



# TEROS 12

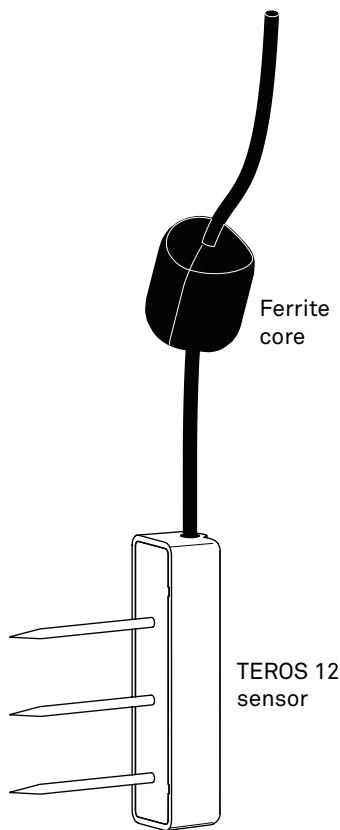
METER



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# 1. INTRODUCTION

Thank you for choosing the TEROS 12 Soil Moisture + Electrical Conductivity (EC) + Temperature sensor.

The TEROS 12 sensor is designed to be installed in mineral soils, many types of growing media, and other porous materials. This manual guides the customer through the sensor features and describes how to use the sensor successfully.

## TEROS 12 APPLICATIONS

- Volumetric water content measurement
- Soil/substrate water balance
- Irrigation management
- Soil electrical conductivity measurement
- Soil/substrate temperature measurement
- Solute/fertilizer movement

Prior to use, verify the TEROS 12 arrived in good condition. METER recommends testing the sensors with the data logging device and software before going to the field.

## 2. OPERATION

Please read all instructions before operating the TEROS 12 to ensure it performs to its full potential.

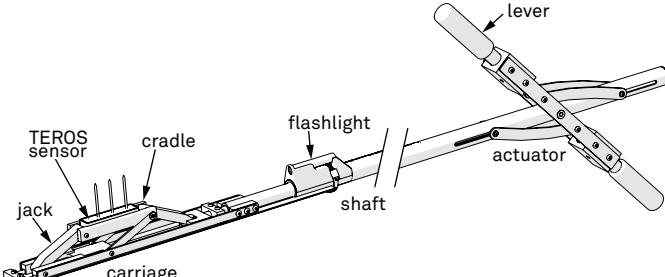
### ⚠ SAFETY PRECAUTIONS

METER sensors are built to the highest standards. Misuse, improper protection, or improper installation may damage the sensor and possibly void the manufacturer's warranty. Before integrating the TEROS 12 into a system, follow the recommended installation instructions and have the proper protections in place to safeguard sensors from damage. If installing sensors in a lightning-prone area with a grounded data logger, see the application note [Lightning surge and grounding practices](https://www.metergroup.com/lightning-surge-and-grounding-practices) (<https://www.metergroup.com/lightning-surge-grounding-practices>).

### 2.1 INSTALLATION

Follow the steps listed in [Table 1](#) to set up the TEROS 12 and start collecting data. For more detailed installation information consult the [TEROS Sensors Best Practices Installation Guide](#) (<http://www.metergroup.com/teros12-support>).

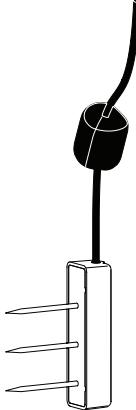
**Table 1** Installation

Tools Needed	<p><b>Auger or Shovel</b></p> <p><b>Secure Mounting Location for Data Logger and Cable</b></p> <p><b>Optional Tool</b></p> <p>Borehole Installation Tool</p> 
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**Table 1 Installation (continued)**

<b>Preparation</b>	<p><b>Determine Best Installation Method</b> There are several methods for installing soil moisture sensors. These methods are described in <a href="#">Table 2</a>.</p> <p><b>Check Sensor Functionality</b> Plug the sensor into the data logger (<a href="#">Section 2.2</a>) to make sure the sensor is operating as expected.</p> <p><b>Conduct System Check</b> Verify all sensors read within expected ranges. To validate both sensor function and logger functionality, take a sensor measurement in air and water. The TEROS 12 will read ~0.70 m<sup>3</sup>/m<sup>3</sup> in water and a slightly negative value in air.</p> <hr/> <p>There are several methods for installing soil moisture sensors (<a href="#">Table 2</a>). Keys to a good installation and collecting good soil moisture data are described below.</p> <p><b>Create Hole</b> Auger or trench a hole to the desired sensor installation depth and direction according to the installation method desired.</p> <p><b>Insert Sensor</b></p> <ol style="list-style-type: none"> <li>1. Load the TEROS 12 using the Borehole Installation Tool.</li> <li>2. Lower the tool into the hole or trench with the back of the tool supported by the far wall.</li> <li>3. Pull the tool lever to activate the jack and insert the sensor into the sidewall.</li> </ol> <p><b>NOTE:</b> See <a href="#">Table 2</a> for instruction on installing the TEROS 12 without the Borehole Installation Tool.</p> <p>The soil closest to the sensor has the strongest influence on readings. It is ideal to install the sensor in the native soil to get accurate soil moisture readings.</p> <p><b>ATTENTION! Minimize air gaps around the sensor.</b> Air gaps around the sensor needles will result in low readings of soil moisture.</p> <p><b>Avoid interfering objects.</b> If the TEROS 12 is installed near large metal objects they can affect the sensor function and distort readings. Avoid large objects like roots or rocks that could potentially bend the needles.</p>

