how to irrigate, people don’t always consider how water moves in soil, how the various types of soil retain moisture, and how plants’ needs differ.

The purpose of this document is to establish the reputation of the Baseline soil moisture sensor as a valuable irrigation tool and to help professional irrigators meet their challenges by raising their awareness of the issues related to effective watering.

Common Myths

Before we start discussing the benefits of using soil moisture sensors and covering the details of the technology, we should attempt to dispel the common myths that always seem to surface whenever this topic comes up. If you have doubts about the effectiveness of soil moisture sensors, we encourage you to review the following information.

Myth #1 “I used a soil moisture sensor before and it did not work!”
Several kinds of soil moisture sensors have been used for irrigation management and automation during the past 50 years, but not always successfully. Certainly some of the failures can be attributed to product issues, and some failures can be blamed on misuse or misunderstood soil conditions.

Not all soil moisture sensors are created equal. The design and technology of Baseline’s soil moisture sensors make them the most advanced sensors in today’s market. Baseline sensors can reliably track changes in soil moisture content at less than 1/10th of a percent, and the sensors are expected to last 25 years in the soil regardless of climate. If you have had a negative experience with another type of soil moisture sensor, you might want to reconsider Baseline’s version of this valuable irrigation management tool.
Myth #2 “I have different soil types in my landscape, so a soil moisture sensor won’t work for me.”
When we see a plant in the landscape that is doing poorly, we often assume that it’s not getting enough water, and if the poor-looking plant is located near other healthy plants, it’s typical to assume that the water-holding issues are due to variations in soil type. In an effort to get extra water to the poor-looking plant, we can easily end up overwatering the zone.

While it’s true that variations in plant appearance are usually related to variations in soil type, the primary factor is the nutrient-holding capacity of the soil, rather than the water-holding capacity. If you use a soil moisture sensor to ensure that you are not under or over watering, you can isolate the nutrient-related issues and then treat them accordingly.

Myth #3 “Soil moisture sensors probably work better in a high rainfall area, but I live in the desert.”
In a desert climate, the surface of the soil dries out quickly, but adequate moisture is often available in the root zone of adapted plants. If you are serious about conserving water and maintaining healthy plants in a desert climate, a soil moisture sensor is a valuable tool.

Without a soil moisture sensor, you have to continually monitor your plants for signs of stress and make assumptions about the cause, and then base your remedies on those assumptions. The soil moisture sensor eliminates the need for constant monitoring and guesswork based on general observations.

Myth #4 “Soil moisture sensors probably work well in the desert, but we get rain here.”
Installing a soil moisture sensor in a wet climate allows you to conserve water by making better use of effective rainfall. The soil moisture sensor detects the rainfall that reaches the root zone (the “effective” rainfall), and adjusts the irrigation schedule accordingly. In a wet climate, a soil moisture sensor helps prevent overwatering that often drowns plants especially while they are getting established in a new landscape. If you are a contractor who is monitoring a new landscape, you’ll find that soil moisture sensors are a wise investment because they can prevent the costly and time-consuming efforts of having to replace plant material that died due to improper watering.

Myth #5 “Soil moisture sensors probably work fine on flat ground, but we have hills.”
If your site includes slopes, you’ve probably faced significant irrigation challenges related to the topography. However, if the top, slope, and bottom of the hills are irrigated by different zones, you have the ideal setting for using soil moisture sensors to manage the irrigation in this challenging environment. Simply install a sensor in each of the zones, and then set up a watering strategy for each location.

If the hills are irrigated by only one zone, you can still benefit from installing a sensor on the slope and monitoring the soil moisture levels in the location that is most prone to runoff.

Myth #6 “Soil moisture sensors won’t work here; we have heavy clay, or we have sand.”
While it’s true that many soil moisture sensors on the market aren’t effective in heavy clay or sand, Baseline’s patented TDT technology enables our sensors to detect minute moisture level changes in all types of soil. Our sensor’s responsiveness coupled with other water saving tools such as the Intelligent Soak Cycle features built into our controllers provide an ideal fit for monitoring and successfully irrigating extreme soil types.
Baseline Soil Moisture Sensor Technology

Soil moisture sensors have been used for many years to measure how much water is held between the soil particles. This is no easy task because not all soils are created equal, not even close. (For more information about soil characteristics, read Not All Soils Are Created Equally below.) Many sensors on the market use a variation of conductive or capacitive technology.

Baseline’s patented soil moisture sensors use TDT (time domain transmission) technology to provide sensors that are so much more sensitive (which means they are highly responsive to changes in moisture levels) than previously available sensors — they actually change the rules of the game. TDT sensors are the most advanced sensors available as well as the most accurate and sensitive soil sensors on the market. Baseline’s patented design is not only sensitive to small changes in moisture content, they are also extremely durable and reliable, easier to install (over new or existing wire), and they are maintenance free and cost effective.

What does it take to make a great soil moisture sensor?

Consider the following factors when you are evaluating the quality and usability of a soil moisture sensor:

**Sensitivity** is the sensor’s ability to monitor small changes in soil moisture content. Many sensors on the market are ± 2-3 percent; however, Baseline sensors can reliably track less than 1/10th of a percent of change volumetrically. Sensitivity is very important in light soil such as sand or engineered soils.

**Repeatability** refers to how well the sensor can report the same value when measuring the same moisture content. You cannot have repeatability without sensitivity. Often this number is reported as the same value as sensitivity. Baseline’s repeatability and sensitivity is outstanding at less than 1/10th of a percent.

**Accuracy** is sometimes used to describe sensitivity and repeatability; however, it can also describe the sensor’s ability to report true volumetric moisture content (VMC). Not all sensors report in VMC: some use a scale of 1-100, while others simply display a graph. Baseline has chosen to standardize on the VMC method of reporting, and consequently, accuracy is a measurement of our ability to accurately report VMC. Baseline’s soil moisture sensors are ± 3 percent in accuracy within most soil types.

**Durability** or reliability is arguably the most important factor in a commercially used soil moisture sensor. Baseline has been building soil moisture sensors for over 13 years. Our sensors are used all over the globe — from Death Valley where soil temperatures can be in excess of 100° to northern environments with freezing conditions. Baseline sensors are expected to last 25 years in the soil.

How do soil moisture sensors work?

Baseline’s soil moisture sensors work by sending a high frequency pulse of electricity down an embedded wire path. The high frequency of the pulse causes the sphere of influence of the pulse to move outside the sensor blade and into the soil around it. When the pulse travels through moisture, it slows down. The sensor measures the speed, and then converts this measurement to a moisture content reading.

