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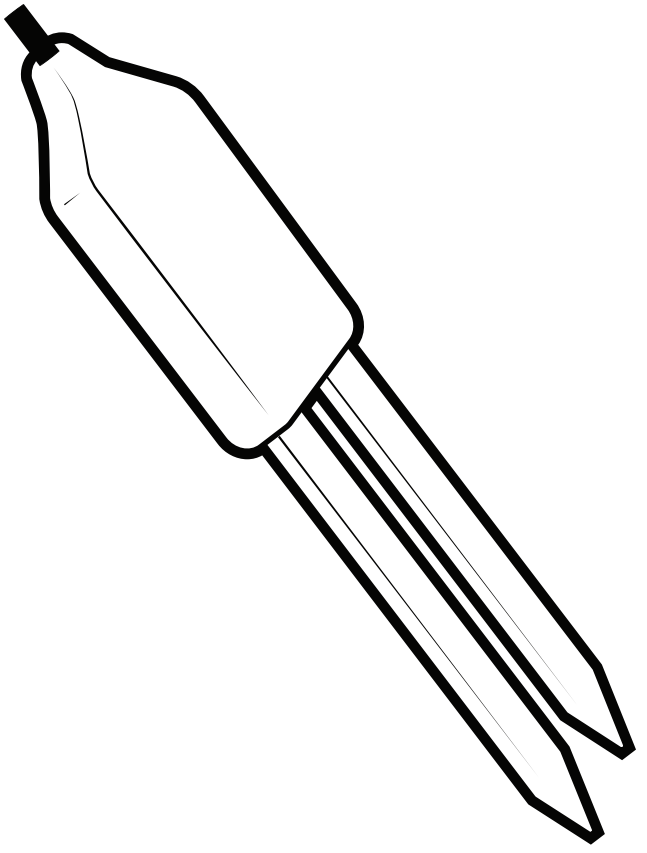

1. INTRODUCTION

Thank you for choosing the ECH$_2$O EC-5 Volumetric Water Content sensor from METER Group.

This manual guides the customer through the sensor features and describes how to use the sensor successfully. METER hopes the contents of this manual are useful in understanding the instrument and maximizing its benefit.

Prior to use, verify the EC-5 arrived in good condition.

2. OPERATION

Please read all instructions before operating the EC-5 to ensure it performs to its full potential.

⚠ PRECAUTIONS

METER sensors are built to the highest standards, but misuse, improper protection, or improper installation may damage the sensor and possibly void the manufacturer's warranty. Before integrating EC-5 into a system, follow the recommended installation instructions and have the proper protections in place to safeguard sensors from damage.

2.1 INSTALLATION

When selecting a site for installation, it is important to remember that the soil adjacent to the sensor surface has the strongest influence on the sensor reading and that the sensor measures the VWC.

Any air gaps or excessive soil compaction around the sensor can profoundly influence the readings. Also, do not install the sensors adjacent to large metal objects, such as metal poles or stakes. This can attenuate the sensors electromagnetic field and adversely affect output readings. Because the EC-5 has gaps between its prongs, it is also important to consider the particle size of the media. It is possible to get sticks, bark, roots or other material stuck between the sensor prongs, which will adversely affect readings. Finally, be careful when inserting the sensors into dense soil, as the prongs will break if excessive sideways force is used.

When installing the EC-5, it is best to maximize contact between the sensor and the soil.

- If installing sensors in a lightning prone area with a grounded data logger, please read Lightning surge and grounding practices.
- Test the sensors with the data logging device and software before going to the field.

When installing the EC-5, it is imperative to maximize contact between the sensor and soil. For most accurate results, the sensor should be inserted into undisturbed soil. There are two basic methods to accomplish a high-quality installation.

With either of these methods, the sensor may still be difficult to insert into extremely compact or dry soil.

NOTE: Never pound the sensor into the soil! If there is difficulty inserting the sensor, loosen or wet the soil.

METHOD 1. HORIZONTAL INSTALLATION

1. Excavate a hole or trench a few centimeters deeper than the depth at which the sensor is to be installed.
2. At the installation depth, shave off some soil from the vertical soil face exposing undisturbed soil.

3. Insert the sensor into the undisturbed soil face until the entire sensor is inserted. The tip of each prong has been sharpened to make it easier to push the sensor into the soil. Be careful with the sharp tips!
4. Backfill the trench taking care to pack the soil back to natural bulk density around the sensor body of the EC-5 .