**Table 1 Installation (continued)**

<b>Installation (continued)</b>	<p><b>Sensor orientation.</b> When the TEROS 12 sensor is installed, it may be positioned in any direction (needles aligned horizontally or vertically). However, installing the sensors with the needles in a horizontal position (as shown below) will provide the least restriction to water flow through soil because the water will flow through the soil directly to the needles.</p>  <p><b>Sensor body vertical and needles horizontal</b></p> <p>Because of the shape of the sensor electromagnetic field, installing the sensor with the body oriented vertically will integrate more soil depth into the soil moisture measurement. Installing the sensor with the body oriented horizontally (on its side) will provide measurements at a more discreet depth. See <a href="#">Measurement volume of METER volumetric water content sensors</a> for more information on sensor measurement volume.</p> <p><b>Connect to logger</b>      Connect the 3.5-mm stereo plug connector into stereo port on METER data logger. METER data loggers will auto-recognize TEROS sensors. Use ZENTRA Utility software (<a href="#">Section 2.2</a>) to configure desired measurement intervals and verify proper sensor identification by the logger. Use the SCAN function in the software to show a list of TEROS 12 readings. Verify that these readings are reasonable based on soil conditions. To connect to a non-METER data logger, refer to the <a href="#">TEROS 12 Integrator Guide</a>.</p> <p><b>Backfill the hole</b>      Return soil to the hole, packing the soil back to its native bulk density. Do not hit the ferrite core as this could potentially pull the sensor out of the soil.</p> <p><b>Secure and protect cables</b>      Secure and protect cables with PVC casing or flexible conduit to protect against damage from rodents or driving over sensor cables.</p>
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**Table 1 Installation (continued)****Secure excess cable**

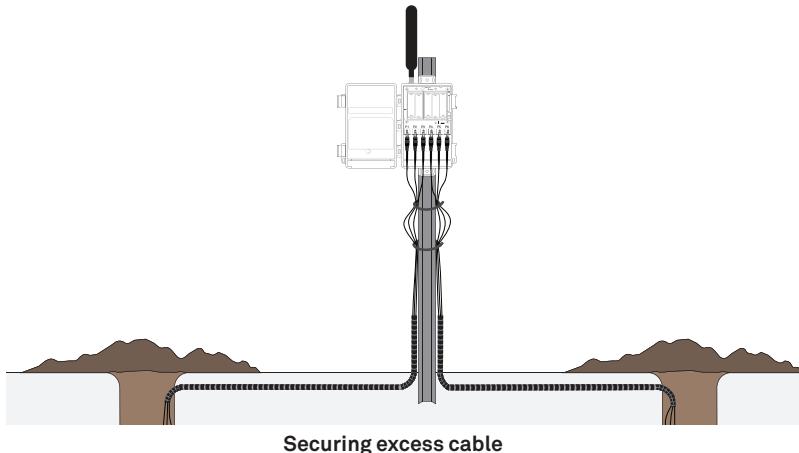
To prevent loose cabling from being inadvertently snagged or tripped over, gather and secure excess cable to the mounting mast in one or more places. Tie excess vertical cable to the data logger mast to ensure cable weight does not cause sensor to unplug.

**Relieve cable strain**

To relieve strain on the connections, leave the cables a little loose between the logger and the closest secured point on the mast. This will allow for thermal expansion and contraction of the cable without potentially pulling the stereo connection out of the logger.

**Avoid putting any metal in between the sensor and the ferrite core**

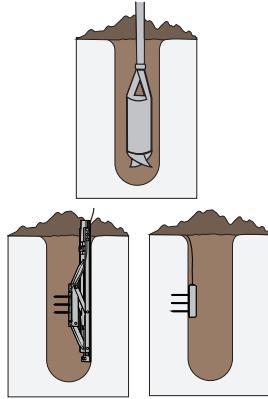
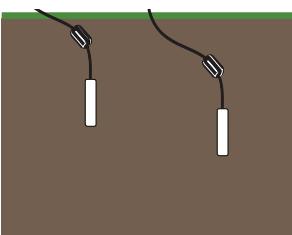
Any metal located between the sensor and the ferrite core can interfere with the TEROS 12 VWC measurement.

**Installation  
(continued)**

## OPERATION

**Table 2** contains brief descriptions for typical installation methods. Each has its own advantages and disadvantages. For more information about which installation method is best for specific applications, please see the [TEROS 12 Installation Guide](#) or contact [Customer Support](#).

**Table 2 Installation methods**

Borehole		Advantage	Disadvantage
<p>This method uses the Borehole Installation Tool (<a href="#">Table 1</a>) that allows a profile of soil moisture sensors to be installed at different depths within a single augered borehole. A 10-cm (4-in) borehole is augered vertically at the measurement location. The Borehole Installation Tool is then used to install the sensors in the sidewall of the borehole.</p> <p><b>NOTE:</b> The Borehole method requires specialized installation tool available from METER if installing at depths greater than 50 cm.</p>		Minimizes soil disturbance at measurement site.	Requires a specialized installation tool that can be rented from METER Group.
Trench		Advantage	Disadvantage
<p>The trench installation method is best for shallow installations (less than 40 cm). This requires digging a trench with a shovel, excavator, etc. The trench needs to be dug to the depth of the deepest installed sensor. For deep installations this may require a large trench. The sensors are then installed carefully by hand into the undisturbed soil of the trench sidewall. The trench is then carefully backfilled, preserving the bulk density of the undisturbed soil, and with care taken to avoid dislodging the installed sensors by accidentally snagging the ferrite core.</p>		Does not require specialized equipment.	Large soil disturbance at measurement site. Potentially large excavation effort.