How can soil moisture sensor readings affect irrigation schedules?

If the Baseline soil moisture sensor were a simple reporting device, you would have to interpret the moisture content readings and then figure out how to apply them to your irrigation schedule. Fortunately, a Baseline soil moisture sensor is much more than a reporting device. It sends the soil
moisture readings to the Baseline controller, which then interprets the soil moisture data and uses that information to automate when/how often to turn on the sprinklers and how long to run/when to shut off the sprinklers.

Here’s an analogy to explain how a soil moisture sensor works with a Baseline irrigation controller. Think of the soil moisture sensor as a thermometer and the controller as a thermostat. When you set your thermostat to turn on your air conditioning, the temperature you set it at is the threshold. As long as the air surrounding the thermostat is cooler than the threshold, the air conditioner remains off. When the air temperature rises to the threshold, the A/C turns on and remains on until the temperature drops back below the threshold.

Similarly, you set a soil moisture threshold in the Baseline irrigation controller. The sensor monitors the soil moisture, and when the threshold is met, the system can be set to either turn on the irrigation at the next scheduled start time or shut off irrigation.

What is a good irrigator trying to accomplish?
To be a good irrigator, your number one goal is to use the least amount of water possible to keep the soil moisture content in the root zone at the appropriate levels. To meet this goal, you have to turn on the water before the moisture content drops below the lowest allowed level (maximum allowed depletion), and shut off the water before it goes above the highest allowed level (field capacity). Read more about Soil Moisture Content Levels below.

Your second goal should be to water as infrequently as possible because this strategy will promote deeper plant roots while minimizing the incidence of disease. Maximizing the rooting potential of the plant allows it to access as much water and nutrients as possible. Many scientific studies have examined the potential for improving a plant’s water-use efficiency (usually referred to as WUE), and it is widely accepted that a plant’s water use can be optimized with good irrigation practices.

We know deep and infrequent watering can get complicated, and it is not always possible due to watering restrictions, available water supply, or events. Baseline has many tools designed to meet these challenges. You can find more information in the Watering Strategies section on page 14.

Why is it so challenging to water efficiently and effectively?
On paper, your goals look pretty simple: turn water on, turn water off. In reality, using water efficiently and effectively is quite challenging. In order to meet the goals, you need to be part soil scientist, part hydrologist, part physicist, and part botanist. Fortunately, Baseline’s products can help you look like an expert in all these areas.

Understanding Soil Moisture Content Levels
In order to monitor your water use, you need to understand how the following levels of soil moisture content correlate with the availability of water in the soil. Having a familiarity with these levels will help you understand the way soil holds water. This information will also help you set the thresholds for watering with a soil moisture sensor.
**Saturation:** At the saturation level, nearly all of the spaces between soil particles are filled with water. After a soil has reached saturation, it does not become more saturated; although, in some situations where water is trapped, it can become flooded.

As a rule, irrigators do not want to saturate the soil because it cuts off the plant’s supply of oxygen, which, in effect, drowns the plant. However, at the saturation level, gravity pulls water downward through the soil more rapidly. A professional irrigator might saturate the surface layer of the soil in order to move water deeper into the soil and soften the effects of poor distribution uniformity.

Do not confuse saturation with field capacity.

**Field Capacity:** When soil is at the field capacity level, it means that all excess moisture has drained freely from that soil. The amount of remaining moisture is the field capacity. Imagine dipping a sponge in a bucket and allowing it to soak up water (it becomes saturated). When you pull the sponge from the bucket, water drips freely. When the dripping stops, the sponge has reached field capacity.

To irrigate properly, you would turn off the water when the soil in the root zone of the plants reaches field capacity. A Baseline soil moisture sensor measures field capacity in the calibration process and uses this value as the basis for other settings.

**Maximum Allowed Depletion (MAD):** When the soil moisture content reaches this level, irrigation needs to start. In most cases, the maximum allowed depletion level is just before the plants begin to show visible signs of stress. Irrigators typically start watering at or before MAD is reached because they don’t want their landscapes to show signs of stress.

For example, a homeowner might decide that it’s more important to conserve water than to have a perfect yard, so he might not irrigate until his turf begins to show signs of stress. However, the irrigation manager for a resort property cannot start watering at the same threshold because a beautiful lawn is likely the most important goal. You can achieve either of these goals with a Baseline soil moisture sensor.

MAD is not measured because it is based on observation and opinion. The Baseline soil moisture sensor can automatically set a MAD threshold for you based on the measurement of field capacity; however, keep in mind, the setting is an opinion, and we encourage our customers to fine tune their thresholds.

**Permanent Wilting Point:** At the permanent wilting point, the level of water in the soil is not sufficient to meet the plant’s needs. This term is of little importance to most landscape irrigators unless you are considering a true high deficit irrigation strategy. If you are interested in using a Baseline system to achieve a high deficit irrigation strategy and would like specific agronomic advice, please contact us directly.
**Oven Dry:** When soil is dried in an oven, nearly all water is removed. This moisture content level is used to provide a reference for measuring and reporting volumetric soil moisture content (VMC). VMC is the most common way to communicate a soil moisture point. If you dig up a volume of soil, weigh it, then cook it until it’s dry, and then weigh it again, the VMC is the percent of change in weight.

Several terms are used to describe the water held between these different water contents. Gravitational water refers to the amount of water held by the soil between saturation and field capacity. Water holding capacity refers to the amount of water held between field capacity and wilting point. Plant available water is that portion of the water holding capacity that can be absorbed by a plant. As a general rule, plant available water is considered to be 50 percent of the water holding capacity.

**Not All Soils Are Created Equally**
The soil is the plant’s water and food supply. Soil is made up of mineral particles weathered out of rock. These particles are identified by their size as sand, silt, or clay. The mineral particles are held together by organic matter. Soil is classified based on the relative proportions of sand, silt, and clay.

Most naturally occurring soils are a combination of the various particle types (as illustrated in the USDA soil texture diagram) plus organic material, gravel, rock, and plant material.

When you look at soil, it appears that the particles touch each other, but in reality there are spaces, called pores, in between. When soil is dry, the pores are filled with air, but after irrigation or rainfall, the pores fill with water. Water is also held on the soil particles through adhesion and cohesion.
In sandy soil, the individual sand particles are larger than those in clay soil. The sand particles fit together in a way that creates large pores, but because the particles are large, there are fewer of them in a specified volume of soil, and the amount of total pore space is low. For these reasons, water moves through the large pores between the sand particles relatively quickly. Water adheres to the sand particles, but because there are relatively few of them, the amount of water retained in the sandy soil is low.