METHOD 2. VERTICAL INSTALLATION

1. Auger a 3-in hole to the depth at which the sensor is to be installed.
2. Insert the sensor into the undisturbed soil at the bottom of the auger hole using a hand or any other implement that will guide the sensor into the soil at the bottom of the hole. Many people have used a simple piece of PVC pipe with a notch cut in the end for the sensor to sit in, with the sensor cable routed inside the pipe.
3. After inserting the sensor, backfill the hole, taking care to pack the soil back to natural bulk density while not damaging the black overmolding of the sensor and the sensor cable in the process.

Make sure that the sensor prongs and sensor body are buried completely. Carefully backfill the hole to match the bulk density of the surrounding soil. Be careful not to bend the black overmolding connecting the sensor to the cable.

View a visual demonstration on proper installation of the sensor in How to install soil moisture sensors.

The sensor can be oriented in any direction. However, orienting the flat side perpendicular to the surface of the soil will minimize effects on downward water movement.

2.2 REMOVING THE SENSOR

When removing the sensor from the soil, do not pull it out of the soil by the cable. Doing so may break internal connections and make the sensor unusable.

2.3 CONNECTING

The EC-5 works most efficiently with METER ZENTRA, EM60, or Em50 data loggers, and it can also be used with other data loggers, such as those from Campbell Scientific, Inc. (Section 2.4).

EC-5 sensors require an excitation voltage in the range of 2.5 to 3.6 VDC.

The EC-5 sensors come with a 3.5-mm stereo plug connector (Figure 1) to facilitate easy connection with METER loggers. EC-5 sensors may be ordered with stripped and tinned wires to facilitate connecting to some third-party loggers (Section 2.3.2).

Figure 1 Stereo plug connector

The EC-5 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 40 m.

2.3.1 CONNECT TO A METER DATA LOGGER

The EC-5 sensor works seamlessly with METER ZENTRA, EM60, or Em50 data loggers. Check the METER download webpage for the most recent data logger firmware. 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) (Section 2.4.2).

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 EC-5.
3. Set the measurement interval.

2.3.2 CONNECT TO A NON-METER DATA LOGGER

The EC-5 sensor can be used with non-METER (third-party) data loggers. Refer to the third-party logger manual for details on logger communications, power supply, and ground ports. EC-5 sensors can be ordered with stripped and tinned (pigtail) connecting wires for use with screw terminals. Connect the EC-5 wires to the data logger as illustrated in Figure 2 and Figure 3, with the power supply wire (brown) connected to the excitation, the analog out wire (orange) to an analog input, and the bare ground wire to ground.

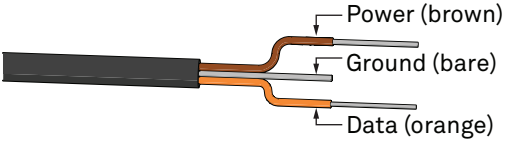

Figure 2 Pigtail wiring

NOTE: Some EC-5 sensors may have the older Decagon wiring scheme where the power supply is white, the analog out is red, and the bare wire is ground.

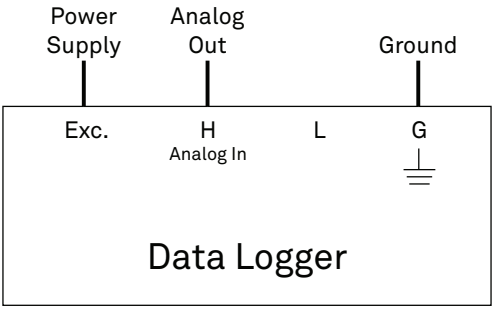

Figure 3 Wiring diagram

If the EC-5 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 female stereo plug connector on one end and three wires (or pigtail adapter) for connection to a data logger on the other end. 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 stereo plug connector to the pigtail adapter connections to ensure the sensor does not become disconnected during use.

2.4 INTERFACING WITH DATA LOGGERS

2.4.1 DATA LOGGER REQUIREMENTS

The EC-5 sensor is designed to work most efficiently with METER data loggers. All METER readout devices use a 3.0-VDC excitation.

The sensors, however, may be adapted for use with other data loggers, such as those from Campbell Scientific, Inc., for example. The EC-5 requires an excitation voltage in the range of 2.5 to 3.6 VDC. The sensors produce an output voltage that depends on the dielectric constant of the medium surrounding the sensor, and ranges between 10% and 50% of the excitation voltage. Any data logger which can produce a 2.5- to 3.6-VDC excitation with approximately 10-ms duration and read a volt level signal with 12-bit or better resolution should be compatible with the EC-5 sensor. The current requirement for the EC-5 is 10 mA at 2.5 VDC.