## 2.2 CONNECTING

The TEROS 12 works most efficiently with METER ZENTRA, EM60, or Em50 data loggers. The TEROS 12 can also be used with other data loggers, such as those from Campbell Scientific, Inc. For extensive directions on how to integrate the sensors into third-party loggers, refer to the [TEROS 12 Integrator Guide](#).

TEROS 12 sensors require an excitation voltage in the range of 4 to 15 VDC and operate at a 4 VDC level for data communication. TEROS 12 can be integrated using SDI-12 protocol. See the [TEROS 12 Integrator Guide](#) for details on interfacing with data acquisition systems.

TEROS 12 sensors that are ordered for use with ZENTRA, EM60, or Em50 data loggers come with a 3.5-mm stereo plug connector ([Figure 1](#)) to facilitate easy connection with METER loggers.



**Figure 1 Stereo plug connector**

The TEROS 12 sensor comes standard with a 5-m cable. It may be purchased with custom cable lengths for an additional fee (on a per-meter basis). This option eliminates the need for splicing the cable (a possible failure point). However, the maximum recommended length is 75 m.

### 2.2.1 CONNECT TO METER DATA LOGGER

The TEROS 12 sensor works seamlessly with METER ZENTRA, EM60, or Em50 data loggers. Logger configuration may be done using either ZENTRA Utility (desktop and mobile application) or ZENTRA Cloud (web-based application for cell-enabled ZENTRA data loggers).

1. Plug the 3.5-mm stereo plug connector into one of the sensor ports on the logger.
2. Using the appropriate software application, configure the chosen logger port for TEROS 12.
3. Set the measurement interval.

ZENTRA, EM60, or Em50 data loggers measure the TEROS 12 every minute and return the minute-average data across the chosen measurement interval. TEROS 12 data can be downloaded from these loggers using either ZENTRA Utility (desktop and mobile application) or ZENTRA Cloud (web-based application for cell-enabled data loggers).

## 2.2.2 CONNECTING TO A NON-METER LOGGER

The TEROS 12 can be used with non-METER (third-party) data loggers. Refer to the third-party logger manual for details on logger communications, power, and ground ports.

The [TEROS 12 Integrator Guide](#) provides detailed instructions on connecting sensors to non-METER loggers.

TEROS 12 sensors can be ordered with stripped and tinned (pigtail) connecting wires for use with screw terminals. Connect the TEROS 12 wires to the data logger illustrated in [Figure 2](#), with the supply wire (brown) connected to the excitation, the digital out wire (orange) to a digital input, and the bare ground wire to ground.

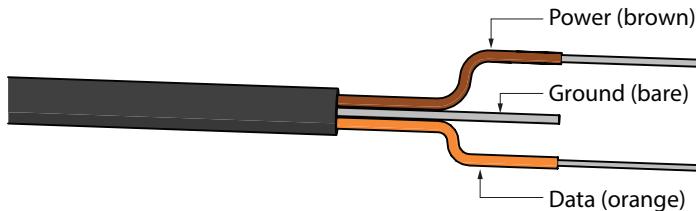


Figure 2 Pigtail wiring

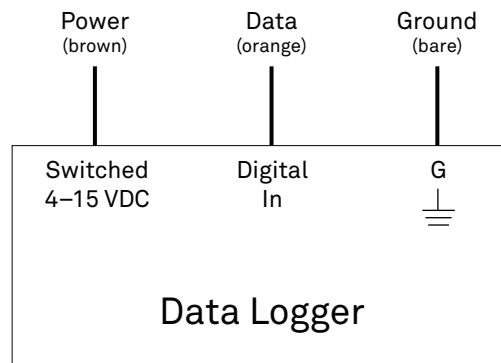


Figure 3 Wiring diagram

NOTE: The acceptable range of excitation voltages is from 4 to 15 VDC. To read TEROS 12 sensors with Campbell Scientific, Inc. data loggers, power the sensors from a switched 12 V port or a 12 V port if using a multiplexer.

If the TEROS 12 cable has a standard 3.5-mm stereo plug connector and will be connected to a non-METER data logger, please use one of the following two options.

#### Option 1

1. Clip off the 3.5-mm stereo plug connector on the sensor cable.
2. Strip and tin the wires.
3. Wire it directly into the data logger.

This option has the advantage of creating a direct connection with no chance of the sensor becoming unplugged. However, it then cannot be easily used in the future with a METER readout unit or data logger.

#### Option 2

Obtain an adapter cable from METER.

The adapter cable has a connector for the stereo plug connector sensor jack on one end and three wires (or pigtail adapter) on the other end for connection to a data logger. The stripped and tinned adapter cable wires have the same termination as seen in [Figure 3](#); the brown wire is excitation, the orange is output, and the bare wire is ground.