In clay soil, the pores between the particles are small, but because the soil particles are also small, there are a large number of pores. Due to the greater number, the pores in clay soil can hold more water than the pores in sandy soil. And because there are more soil particles present, the amount of water adhering to those particles is greater than in a sandy soil. However, due to the small size of the pores and the large number of small soil particles, the clay soil holds the water more tightly than sand, and consequently, the plant has to work harder to extract the water from the clay soil.

In order to irrigate properly, you need to understand the capacity of plant available water in your soil. Depending on the predominate type of particles present in the soil, water will either penetrate and drain quickly (as in coarse-textured soil made up largely of sand) or water will penetrate and drain slowly (as in fine-textured soils made up largely of silt or clay). However, even if you have your soil properly identified by a qualified soil lab, there are still many factors such as compaction, soil depth, layering, or slope that complicate the ability to estimate plant available water capacity. The Baseline soil moisture sensor makes this process much easier by simply measuring the moisture content in the soil.

<table>
<thead>
<tr>
<th>Textural Class</th>
<th>Plant Available Water Holding Capacity inches/foot of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coarse sand</td>
<td>0.25 – 0.75</td>
</tr>
<tr>
<td>Fine sand</td>
<td>0.75 – 1.00</td>
</tr>
<tr>
<td>Loamy sand</td>
<td>1.10 – 1.20</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>1.25 – 1.40</td>
</tr>
<tr>
<td>Fine sandy loam</td>
<td>1.50 – 2.00</td>
</tr>
<tr>
<td>Silt loam</td>
<td>2.00 – 2.50</td>
</tr>
<tr>
<td>Silty clay loam</td>
<td>1.80 – 2.00</td>
</tr>
<tr>
<td>Silty clay</td>
<td>1.50 – 1.70</td>
</tr>
<tr>
<td>Clay</td>
<td>1.20 – 1.50</td>
</tr>
</tbody>
</table>

Infiltration and Water Movement
We have briefly discussed the different water holding characteristics of soils. You also need to be aware of infiltration and how water moves within the soil. While the details of this complex topic are based on physics and soil science, there are a few high-level concepts that will help you make good day-to-day irrigation decisions.

The soil’s infiltration rate is the rate at which the soil is able to absorb water. As water is added to the surface, it begins to work its way down into the soil. Some soils can accept water much more quickly than others. For example, consider what happens when you dip a paper towel into water. At first, the water moves very quickly into the paper towel, and then it slows down and eventually appears to stop. This example demonstrates the effect of saturation on capillary action. The same thing happens in the soil when water is first applied to the surface — it fills the soil pores nearest the surface first, and as these pores fill up, the water moves deeper into the profile. The time it takes for water to move through the soil depends on the size of the spaces and pores between the soil particles.

If you are trying to achieve your number one goal of “using the least amount of water possible to keep the soil moisture content in the root zone between field capacity and maximum allowed depletion,” you need to ensure that the applied water is making it to the root zone of the plant.
Typically, the application rate of the sprinkler outpaces the intake rate of the soil. So you need to be aware of the slowest infiltration rate per zone/station. (See Not All Irrigation Systems Are Created Equally on page 11 for more information on zones/stations). You can deal with this issue by using the Intelligent Soak Cycle feature of a Baseline controller. Read An Important Note on Intelligent Soak Cycles on page 12.

Estimating water infiltration can be greatly complicated by slope, compaction, and variations in ground cover or soil structure. The graph is a reasonable starting point; however, the most practical way to figure out how much water can be applied is to turn on the sprinklers and time how long it takes before you see runoff, then subtract a minute or two and make this your cycle time.

The soil dries out in somewhat the opposite way that it gets wet. Evaporation on the surface causes the soil to dry out from the top down, which causes the plant to rely on the deeper roots to access the nutrients such as minerals and elements that are dissolved in the available water. Allowing the surface to dry out between irrigation cycles helps reduce the incidence of disease and in many cases can improve the plant’s water-use efficiency.

**Topography of the Site**

You also need to consider the “lay of the land” when you are estimating water needs. The slope of your irrigation site will affect runoff and infiltration. The typical assumption is that surface water runs off a slope, but factors such as the percent of the slope, the shape of the slope, and the ground cover on the slope greatly influence the infiltration rate.

**Plants Are Different**

The roots of a plant do more than just keep it anchored to one spot — they draw water and dissolved nutrients from the soil up through the plant and out through the leaf. This process is called transpiration. Different plants have different transpiration rates at different stages of growth, but all plants transpire. The nutrients dissolved in this water provide the plant nourishment.

The plant plays an important role in determining when to irrigate. Unfortunately, there are a lot of misconceptions about the amount of water that plants really need. Some plants that are categorized as drought-tolerant, water-wise, or native will survive with limited water, but when water is present, they become water hogs and put out rampant growth. Rather than estimating a plant’s water needs based on a general category, it’s better to observe that plant carefully and determine its water-use efficiency (WUE). This process supports your goal of watering as infrequently as possible and promoting deeper plant roots while minimizing the incidence of disease. Remember, too, that proper irrigation practices can maximize a plant’s WUE by increasing its rooting potential and allowing the plant to access as much water and nutrients as possible.
When you’re evaluating your plants, also consider the plant’s effective root depth as compared with its total root depth. If you were to remove a plant from the soil along with its complete root structure, and then carefully remove the soil from the roots, you would notice that the top half of the root structure is much denser than the lower half.

The length of this section of dense roots is known as the plant’s effective root depth, while the length of the roots from the crown to the tip of the root is known as the plant’s total root depth. The plant draws most of its water and nutrients from the effective root zone rather than from the zone at the total root depth. When you install a soil moisture sensor, it is best to place it in the center of the plant’s effective root zone.

There is no simple rule of thumb when it comes to the best way to irrigate a particular species in a particular area — this is where local agronomic or horticultural experience plays a vital role.

Variation in soil types across the landscape can cause changes in plant appearance, which is often misdiagnosed as a lack of plant available water. However, changes in soil moisture holding capacity is often made up by rooting depth. In other words, a plant grown in heavy clay type soils will struggle to have deep roots, but the soil holds more water per inch. Whereas a plant grown in a lighter sandy soil will be able to root more deeply and access more soil, which makes more water available to the plant. The differences in plant appearance are often caused by a nutrient deficiency (usually N) because the lighter soils do not hold nutrients as well as the heavier soils. To follow this misdiagnosis with more water only makes the problem worse.