METER designed the EC-5 sensor for use with data loggers and readout devices that provide short excitation pulses, leaving the sensors turned OFF most of the time. Continuous excitation not only wastes battery power, but may, under certain circumstances, cause the sensor to exceed government specified limits on electromagnetic emissions. Do not continuously power the EC-5 sensor.

2.4.2 METER DATA LOGGERS

METER data loggers can be configured using ZENTRA Utility (a desktop and mobile application) or ZENTRA Cloud (a web-based application for cellular-enabled ZENTRA data loggers). Contact Customer Support for more information about these programs.

2.4.3 NON-METER DATA LOGGERS

Non-METER data loggers may require programming to read the EC-5 sensor. METER provides some resources to help interface with Campbell Scientific loggers.

The Campbell Scientific SCWin (Short Cut) program for the EC-5 soil moisture sensor is available.

3. SYSTEM

This section describes the EC-5 sensor.

3.1 SPECIFICATIONS

MEASUREMENT SPECIFICATIONS

Volumetric Water Content (VWC)	
Range	0%–100%
Resolution	0.001 m^3/m^3 VWC in mineral soils, 0.25% in growing media
Accuracy	
Generic calibration	±0.03 m^3/m^3 typical in mineral soils that have solution EC <8 dS/m
Medium-specific calibration	±0.02 m^3/m^3 in any porous medium (± 2%)
Temperature	
Range	–40 to +60 °C
Resolution	0.1 °C
Accuracy	±1 °C

COMMUNICATION SPECIFICATIONS

Output

10%–40% of excitation voltage (250–1,000 mV at 2,500 mV excitation)

Data Logger Compatibility

Data aquisition systems capable of switched 2.5–3.6 VDC excitation and single-ended voltage measurement at greater than or equal to 12-bit resolution.

NOTE: These calibration constants only apply to 2,500-mV exictation; use of these numbers with any other excitation voltage results in erroneous readings!

PHYSICAL SPECIFICATIONS

Dimensions	
Length	8.9 cm (3.50 in)
Width	1.8 cm (0.71 in)
Height	0.7 cm (0.28 in)
Prong Length	
5 cm (1.97 in)	
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.

Cable Length
5 m (standard) 40 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 (VIN to GND)	
Minimum	2.5 VDC at 10 mA
Typical	NA
Maximum	3.6 VDC at 10 mA
Measurement Duration	
Minimum	NA
Typical	NA
Maximum	10 ms

COMPLIANCE
Manufactured under ISO 9001:2015
EM ISO/IEC 17050:2010 (CE Mark)
2014/30/EU
2011/65/EU
EN61326-1:2013
EN50581:2012

3.2 ABOUT EC-5

The EC-5 determines volumetric water content (VWC) by measuring the dielectric constant of the media using capacitance and frequency domain technology. The 70-MHz frequency minimizes salinity and textural effects, making this sensor accurate in almost any soil or soilless media. It arrives with factory calibration for mineral soils, potting soils, and perlite included in this user manual.

The two-prong design and higher measurement frequency allows the EC-5 to measure VWC from 0% to 100% (VWC of saturated soils is generally 40% to 60% depending on the soil type) and allows accurate measurement of all soils and soilless medias with a wide range of salinities.

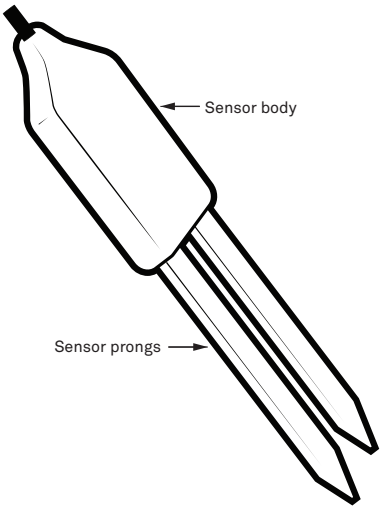

Figure 4 EC-5 components

4. SERVICE

This section contains calibration information, cleaning and maintenance guidelines, troubleshooting guidelines, customer support contact information, and terms and conditions.

4.1 CALIBRATION

METER software tools automatically apply factory calibrations to the sensor output data. However, this general calibration may not be applicable for all soil types. For added accuracy METER encourages customers to perform soil-specific calibrations.