**NOTE:** Secure the 3.5-mm stereo plug connector to the pigtail adapter connections to ensure the sensor does not become disconnected during use.

## 2.3 COMMUNICATION

The TEROS 12 sensor communicates using two different methods:

- DDI serial string
- SDI-12 communication protocol

To obtain detailed instructions, read the [TEROS 12 Integrator Guide](#).

## 3. SYSTEM

This section reviews the components and functionality of the TEROS 12 sensor.

### 3.1 SPECIFICATIONS

#### MEASUREMENT SPECIFICATIONS

##### Volumetric Water Content (VWC)

Range	
Mineral soil calibration	0.00–0.70 m <sup>3</sup> /m <sup>3</sup>
Soilless media calibration	0.0–1.0 m <sup>3</sup> /m <sup>3</sup>
Apparent dielectric permittivity ( $\epsilon_a$ )	1 (air) to 80 (water)
NOTE: The VWC range is dependent on the media the sensor is calibrated to. A custom calibration will accommodate the necessary ranges for most substrates.	
Resolution	0.001 m <sup>3</sup> /m <sup>3</sup>
Accuracy	
Generic calibration	±0.03 m <sup>3</sup> /m <sup>3</sup> typical in mineral soils that have solution EC <8 dS/m
Medium specific calibration	±0.01–0.02 m <sup>3</sup> /m <sup>3</sup> in any porous medium
Apparent dielectric permittivity ( $\epsilon_a$ )	1–40 (soil range), ±1 $\epsilon_a$ (unitless) 40–80, 15% of measurement

##### Dielectric Measurement Frequency

70 MHz

##### Temperature

Range	-40 to 60 °C
Resolution	0.1 °C
Accuracy	±1 °C

##### Bulk Electrical Conductivity (EC<sub>b</sub>)

Range	0–20 dS/m (bulk)
Resolution	0.001 dS/m
Accuracy	±3% of measurement

**Output**

DDI serial or  
SDI-12 communications protocol

**Data Logger Compatibility**

Any data acquisition system capable of 4.0- to 15-VDC power  
and serial or SDI-12 communication

**PHYSICAL SPECIFICATIONS****Dimensions**

Length	9.4 cm (3.70 in)
Width	2.4 cm (0.95 in)
Height	7.5 cm (2.95 in)

**Needle Length**

5.5 cm (2.17 in)

**Cable Length**

5 m (standard)  
75 m (maximum custom cable length)

NOTE: Contact [Customer Support](#) if a nonstandard cable length is needed.

**Connector Types**

3.5-mm stereo plug connector or stripped and tinned wires

**ELECTRICAL AND TIMING CHARACTERISTICS****Supply Voltage (VCC) to GND**

Minimum	4.0 VDC
Typical	NA
Maximum	15.0 VDC

**Digital Input Voltage (logic high)**

Minimum	2.8 V
Typical	3.6 V
Maximum	3.9 V

**Digital Input Voltage (logic low)**

Minimum	-0.3 V
Typical	0.0 V
Maximum	0.8 V

**Power Line Slew Rate**

Minimum	1.0 V/ms
Typical	NA
Maximum	NA

**Current Drain (during 25-ms measurement)**

Minimum	3.0 mA
Typical	3.6 mA
Maximum	16.0 mA

**Current Drain (while asleep)**

Minimum	NA
Typical	0.03 mA
Maximum	NA

**Operating Temperature Range**

Minimum	-40 °C
Typical	NA
Maximum	60 °C

NOTE: Sensors may be used at higher temperatures under certain conditions; contact [Customer Support](#) for assistance.

**Power Up Time (DDI serial)**

Minimum	80 ms
Typical	NA
Maximum	100 ms

**Power Up Time (SDI-12)**

Minimum	NA
Typical	245 ms
Maximum	NA

## Measurement Duration

Minimum	25 ms
Typical	NA
Maximum	50 ms

## COMPLIANCE

Manufactured under ISO 9001:2015

EM ISO/IEC 17050:2010 (CE Mark)

2014/30/EU and 2011/65/EU

EN61326-1:2013 and EN55022/CISPR 22

## 3.2 COMPONENTS

The TEROS 12 sensor measures soil moisture, temperature, and electrical conductivity of soil using stainless steel needles (Figure 4). TEROS 12 sensors measure soil moisture between Needle 1 and Needle 2 and EC between Needle 2 and Needle 3. Temperature is measured with an embedded thermistor in Needle 2. These sensors have a low power requirement, which makes them ideal for permanent burial in the soil and continuous reading with a data logger or periodic reading with a handheld reader.

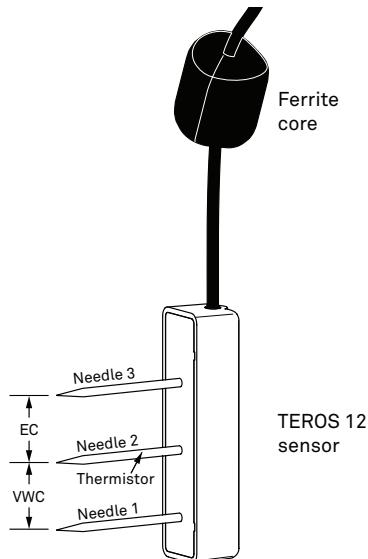


Figure 4 TEROS 12 sensor

## SYSTEM

A ferrite core positioned on the TEROS 12 sensor cable 7.6 cm (3 in) away from the sensor head is utilized to isolate the sensor from any interferences in the system. This mitigates any potential noise from the system on the measured sensor data. It is important to not attach anything to the section of cable between the sensor head and the ferrite core as this may influence the measurements.