Checking for moisture in the soil is easy — don’t assume that you have a dry spot without digging into the soil with a probe or shovel.

**Putting All These Factors Together**

When you are trying to factor the differences in soil types and differences in plants and the soil moisture sensor’s readings into your irrigation decisions, consider the following analogy:

Think of your soil as a cup. Soil that holds a lot of water would be represented by a large cup. Soil that holds less water would be represented by a smaller cup.

When the cup is filled with water, it’s at field capacity. A lower water level is designated as the maximum allowed depletion (MAD).

Think of the plant as a straw used to suck water out of the cup. A thirsty plant would be represented by a large straw, while a plant with high WUE would be a small straw.

Think of the irrigation system as a water source that refills the cup.

Now think of the soil moisture sensor as a float gauge in the cup. The float is aware of the field capacity level and the MAD level. If the float goes below the MAD level as the plant takes water out of the cup, the water turns on and fills the cup back up to field capacity.
Not All Irrigation Systems Are Created Equally
In order to irrigate properly, you need to understand the basics of your system. Irrigation systems are broken into smaller sections called zones or stations. The zone is made up of a group of sprinkler heads that are turned on by the same valve.

Always remember that the smallest area the controller can manage is a zone. If you have a dry or wet zone, you can adjust it in several ways from the controller, but if you have a wet or dry spot inside the zone, you can either choose to fix whatever is causing the issue or you can carry on and find other ways to compensate. If you choose not to fix the issues within the zone, but you’re still trying to achieve the goal of using the least amount of water possible to keep the soil moisture content in the root zone between field capacity and maximum allowed depletion, you will end up over-irrigating some parts of the zone in order to compensate for the dry areas. A soil moisture sensor can help establish a better watering schedule, but you will continue to fight with wet areas and the problems they cause. Because it is nearly impossible to get perfect distribution uniformity, each manager has to decide where the line is between making system improvements and watering to the dry spot.

In addition to issues within your zones, you might also be fighting with a sprinkler system that is woefully inadequate, which is the case with many of the best-selling sprinkler systems in the irrigation industry today. To learn more about distribution uniformity (DU) issues and how to fix them, refer to the following resources:

- Landscape Irrigation System Evaluation and Management
- The Irrigation Association’s Technical Paper Library (search on “distribution uniformity”)
  http://www.irrigation.org/resources/technical_papers/

How Distribution Uniformity Affects Your Watering Goals
Perfect distribution uniformity (100%) is not really practical in landscape irrigation; however, it does help the irrigator understand the ideal situation. If you had 100% distribution uniformity, where the applied water infiltrates the soil consistently both laterally and vertically (as illustrated below) all plants would respond to soil moisture conditions equally.
A sprinkler zone with good distribution will look more like the illustration below where you are forced to “over irrigate” the entire zone to ensure that the dry areas receive an adequate supply of water.

If you ignore the poor distribution in the zone, the soil moisture level in some areas will reach the permanent wilting point, and you will lose plants in those areas as shown in the illustration below.

If a zone has poor distribution, you have two choices for keeping the plants green: one, over irrigate the zone in order to provide enough water to the dry area, or two, diagnose and fix the problem.

An Important Note on Intelligent Soak Cycles

Soak cycling breaks the total run time set in the irrigation controller into shorter water “cycles” (timed water applications) with “soak” periods in between to allow time for water to soak into the soil before applying more water. Soak cycles save water by avoiding surface soil saturation and runoff.

Even on a perfectly designed system, it is important to match the water application rate to the infiltration rate of your soil. You configure this by breaking the total run time for any zone into multiple cycles and soaks.

Remember that your number one goal is to use the least amount of water possible to keep the soil moisture content in the root zone between field capacity and maximum allowed depletion (MAD). When you combine the power of a Baseline soil moisture sensor with the Intelligent Soak Cycle functionality of a Baseline irrigation controller, you’ll be amazed how easy it is to meet this goal. Based on the soil moisture sensor readings, the system will automatically turn on the water before the moisture content drops below MAD, and shut off the water before it goes above field capacity. Soak cycling will minimize runoff and move the moisture to the root zone of the plants.
How Baseline’s Soil Moisture Sensors Can Help You Meet Your Goals

So back to the basics: when to start watering and when to stop. No matter what causes the soil to dry out or maintain moisture, a properly placed and configured Baseline soil moisture sensor measures the results. And because we are measuring and not estimating, the soil moisture sensor makes a better and more repeatable decision, which, in turn, makes irrigation management easier.

Sensor Placement Tips

Complete installation instructions are included with the sensor product. This section has some simple tips for sensor placement. The sensor needs to be placed in the effective root zone of the plant it is monitoring. Usually the sensor will be making the irrigation decision for many plants or even multiple zones of plants with similar water needs, so it should be placed in the effective root zone of a representative plant.

Back to the thermostat analogy: if your thermostat is next to a window or door that is left open on a hot day, the thermostat will sense the incoming hot air and cause the air conditioner to run continuously trying to lower the temperature. Similarly, if you put your soil moisture sensor in the driest spot of the landscape, your system will over irrigate the rest of the landscape in order to put enough water on the spot where the sensor is located.

Consider another example: if your thermostat is located above your oven, it will think the whole house is hot every time you cook, and it won’t allow the furnace to come on. Likewise, if you place your sensor next to your driveway, every time you wash your car, the sensor will think that the whole zone is wet and not allow irrigation in that area.

Based on these examples, you will want to consider the following guidelines when deciding where to place your sensors.

- Consider your various plant types first. For most sites, the ideal scenario would be to place one sensor in the lawn, one in the shrubs, and one in the trees if these plant types are in separate zones.
- Bury the sensor in the zone that needs to be watered the most frequently (the one that dries out the quickest). Configure the program in the irrigation controller to meet the needs of this zone.
- Place the sensor in an average to slightly dry area (a spot that receives an average amount of water for that zone).
- If you have very poor distribution uniformity (for example, mixed sprays and rotors), then you need to bury your sensor in a drier spot within the zone to avoid higher than average moisture readings. But keep in mind, the drier the area where the sensor is placed, the more the system will overwater the wet areas.
- Bury the sensor in the top third of the root zone, usually 2 - 3 inches deep.
- Be sure to use some water to compact the soil against the sensor.
- Mark or record the location of the sensor. This way, you can avoid damaging it when aerating or digging.
- Group all zones that use the same watering schedule, such as lawn, shrubs, or trees. With Baseline’s BaseStation 1000 irrigation controller, put all zones that you want to group into one program. With Baseline’s BaseStation 3200 irrigation controller, designate the zone where the sensor is buried as the primary zone, and then link the other zones that water on the same interval as the primary.
**Watering Strategies**

As we talked about in a previous section, there are only two basic decisions that can be made by the irrigation controller: when to turn on and when to turn off the valve. The smarter the controller, the more variables the controller can consider when deciding when to turn on or off the valve.