Which calibration equation to use depends on where it is used. If the calibration equation is used with sensors connected to a non-METER data logger, use the calibration appropriate to the excitation voltage. If any METER software is used or the user calibration menu in the ProCheck is used, use the RAW calibration.

4.2 SENSOR CALIBRATION VALUES

Following is a list of both the millivolt and RAW calibration values for the EC-5, where ε_a is the VWC, mV is the millivolt output of the sensor, and RAW is the raw sensor output.

The EC-5 is less sensitive to variation in texture and electrical conductivity because it runs at a much higher measurement frequency. Therefore, its general calibration equation should apply for all mineral soils up to 8 dS/m saturation extract. Its calibration equations are shown below for mineral soil and potting soil growing media.

4.2.1 APPARENT DIELECTRIC PERMITTIVITY

Dielectric permittivity can be used to determine VWC using external published equations such as the Topp equation (Topp, David, and Annan 1980). Dielectric permittivity is given by Equation 1:

$$\varepsilon_a = \frac{1}{(-1.10570\times10^{-9})(RAW^3)+(3.575\times10^{-6})(RAW^2)-(3.9557\times10^{-3})(RAW)+1.53153} \quad \textbf{Equation 1}$$

where RAW is the output from the METER data logger using 3-V excitation.

If using a non-METER data logger, dielectric permittivity is given by Equation 2:

$$\varepsilon_a = \frac{1}{(-3.3325\times10^{-9})(mV^3)+(7.0218\times10^{-6})(mV^2)-(5.11647\times10^{-3})(mV)+1.30746} \quad \textbf{Equation 2}$$

4.2.2 MINERAL SOILS

According to METER tests, a single calibration equation generally suffices for all mineral soil types with electrical conductivities from 0.1 to 10 dS/m saturation extract. VWC (θ) is given by Equation 3:

$$\theta = (8.5\times10^{-4})(RAW)-0.48 \quad \textbf{Equation 3}$$

where RAW is the output from the METER data logger using 3-V excitation.

If a non-METER data logger is being used, VWC is given by Equation 4:

$$\theta = (11.9 \times 10^{-4})(mV) - 0.401 \quad \textbf{Equation 4}$$

where mV is the output of the sensor when excited at 2,500 mV. Please note that the equation reaches a maximum at ~60% VWC in pure water. To display data on a scale from 0% to 100%, VWC should be modeled with a quadratic equation (which would result in a 100% VWC in water), but a linear equation fits the mineral soil VWC range as well as the quadratic, and linear equations are easier to deal with, especially since mineral soil typically saturates at ~40% to 50% VWC.

4.2.3 POTTING SOIL

The following equations can be used to convert EC-5 output to water content in potting soil. METER tested several types of potting soil (Sunshine mix, Miracle Grow Potting Mix, and Custom Nursery soil) at several salinities and found that VWC is given in Equation 5 for a METER data logger

$$\theta = (1.3 \times 10^{-3})(RAW) - 0.696 \quad \textbf{Equation 5}$$

and in Equation 6 for a non-METER data logger

$$\theta = (2.11 \times 10^{-3})(mV) - 0.675 \quad \textbf{Equation 6}$$

NOTE: These calibration constants only apply to 2,500-mV excitations; use of these numbers with any other excitation voltage results in erroneous readings!

4.3 TROUBLESHOOTING

If problems with the EC-5 are encountered, they most likely manifest themselves in the form of incorrect or erroneous readings. Review the information in Table 1 and the Troubleshooting METER soil moisture sensors video to identify the problem. Contact Customer Support for more information.

Table 1 Troubleshooting the EC-5

Problem	Possible Solution
Sensor not responding	Check power to the sensor. Check sensor cable and stereo plug connector integrity. Check data logger wiring to ensure brown is power supply, orange is analog out, and bare is ground. **NOTE: Some EC-5 sensors may have the older Decagon wiring scheme where the power supply is white, the analog out is red, and the bare wire is ground.**
Sensor reading too low (or slightly negative)	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. 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.
Sensor reading too high	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. 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. 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 >10 dS/m require substrate-specific calibrations (Section 4.1).
Cable or stereo plug connector failure	If a stereo plug connector is damaged or needs to be replaced, contact Customer Support for a replacement connector and splice kit. If a cable is damaged, follow these these guidelines for wire splicing and sealing techniques.

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
sales.environment@metergroup.com

Phone: +1.509.332.5600

Fax: +1.509.332.5158

Website: 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 EC-5 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

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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