The TEROS 12 VWC measurement sensitivity is contained within a 1010 mL volume roughly depicted in [Figure 5](#). Please see the application note [Measurement volume of METER volumetric water content sensors](#) (<https://www.metergroup.com/environment/articles/measurement-volume-meter-volumetric-water-content-sensors>) for testing protocol and more thorough analysis.

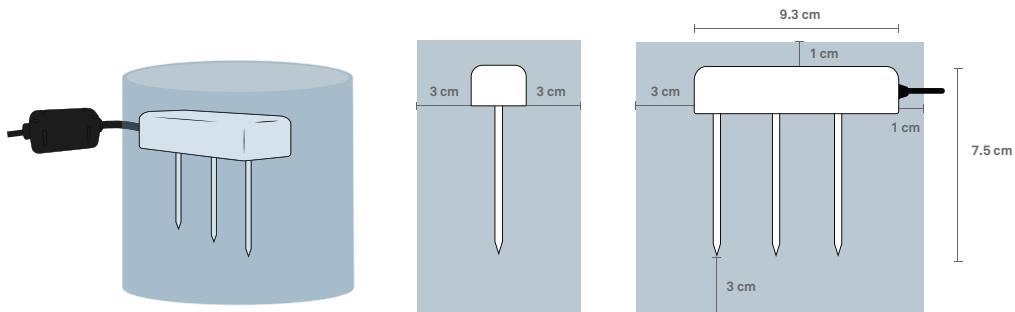


Figure 5 VWC volume of influence

NOTE: The TEROS 12 provides instantaneous or near-instantaneous measurements; however, because of the sensitivity of the measurement of the sensor head, the TEROS 12 is not well suited for spot measurements of VWC.

## 3.3 THEORY

### 3.3.1 VOLUMETRIC WATER CONTENT (VWC)

TEROS 12 sensors use an electromagnetic field to measure the dielectric permittivity of the surrounding medium. The sensor supplies a 70-MHz oscillating wave to the sensor needles, which charge according to the dielectric of the material. The charge time is proportional to substrate dielectric and substrate VWC. The TEROS 12 microprocessor measures the charge time and outputs a raw value based on the substrate dielectric permittivity. The raw value is then converted to VWC by a calibration equation specific to the substrate ([Section 4.1](#)).

### 3.3.2 TEMPERATURE

The TEROS 12 uses a thermistor in the center needle to take temperature readings. This is more important for measurements near the surface where temperature changes are faster. The TEROS 12 sensor output temperature is in degrees Celsius unless otherwise stated in the data logger program, such as in preferences in the ZENTRA software.

**NOTE:** Even though the sensor head is white, in direct sunlight, the temperature measurement may read high. Use caution when installing the sensor with the sensor head in the sun.

### 3.3.3 ELECTRICAL CONDUCTIVITY

Electrical conductivity (EC) is the ability of a substance to conduct electricity and can be used to infer the amount of ions that are present in solution. EC is measured by applying an alternating electrical current to two electrodes and measuring the resistance between them. Bulk electrical conductivity (Bulk EC) is derived by multiplying the inverse of the resistance (conductance) by the cell constant (the ratio of the distance between the electrodes to their area). TEROS 12 sensor bulk EC measurements are normalized to EC at 25 °C. The bulk EC measurement is factory calibrated to be accurate within ±3% of measurement from 0 to 20 dS/m. This range is adequate for most soil and growth substrate applications.

EC measurements above 10 dS/m are sensitive to contamination of the electrodes by skin oils, etc. Be sure to read [Section 4.2](#) about sensor cleaning if measuring the EC of salty soils.

### 3.3.4 CONVERTING BULK EC TO PORE EC

For many applications, it is advantageous to know the EC of the solution contained in the soil pores ( $\sigma_p$ ), which is a good indicator of the solute concentration in the soil. Traditionally,  $\sigma_p$  is obtained by extracting pore water from the soil and measuring  $\sigma_p$  directly, a time-consuming and labor-intensive process. The TEROS 12 sensor measures the EC of the bulk soil surrounding the sensors ( $\sigma_b$ ). A considerable amount of research has been conducted to determine the relationship between  $\sigma_b$  and  $\sigma_p$ . Hilhorst (2000) took advantage of the linear relationship between the soil bulk dielectric permittivity ( $\epsilon_b$ ) and  $\sigma_b$  to accurately convert  $\sigma_b$  to  $\sigma_p$  if the  $\epsilon_b$  is known. The TEROS 12 sensor measures  $\epsilon_b$  and  $\sigma_b$  nearly simultaneously in the same soil volume. Therefore, the TEROS 12 is well-suited to this method.