In this section, we will explore how a Baseline controller uses the soil moisture sensor information to influence the decision of when to turn on and off the valve.

The more sensors you use, the more flexibility you have when fine tuning. The fewer sensors, the simpler the system is to operate. Keep in mind, you can always add more sensors, and when you have been running the system for a few months and decide to add a sensor, you will know exactly why.

**Lower and Upper Thresholds**

A Baseline irrigation controller can use two basic watering strategies: lower threshold and upper threshold (also known as lower limit and upper limit).

**Lower threshold** tells the system to turn on based on soil moisture, and then turn off based on time.

To conserve water and optimize the plants’ water-use efficiency (WUE), lower threshold is the recommended strategy. With lower threshold, you could set your controller to one or more start times each day, but the sensor will only allow irrigation when the soil has dried out to a level at or below the threshold.

**Upper threshold** tells the system to turn on based on time, and then turn off based on soil moisture.

For areas that have a restricted schedule such as specific watering days or specific use schedules like sports fields, upper threshold is a more popular option. With upper threshold, you can choose which day and what time of day to start watering and the sensor will shut off watering when soil moisture reaches the upper threshold.
You can set up a watering strategy for each sensor on a Baseline controller. For example, you might want to set up all the common areas to irrigate based on lower threshold and set up the sports fields to irrigate based on upper threshold. For more details on how to set up the system for specific uses, see the section Special Soil Moisture Sensor Applications on page 17.

Setting a Threshold (Calibrating the Sensor)
After you have decided which watering strategy you want to use for each sensor, you need to establish a threshold. We recommend that you read through all the calibration options below, and then choose the one that best fits your needs.

Method #1 — Auto-calibration: The Baseline controller has an auto-calibration option that enables the controller to measure the field capacity of the soil. During auto-calibration, the controller applies water to the auto zone (the zone where the sensor is buried) until the response curve slows. After the controller has measured field capacity, it is able to use this data to set an upper or lower threshold based on this reading. You can then choose to use this threshold or adjust it as needed.

This method is convenient; however, there are a few things to keep in mind.

- Auto-calibration will take one or more irrigation cycle to complete depending on programming and could potentially take more than a week.
- Auto-calibration can use a lot of water while attempting to determine field capacity especially if the sensor is placed in a very dry area.
- If you run auto-calibration when the soil moisture content is already high, the calibration will fail because the system must be able to detect a change in soil moisture content.
- If your run time is too short, not enough water is applied to the location and the sensor cannot detect a slowdown in the response curve. If the run time is not long enough to fill the soil to field capacity, the calibration cycle will fail.
Again, consider the analogy of filling a cup. Field capacity is a full cup. If you attempt to calibrate when the cup is already full, the sensor will not detect a change and will not be able to determine field capacity. If you do not leave the spigot on long enough while calibrating, the cup will not get full and the sensor will not be able to identify a slowdown in the fill rate.

Method #2 — Manually Identifying Field Capacity: If you are installing a sensor in soil that is already at field capacity or you are worried about the amount of water it may take to auto-calibrate, you may choose to manually identify field capacity. After the sensor has been installed, pour a couple gallons of water directly over the spot where the sensor is buried to saturate the soil around the sensor. Over the next several hours, the water will spread out through capillary action. As a rule, it is best to wait 24 hours to get an accurate field capacity reading.

After you have established a field capacity value, you can set your initial threshold. For the upper threshold, set the value at or slightly below this number. For lower threshold, use the graph below.

Method #3 — Manually Identifying Maximum Allowed Depletion (MAD): Before Baseline released the auto-calibration feature, the most common method for calibrating a sensor for lower threshold was to simply let the landscape dry out to the point where irrigation was desired. This method is still a viable option, and in some situations such as engineered soils found on a green roof or green wall, this is still the best method.
Special Soil Moisture Sensor Applications

Sports Fields and High Use Areas
Baseline soil moisture sensors are commonly used for irrigating sports fields and other high use areas because of the system’s ability to separately manage the schedule on each field in the complex and to fill the profile up to the desired level on a stringent schedule.

When you are using soil moisture sensors to monitor irrigation in a sports complex, it’s best to install a sensor in each field, and then program the zones that water each field as a group. We recommend this approach because you may have a game on one field but not on the one next to it. The use of the fields causes a difference in irrigation frequency, and separate sensors are required to control the separate irrigation schedules.

The goals and challenges
- Maintain a firm and consistent playing surface at game time (not so hard that it creates a higher risk of injury, not too soft or the surface will get damaged).
- Schedule irrigation around games and other events.
- Allow different schedules for different fields within the complex.
- Deal with all the other challenges of a regular irrigation system, such as limited water supplies, distribution uniformity, maintenance needs, and so on...

Suggested features and practices
- Use the upper threshold watering strategy. Set the upper threshold below field capacity to increase turf durability.
- When possible, try to set the start time long enough before play begins to give the surface a chance to firm up. Start irrigating again after the event to help the field recover.
- Place a sensor in each field that has a different schedule. The operator can pause the irrigation at any time and then the system will automatically “catch up” at the next opportunity.
- Place the sensor in an average area in the field, but not the highest use area. Avoid areas that may receive water from an alternate source such as water and drinks being poured out along the sidelines.
- Keep the sensor wire below the aeration depth to avoid damaging it when aerating. Do not bury the sensor too deep, but keep the sensor itself within the most active part of the root zone. Mark the spot where the sensor is buried using GPS, a sight marker, or a measurement.

Engineered Environments (Green Roofs, Green Walls, Interior Plantings)
Baseline soil moisture sensors are used in engineered environments because it is often the only way to effectively automate the control of these systems. The engineered environment presents many challenges that cannot be managed by an open looped system such as a weather-based system. The primary challenge that is created is the extremely small amount of plant available water that can be stored in the soil reservoir. This is often coupled with extreme environments.