## SYSTEM

The pore water conductivity ( $\sigma_p$ ) is determined from [Equation 1](#) (see Hilhorst 2000 for derivation):

$$\sigma_p = \frac{\epsilon_p \sigma_b}{\epsilon_b - \epsilon_{ob=0}}$$
 **Equation 1**

where

- $\sigma_p$  is the pore water electrical conductivity (dS/m),
- $\epsilon_p$  is the real portion of the dielectric permittivity of the soil pore water (unitless),
- $\sigma_b$  is the bulk electrical conductivity (dS/m), measured directly by the TEROS 12,
- $\epsilon_b$  is the real portion of the dielectric permittivity of the bulk soil (unitless), and
- $\epsilon_{ob=0}$  is the real portion of the dielectric permittivity of the soil when bulk electrical conductivity is 0 (unitless).

Dielectric permittivity of the soil pore water ( $\epsilon_p$ ) is calculated from soil temperature using [Equation 2](#):

$$\epsilon_p = 80.3 - 0.37 \cdot (T_{soil} - 20)$$
 **Equation 2**

where  $T_{soil}$  is the soil temperature (°C) measured by the TEROS 12.

Finally,  $\epsilon_{ob=0}$  is an offset term loosely representing the dielectric permittivity of the dry soil. Hilhorst (2000) recommended that  $\epsilon_{ob=0} = 4.1$  be used as a generic offset. Hilhorst (2000) offers a simple and easy method for determining  $\epsilon_{ob=0}$  for individual soil types, which improves the accuracy of the calculation of  $\sigma_p$  in most cases.

METER testing indicates that the method for calculating  $\sigma_p$  ([Equation 1](#)) results in good accuracy ( $\pm 20\%$ ) in moist soils and other growth media. In dry soils, where VWC is less than about  $0.10 \text{ m}^3/\text{m}^3$ , the denominator of [Equation 1](#) becomes very small, leading to large potential errors. METER recommends that  $\sigma_p$  not be calculated in soils with  $\text{VWC} < 0.10 \text{ m}^3/\text{m}^3$  using this method.

### 3.3.5 PORE WATER VERSUS SATURATION EXTRACT EC

As noted in [Section 3.3.4](#), pore water electrical conductivity (EC) can be calculated from bulk EC using the sensor-measured dielectric permittivity of the medium. However, pore water EC is not the same as saturation extract EC.

Pore water EC is the electrical conductivity of the water in the pore space of the soil. This could be measured directly if the soil was squeezed under high pressure to force water out of the soil matrix and that water was collected and tested for EC.

Saturation extract EC is the electrical conductivity of pore water removed from a saturated paste. Saturation extract EC can be measured directly if distilled water is used to wet the soil until the soil saturates. The soil is then placed on filter paper in a vacuum funnel and suction is applied. An EC measurement on the water extracted from the saturated sample will give the saturation extract EC.

Theoretically, the pore water EC and saturation extract EC are related by the degree of saturation (VWC/total porosity) of the soil.

An example calculation illustrates this relationship:

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**Example** A soil is at 0.1 m<sup>3</sup>/m<sup>3</sup> VWC, has a pore water EC of 0.7 dS/m, and a dry bulk density of 1.5 Mg/m<sup>3</sup>

The total porosity of the soil can be calculated using [Equation 3](#):

$$\begin{aligned}\phi &= 1 - \frac{\rho_b}{\rho_s} \\ &= 1 - \frac{1.5}{2.65} \\ &= 0.43\end{aligned}\tag{Equation 3}$$

The saturation extract EC can be calculated as illustrated in [Equation 4](#):

$$\begin{aligned}\text{Solution EC} &= \frac{\sigma_p \Theta + \sigma_d(\phi - \Theta)}{\phi} \\ &= \frac{0.7(0.1) + 0}{0.43} \\ &= 0.162 \text{ dS/m}\end{aligned}\tag{Equation 4}$$

where

$\phi$  is the porosity,

$\rho_b$  is soil dry bulk density,

$\rho_s$  is density of the minerals (assumed to be 2.65 Mg/m<sup>3</sup>),

$\sigma_d$  is the EC of distilled water (0 dS/m), and

$\Theta$  is VWC.

In practice, solution EC calculated from this method and solution EC taken from a laboratory soil test may not agree well because wetting soil to a saturated paste is very imprecise.

## 4. SERVICE

### 4.1 CALIBRATIONS

Following is a list of the mineral soil, soilless media, and dielectric calibrations for TEROS 12, where  $\Theta$  is the VWC (in  $m^3/m^3$ ), where  $\epsilon$  is dielectric, and where RAW is the raw sensor output, when read with a METER or third-party data logger.

The TEROS 12 is not sensitive to variation in soil texture and EC because it runs at a high measurement frequency. Therefore, its generic calibration equation should result in reasonable absolute accuracy;  $0.03\ m^3/m^3$  for most mineral soils up to  $8\ dS/m$  saturation extract. Its calibration equations are shown below for mineral soil, soilless growing media (i.e., potting soil, perlite, or peat moss), and dielectric permittivity. However, for added accuracy, customers are encouraged to perform [soil-specific calibrations](https://www.metergroup.com/soil-sensor-calibration) (<https://www.metergroup.com/soil-sensor-calibration>).

#### 4.1.1 CALIBRATION FOR MINERAL SOILS

According to METER tests, a single calibration equation will generally suffice for most mineral soil types with ECs from  $0\ dS/m$  to  $8\ dS/m$  saturation extract. VWC ( $\Theta$ ) is given by [Equation 5](#):

$$\Theta(m^3/m^3) = 3.879E^{-4} \cdot RAW - 0.6956 \quad \text{Equation 5}$$

A linear equation is used for the mineral soil calibration because it provides the best predictions of VWC in the range of VWC found in mineral soils, but this equation reaches a maximum at approximately  $0.70\ m^3/m^3$  in pure water. To display data on a scale from  $0$  to  $1.0\ m^3/m^3$ , VWC should be modeled with a quadratic equation (which would result in a  $1.0\ m^3/m^3$  in water). However, METER does not recommend this for mineral soils because it often makes the calibration in the range of VWC found in mineral soil less accurate.

#### 4.1.2 CALIBRATION FOR SOILLESS MEDIA

TEROS 12 sensors are calibrated in potting soil, perlite, and peat. The goal is to create a generic calibration equation that will work in many nonsoil substrates with an accuracy of better than  $0.05\ m^3/m^3$ . For higher accuracy, performing a media-specific calibration should improve the accuracy to  $0.01$  to  $0.02\ m^3/m^3$ . The differences between mineral soil and soilless media calibrations are caused by high-air volume in the organic soils that lowers the starting (dry media) dielectric of the sensor. For more information on how to calibrate sensors or to learn about METER calibration service (calibrations performed for a standard fee), review the article on [soil sensor calibration](https://www.metergroup.com/soil-sensor-calibration) (<https://www.metergroup.com/soil-sensor-calibration>) or contact [Customer Support](#).

The calibration for several potting soils, perlite, and peat moss is shown in [Equation 6](#):

$$\Theta(\text{m}^3/\text{m}^3) = 6.771\text{E}^{-10} \cdot \text{RAW}^3 - 5.105\text{E}^{-6} \cdot \text{RAW}^2 - 1.302\text{E}^{-2} \cdot \text{RAW} - 10.848 \quad \text{Equation 6}$$

### 4.1.3 CALIBRATION FOR APPARENT DIELECTRIC PERMITTIVITY ( $\epsilon_a$ )

Apparent dielectric permittivity ( $\epsilon_a$ ) can be used to determine VWC using external published equations such as the Topp equation (Topp et al., 1980). Dielectric permittivity is also used for calculating pore water EC. Dielectric permittivity is given by [Equation 7](#):

$$\epsilon = 1.112\text{E}^{-18} \cdot \text{RAW}^{5.607} \quad \text{Equation 7}$$

## 4.2 CLEANING THE SENSORS

If the sensor needles become contaminated with oils from contact with skin or another source, it is necessary to clean the needles to ensure accurate EC readings in salty soils with bulk EC greater than 10 dS/m.

1. Clean each needle using a mild detergent such as liquid dish soap and a nonabrasive sponge or cloth.

**NOTE:** Avoid detergents that contain lotions or moisturizers.

2. Rinse the sensor and needles thoroughly with tap or deionized water (DI) water.

**NOTE:** Do not touch the needles with an ungloved hand or bring them in contact with any source of oil or other nonconducting residue.

## 4.3 TROUBLESHOOTING

**Table 3 Troubleshooting the TEROS 12**

Problem	Possible Solution
Sensor not responding	<p>Check power to the sensor.</p> <p>Check sensor cable and 3.5-mm plug connector integrity.</p> <p>Check data logger wiring to ensure brown is power supply, orange is digital out, and bare is ground.</p>
Sensor reading too low (or slightly negative)	<p>Check for air gaps around sensor needles. These could be produced below the surface of the substrate when the needle contacts a large piece of material and pushes it out of the way, or if the sensor is not inserted perfectly linearly.</p> <p>Ensure the calibration equation being used is appropriate for the media type. There are significant differences between substrate calibrations, so be sure to use the one specific to the substrate.</p>

**Table 3 Troubleshooting the TEROS 12 (continued)**

Problem	Possible Solution
Sensor reading too high	<p>Check to make sure that the media was not packed excessively or insufficiently during sensor installation. Higher density can cause sensor reading to be elevated.</p> <p>Ensure the calibration equation being used is appropriate for the media type. There are significant differences between calibrations, so be sure to use the one most suitable to the substrate, or consider developing a substrate-specific calibration for the particular medium.</p> <p>Some substrates have an inherently high dielectric permittivity (soils of volcanic origin or high titanium, for instance). If the substrate has a dry dielectric permittivity above 6, a custom calibration may need to be performed. Soils with a Bulk EC greater than 10 dS/m require substrate specific calibrations (<a href="#">Section 4.1</a>).</p>
Cable or stereo plug connector failure	<p>If a stereo plug connector is damaged or needs to be replaced contact <a href="#">Customer Support</a> for a replacement connector and splice kit.</p> <p>If a cable is damaged follow these <a href="#">guidelines for wire splicing and sealing techniques</a>.</p>

## 4.4 CUSTOMER SUPPORT

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 7 am–5 pm Pacific time.

**Email:** [support.environment@metergroup.com](mailto:support.environment@metergroup.com)  
[sales.environment@metergroup.com](mailto:sales.environment@metergroup.com)

**Phone:** +1.509.332.5600

**Fax:** +1.509.332.5158

**Website:** [metergroup.com](http://metergroup.com)

If contacting METER by email, please include the following information:

Name	Email address
Address	Instrument serial number
Phone	Description of the problem

**NOTE: For TEROS 12 sensors purchased through a distributor, please contact the distributor directly for assistance.**

## 4.5 TERMS AND CONDITIONS

**CONTRACT FORMATION.** All requests for goods and/or services by METER Group, Inc. USA (METER) are subject to the customer's acceptance of these Terms and Conditions. The Buyer will be deemed to have irrevocably accepted these Terms and Conditions of Sale upon the first to occur of the Buyer's issuance of a purchase order or request for goods or services. Unless expressly assented to in writing by METER, terms and conditions different are expressly rejected. No course of dealing between the parties hereto shall be deemed to affect or to modify, amend, or discharge any provisions of this agreement.