The goals and challenges
- Often water conservation oriented sites
- Shallow soils or low water holding capacity, often not enough holding capacity to last a full day during peak usage
- Greatly increased evaporative effects over traditional on-grade plantings
• High to very high replacement cost of plant material
• Environmental benefits from keeping plants healthy and thriving

Suggested features and practices
• Use lower threshold and set the turn-on point much closer to field capacity than would be necessary with on-grade plantings.
• Use multiple start times per day to ensure the plants always have available water.
• Set the threshold manually by following either calibration method #2 or #3 described in the Setting a Threshold (Calibrating the Sensor) section beginning on page 15.
• Set fairly short run times by visually monitoring the site for the first couple weeks. Run times need to be long enough to take the moisture from lower threshold to field capacity, but short enough to prevent runoff.

Steep Slopes
Baseline irrigation controls provide features to irrigate slopes as efficiently as possible. Using Intelligent Soak Cycles and the soil moisture sensor’s ability to measure only effective irrigation, you can minimize runoff and often eliminate it completely.

The goals and challenges
• Eliminate or at least minimize runoff
• Raise healthy plants
• Avoid soil erosion or land movement caused from excessive irrigation

Suggested features and practices
• Know your precipitation rate so you can work toward deep and infrequent watering as much as possible.
• Put zones with steep slopes on a separate program.
• Use Intelligent Soak Cycles™ and adjust cycle times by visually monitoring runoff during an irrigation event. It is not unusual to have cycle times as short as one or two minutes.
• Not all slope issues can be remedied with controller settings. If you have one or more of the following issues, you may need to address the issue before adjusting the controller setting:
  o The slope is too steep.
  o The soil is heavily compacted.
  o The sprinkler heads put out water at too high of a rate (for example, VAN spray nozzles).
  o The zone has very poor distribution uniformity.
• Bury the sensor in line with the slope so that water moving downhill will run past the sensor and not build up on the uphill side.

Subsurface Drip Tubing Irrigation
Subsurface irrigation systems can be difficult to manage because you cannot see the water being applied. The surface can be dry even when the root zone is saturated. A Baseline soil moisture sensor is the perfect tool for managing subsurface irrigation systems because the sensor is buried in the roots where the water is used.
The goals and challenges

- Do not let the soil dry out. Very dry soil loses its capillary action and becomes difficult to rewet. In very dry clay soil, it is nearly impossible to move water up in the profile.
- Do not over irrigate. Subsurface irrigation is often selected for its ability to conserve water. However, if you are not paying careful attention, water can easily be leached below the reach of the plant roots.
- Know when the system is not functioning properly.

Suggested features and practices

- Know your application rate. Don’t guess — use the manufacturer’s chart or run the calculations.
  - Irrigators often falsely assume that water is being applied very slowly and assign very long run times to subsurface zones.
  - Even when installed properly, some drip tubing can apply more than 1.4 inches per hour. This rate is likely higher than your soil can accept.
  - To encourage the water to move up in the profile, set the application rate to match the infiltration rate.
- Use soak cycles to allow time for the water to move up through the soil to the roots.
  - Drip tubing manufacturers typically specify that you install the drip line 6 inches deep. However, this depth is often below the effective root zone of the plant, and consequently, below the recommended depth for burying the sensor.
  - If the drip line is 6 inches deep, bury the sensor in the effective root zone of the plant, and then use the lower threshold watering strategy.
- Make sure the sensor is buried in the right spot. The same sensor placement recommendations apply as in other situations, but in practice finding the “right spot” is not as obvious.
  - Place the sensor in an area that receives average to slightly less than average water from the irrigation system. Typically, this location is between two emitters and half way between the drip tubes.
  - The sensor must be in the root zone of a representative plant.

Point Source Drip Irrigation

A properly installed and maintained point source system can be extremely water efficient because the amount of water each plant receives can be varied to suit the need. Using a soil moisture sensor to irrigate this type of system enables you to fine tune the amount (how much/how long to water), and then use the soil moisture sensor to adjust how often the system runs.

The goals and challenges

- Adjust the frequency of irrigation to match changes in plant need and weather.
- The number one challenge for a point source system is maintenance. The system needs to be checked periodically for the following issues:
  - Plugged emitters
  - Leaks
  - The emitters remain in the right spots to deliver the water to the plants
  - The size or number of emitters remains appropriate as plants grow
**Suggested features and practices**
- Know your plant’s water requirement in comparison with the other plants in the zone. Many point source emitters are labeled based on the GPH (gallons of water that is delivered per hour).
  - As a professional irrigator or landscaper, you need to use your knowledge of plants and water requirements for each plant in the zone.
- Make sure the water is getting delivered to the entire root zone and not just on one side of the plant.
- Use soak cycles to allow time for the water to soak down to the sensor.
- Use either the upper or lower threshold watering strategy.
- Make sure the sensor is buried in the right spot. The same sensor placement recommendations apply as in other situations, but in practice finding the “right spot” is not as obvious.
  - Place the sensor in an area that receives average to slightly less than average water; usually not directly under the emitter and not too far away from it.
  - The sensor must be in the root zone of a representative plant – typically, the one that needs to be watered most frequently.

**Water Feature/Cistern Keep Fill**
You can use a Baseline soil moisture sensor to keep ponds and cisterns full. With no mechanical parts, they are much more reliable than standard floats, and much less expensive than most high quality float solutions.

**The goals and challenges**
- Keep the water level constant

**Suggested features and practices**
- Simple to use and install
  - Water usage can be measured
  - Will not affect the system’s ability to monitor and manage flow (with proper settings in the controller to account for the additional flow)
- Use any standard irrigation valve
- Use any standard valve biCoder (1, 2, 4 or Powered) to operate the valve
- The fill rate needs to be slow enough to allow a full minute of operation each time the pond or cistern is filled. You might need to install an orifice and pressure regulator to slow the water fill rate.
- Use the lower threshold strategy
  - Fill the pond or cistern to the desired low water mark, and then take a manual sensor reading.
  - Set the lower threshold to this number.
  - Set all 8 start times about 2 hours apart.
  - Set the run time of the zone at one minute or long enough to fill the pond or cistern to the desired level.
  - The water will now turn on for one minute up to 8 times per day depending on the need.
**Heavy Clay**

In heavy clay soil water infiltrates slowly, but clay soil holds more water per foot than other types of soil. For these reasons, irrigating in heavy clay can be challenging. If you set your soak cycles correctly and use a Baseline soil moisture sensor to closely monitor moisture levels, you can overcome those challenges.

**The goals and challenges**
- Get water down into the profile
- Don’t drown plants
- Don’t allow the soil to dry out

**Suggested features and practices**
- Use soak cycles to slow the application rate to match the infiltration rate – know your math:
  - Even though the field capacity of heavy clay soils can be more than 4 inches of water per foot of soil, the plant available water in the same soil may only be 1.5 inches of per foot of soil.
  - If your plants have an effective root depth of 6 inches, they can only draw from half of that available water (approximately 0.75 inches).
  - Assume that you need to irrigate when your plants have used half of the moisture in the top 6 inches of soil. In this scenario, you will need to add .375 inches of water to restore the moisture to field capacity.
  - The infiltration rate of clay soil could be as low as 0.10 inches per hour (0.0017 inches per minute).
  - If the zone is watered by spray nozzles that put out 1.5 inches per hour (0.025 inches per minute) assuming the landscape is fairly flat and that the turf or mulch will help hold the water, it will take at least 14 minutes for 1 minute of applied water to soak in.
  - Given the scenario described above, you should set the zone to cycle for 1 minute and soak for 15, and set the total run time to 13-15 minutes. This setting assumes near perfect distribution uniformity, which you do not have with a spray head. Be sure to adjust your settings to compensate for your system’s distribution uniformity.
  - Standard sensor placement rules apply.
  - If you do not get the soak cycles set correctly, both the upper threshold and lower threshold watering strategies will result in over watering by watering longer or more frequently than needed.

**Coarse Sand**

Because water infiltrates rapidly in coarse sand, moisture often ends up below the effective root depth of plants. A Baseline soil moisture sensor monitors the moisture level in the root zone and will cause the irrigation system to run multiple times per day in order to provide sufficient moisture for the plants.

**The goals and challenges**
- Keep the soil from drying out
- Manage dry spots

**Suggested features and practices**
- Be prepared to water more than once per day.
- Extremely coarse sand may only hold 0.5 inches of water per foot.
- Even though plant roots can easily penetrate sand, a plant that is genetically programmed to have 4-6 inch roots will not have a 12-inch effective root depth no matter how good you are at irrigating.
- If your soil holds 0.5 inches of water per foot and the plant’s effective root depth is 6 inches, the plant available water immediately following an irrigation cycle is only 0.25 inches.
- Peak water usage for the plant may be as high as 0.41 inches per day depending on location; therefore, you might need to water more than once per day to keep the soil moisture level above the permanent wilting point.
- Use the lower threshold watering strategy.
  - Set your threshold 1-2 points below field capacity.
  - Set multiple run times for each day trying to avoid the hottest time of the day.
  - Set run times based on application rates and desired watering depth.
    - For example, a spray zone applies 1.5 inches per hour, and the water holding capacity of the soil is 0.5 inches per foot. Filling the soil from dry would take 6 minutes. However, you are not going to start watering when the soil is completely dry, so you need to decrease the run time to something like 4-5 minutes depending on distribution uniformity of the zone.
- Avoiding dry spots
  - Because coarse sand does not allow much horizontal movement of water, distribution uniformity issues are more noticeable in sand.
  - In order to avoid dry spots, you will have to water based on the lowest application rate within the zone.
  - The poorer your uniformity, the more water you will be wasting in the average and above average areas within the zone.
Frequently Asked Questions

Q What happens when lightning strikes near a soil moisture sensor?
A Soil moisture sensors that are made up largely of metal components are susceptible to damage from lightning strikes even though they are buried. If lightning strikes nearby, currents can travel through the interconnecting wires and damage the sensitive circuit elements. Baseline’s soil moisture sensors are much less susceptible to lightning damage because no conductive material is in contact with the soil.

Q If I have a soil moisture sensor, do I need a rain sensor?
A Obviously, the sensor will detect the increased soil moisture caused by rain. However, because it takes time for the rain water to reach the sensor, the sensor reading typically will not cause the system to shut off quickly during a rain event. If you want to avoid the appearance of watering improperly during rain, we recommend that you combine a rain sensor (rain pause device) with your soil moisture sensor. After the rain sensor allows your system to start watering again, the soil moisture sensor will determine when the next irrigation event needs to occur.

Q Can I use a soil moisture sensor with a weather station?
A Remember that there are really only two decisions you need to make irrigating: when/how often to turn on the sprinklers and how long to run/when to shut off the sprinklers. You can use a soil moisture sensor or a weather station to automate these decisions, but using both technologies is redundant. Keep in mind that the soil moisture sensor automates these decisions based on actual measurements, where the weather station uses estimations.

Q Do I have to wire the sensor all the way back to the controller?
A No. you just need to wire it to the nearest valve box or connect it to the two-wire path.

Q How does the soil moisture sensor affect my run time?
A The answer depends on what watering strategy you are using. If you are using the upper threshold watering strategy, the sensor will monitor the moisture level of the soil and then decrease or increase the zone’s defined run time based on the upper moisture level that is set for the sensor. If you are using the lower threshold watering strategy, the system will only start when a start time is reached and the soil moisture level is below the lower moisture level. The zone will then run for its total defined run time. If the soil moisture level is above the lower moisture level when a start time occurs, the system will wait for the next start time. In other words, when you are using the lower threshold watering strategy, the soil moisture sensor does not affect the run time, but it can affect the start time.
Q How many soil moisture sensors do I need? Why?
A The actual answer depends on many factors such as how your irrigation system is configured, how your hydrozones are laid out, what kind of topography your site has, and the variety of plant material that you have. In reality, just one soil moisture sensor can help you change your watering schedule based on actual onsite moisture readings, which will result in water conservation and improved plant health.

Q Where do I put the soil moisture sensor?
A Choose the zone that needs to be watered the most frequently. Place the sensor within that zone, in an area that receives average to slightly less than average water from the irrigation system.

Q How deep do I bury the soil moisture sensor?
A The sensor must be in the effective root zone of a representative plant. A good rule of thumb is 2 – 3 inches deep.

Q How do I know if the soil moisture sensor is not working?
A In the unlikely event that a Baseline soil moisture sensor quits working, it sends an error to the controller. You will see a communication error or an over current error for the sensor address.

Q What happens if it’s really dry and the system can’t put enough water down?
A A Baseline system with flow control and a soil moisture system can help compensate for an under-designed system. However, keep in mind that this advanced functionality will not correct all issues associated with an under-designed system.

Q Should I continue to use the Seasonal Adjust on my controller?
A No. Let the sensor do the work – it makes irrigation decisions based on actual data rather than on anticipated seasonal changes.