**PRICES AND PAYMENT.** Invoice prices will be based upon METER prices as quoted or at METER list price in effect at the time an order is received by the Seller. Prices do not include any state or federal taxes, duties, fees, or charges now or hereafter enacted applicable to the goods or to this transaction, all of which are the responsibility of the Buyer. Unless otherwise specified on the invoice, all accounts are due and payable 30 days from the date of invoice. Unpaid accounts extending beyond 30 days will be subject to a service charge of 2% per month (24% per annum). Should Seller initiate any legal action or proceeding to collect on any unpaid invoice, Seller shall be entitled to recover from Buyer all costs and expenses incurred in connection therewith, including court costs and reasonable attorney's fees.

**RISK OF LOSS AND DELIVERY TITLE.** Liability for loss or damage passes to the Buyer when the Seller delivers the goods on the Seller's dock or to the transporting agent, whichever occurs first. The Seller has the right to deliver the goods in installments. Shipping and delivery dates communicated by the Seller to the Buyer are approximate only.

**SHIPMENT.** In the absence of specific shipping instructions, the Seller, if and as requested by the Buyer, will ship the goods by the method the Seller deems most advantageous. Where the Seller ships the goods, the Buyer will pay all transportation charges that are payable on delivery or, if transportation charges are prepaid by the Seller, the Buyer will reimburse the Seller upon receipt of an invoice from the Seller. The Buyer is obligated to obtain insurance against damage to the goods being shipped. Unless otherwise specified, the goods will be shipped in the standard Seller commercial packaging. When special packing is required or, in the opinion of the Seller, required under the circumstances, the cost of the special packaging shall be the responsibility of the Buyer.

**INSPECTION AND ACCEPTANCE.** Goods will be conclusively deemed accepted by the Buyer unless a written notice setting out the rejected goods and the reason for the rejection is sent by the Buyer to the Seller within 10 days of delivery of the goods. The Buyer will place rejected goods in safe storage at a reasonably accessible location for inspection by the Seller.

**CUSTOM GOODS.** There is no refund or return for custom or nonstandard goods.

**WARRANTIES.** The Seller warrants all equipment manufactured by it to be free from defects in parts and labor for a period of one year from the date of shipment from factory. The liability of the Seller applies solely to repairing, replacing, or issuing credit (at the Seller's sole discretion) for any equipment manufactured by the Seller and returned by the Buyer during the warranty period. SELLER MAKES NO SEPARATE OR OTHER WARRANTY OF ANY NATURE WHATSOEVER, EXPRESS OR IMPLIED, INCLUDING THE WARRANTY OF MERCHANTABILITY OR FOR A PARTICULAR PURPOSE. There shall be no other obligations either expressed or implied.

**LIMITATION OF LIABILITY.** Seller will not be liable to the Buyer or any other person or entity for indirect special, incidental, consequential, punitive, or exemplary damages in connection with this transaction or any acts or omissions associated therewith or relating to the sale or use of any goods, whether such claim is based on breach of warranty, contract, tort, or other legal theory and regardless of the causes of such loss or damages or whether any other remedy provided herein fails. In no event will the Seller's total liability under this contract exceed an amount equal to the total amount paid for the goods purchased hereunder.

**WAIVER.** In the event of any default under or breach of the contract by the Buyer, the Seller has the right to refuse to make further shipments. The Seller's failure to enforce at any time or for any period of time the provisions of this contract will not constitute a waiver of such provisions or the right of the Seller to enforce each and every provision.

**GOVERNING LAW.** The validity, construction, and performance of the contract and the transactions to which it relates will be governed by the laws of the United States of America. All actions, claims, or legal proceedings in any way pertaining to this contract will be commenced and maintained in the courts of Whitman County, State of Washington, and the parties hereto each agree to submit themselves to the jurisdiction of such court.

**SEVERABILITY.** If any of the Terms and Conditions set out in this contact are declared to be invalid by a court, agency, commission, or other entity having jurisdiction over the interpretation and enforcement of this contract, the applications of such provisions to parties or circumstances other than those as to which it is held invalid or unenforceable will not be affected. Each term not so declared invalid or unenforceable will be valid and enforced to the fullest extent permitted by law and the rights and obligations of the parties will be construed and enforced as though a valid commercially reasonable term consistent with the undertaking of the parties under the order has been substituted in place of the invalid provision.

**SET-OFF.** The Buyer may not set-off any amount owing from the Seller to the Buyer against any amount payable by the Buyer to the Seller whether or not related to this contract.

## REFERENCES

- Hilhorst MA. 2000. A pore water conductivity sensor. *Soil Science Society of America Journal* 64:6 1922–1925.
- Topp GC, David JL, and Annan AP. 1980. Electromagnetic determination of soil water content: Measurement in coaxial transmission lines. *Water Resources Research* 16(3): 574–582.

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