Q What do you do if you aerate?
A Record the location of the sensor – either with a GPS reading or with a measurement from a static object like a valve box. Then, avoid that location when you are aerating.

Q Does a soil moisture sensor work with a drip irrigation system?
A Yes. Place the sensor in an area that receives average to slightly less than average water; usually not directly under the emitter and not too far away from it. The sensor must be in the root zone of a representative plant – typically the one that needs to be watered most frequently.
Q  When I calibrate a sensor and get a threshold reading, is that threshold fixed?
   A  No. The calibration process gets you close to an accurate threshold, but you are able to fine tune it.

Q  What is the MAD used in the calibration?
   A  The maximum allowed depletion (MAD) is the soil moisture level where you want irrigation to start. The most common method for calibrating a sensor for the lower moisture level (lower threshold) is to let the landscape dry out to the point where irrigation is desired and then use that moisture level reading as the lower threshold.

Q  It seems like very few companies are promoting soil moisture sensors. I've been using competitors’ irrigation controllers for years. Why don't they offer soil moisture sensors?
   A  Some of Baseline's competitors offered soil moisture sensors in the past, but their products did not turn out to be accurate or durable enough for long-term use in the field.

Q  What is the life expectancy of Baseline’s soil moisture sensor?
   A  Baseline has been building soil moisture sensors for over 13 years. Our sensors are used all over the globe — from Death Valley where soil temperatures can be in excess of 100° to northern environments with multiple freeze/thaw cycles. Baseline sensors are expected to last 25 years in the soil.

Q  If I can only water one day a week, should I still use a soil moisture sensor?
   A  Yes. If you are under a watering restriction that allows you to water only one day a week, you have an ideal scenario for using a soil moisture sensor with the upper threshold watering strategy. Suppose your watering day happens to be on a day after a rainstorm; the soil moisture sensor will help you conserve even more water by determining just how much water is needed to bring the soil moisture level to field capacity.

Q  How do you find a sensor after it has been buried?
   A  If someone buried a sensor and forgot to record its location, it can be challenging to find the sensor later. While it’s best to avoid this problem by always recording the sensor location, you might be able to find the sensor with a wire tracer. You need to know what wire path the sensor is located on. Start at the valve box for that wire path, and follow the signal from the wire tracer to the point where it ends. The soil moisture sensor should be located at that point (no more than 50 feet away from the valve box). Another tip is to look for smaller gauge wire in a valve box. Because the sensor wire is a smaller gauge than the other wire in the valve box, you can use wire size as an indication that a sensor might be connected.
Glossary of Terms

**application rate (precipitation rate):** The rate at which water is applied to an area within the landscape by an irrigation system. In order to determine proper duration of watering, it is essential that you know the application rate for each watering zone.

**capillary action:** A combination of forces that causes water to move through soil often in a direction that is against the force of gravity

**distribution uniformity:** A measure of how uniformly water is being applied by an irrigation system

**evaporation:** Loss of water as vapor from the soil surface or from moisture on the surface of a leaf. Differs from transpiration in that the water does not pass through the plant parts.

**evapotranspiration (ET):** The process of transferring moisture from the earth to the atmosphere by evaporation of water and transpiration from plants

**field-capacity:** When soil moisture content is at this level, it means that all excess moisture has drained freely from that soil. The amount of remaining moisture is the field capacity.

**hydrozone:** A grouping of plants that have similar water requirements and can be irrigated the same

**infiltration:** The process by which water passes through soil – the liquid permeates the soil by passing through the pores in the soil

**Intelligent Soak Cycle™:** When a zone waters using an Intelligent Soak Cycle, the total watering run time includes periods of watering interspersed with periods of soak times, or non-watering times. Baseline’s Intelligent Soak Cycles™ prioritize cycles for zones that have already started to water over zones that have not started in order to maximize watering efficiency and minimize total irrigation time.

**lower threshold:** If you are using soil moisture sensors to control watering, the lower threshold is the point at which the soil water content is low enough to start watering.

**maximum allowable depletion (MAD):** When the soil moisture content reaches this level, irrigation needs to start. In most cases, the maximum allowable depletion level is just before the plants begin to show visible signs of stress.

**microclimate:** The climate of a specific location within a landscape. Variations in climate are influenced by subtle differences in temperature, humidity, and wind exposure. Microclimates can have a significant impact on plant water needs.

**plant available water:** That portion of the water holding capacity that can be absorbed by a plant. As a general rule, plant available water is considered to be 50 percent of the water holding capacity.

**permanent wilting point:** When soil moisture content reaches this level, plants can no longer get water from the soil, and they will wilt and die.

**pore:** In soil, a space between mineral particles that allows water to infiltrate into the soil.

**precipitation rate:** See application rate
**rain sensor:** A device that detects rain and can be configured to halt watering. A rain switch is a type of rain sensor that uses hydroscopic discs to detect rain and halt watering. When the discs dry out, the irrigation system is ready to water again.

**run time:** The total time that a valve is watering. In an Intelligent Soak Cycle, the total watering run time is calculated by multiplying the minutes for each watering cycle by the number of cycles.

**runoff:** When soil is saturated to full capacity and after some water is leached deeper into the soil, any excess water from rain, snow melt, or irrigation drains to a low point in the landscape. That excess water is considered to be runoff.

**saturation:** When the soil moisture content is at this level, nearly all of the spaces between soil particles are filled with water. After a soil has reached saturation, it does not become more saturated; although, in some situations where water is trapped, it can become flooded.

**soak time:** In an Intelligent Soak Cycle, soak time the time when the valve is shut off between cycle times to allow the water to soak into the soil.

**smart controller:** An irrigation controller that uses weather and/or site data to water when needed and to make seasonal adjustments of run times.

**time domain transmission (TDT):** A measurement of how much electrical signals in the soil are slowed down by the presence of water.

**transpiration:** The loss of water vapor from parts of plants. Water is lost primarily from the pores on the leaves but also from stems, and flowers.

**upper threshold:** If you are using soil moisture sensors to control watering, the upper threshold is the point at which the soil water content is high enough to halt watering.

**valve:** A device that opens to allow water to flow to the sprinkler heads or emitters in a zone. It closes to halt watering for that zone.

**volumetric water content:** The ratio of the volume of contained water in a soil compared with the entire soil volume.

**water holding capacity:** The amount of water held between field capacity and wilting point.

**water-use efficiency (often referred to as WUE):** A measure of how well plants use available water.

**zone:** A designated area of landscaping that is watered by a specific valve.