METER
ENVIRONMENT

SLAB-SPECIFIC CALIBRATIONS FOR METER SOIL MOISTURE SENSORS (STONE WOOL)

Our experience with custom calibrations in slabs is that it does not result in the same +/- 1 to 2% accuracy as expected for mineral soils. Generally, it is in the range of 5 to10% or better. Because slabs typically have a gradient of water, the relationship ends up being between sensor output and the water content of the entire slab, not the water content at that exact sensor location within the slab.

The following is a step-by-step instruction guide for performing slab-specific calibrations on stone wool or other non-granular soilless substrates. For convenience, METER also provides a Custom Calibration Service.

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STONE WOOL METHOD INSTRUCTIONS

1. Equipment needed

1.1 **METER soil moisture sensor** (1)

1.1.1. METER sensor output is very similar among sensors of the same type. You can calibrate with a single sensor and apply that calibration to other sensors of that type and maintain excellent accuracy.

1.1.2 Preferred sensors for use in soilless substrate slabs are the GS3 and TEROS 12.

1.1.2.1 Increased spacing between sensor pins (compared to 5TE/TM) and sharp stainless steel pins allow for a cleaner insertion.

1.1.2.2 The idealized measurement volume is focused away from the back of the sensor. This allows the sensor to be installed on the surface/sidewall of a slab with minimal influence from air or other materials.

1.1.3 Note that the measurement volumes of the GS3 and TEROS 12 are quite different (see Figures 1 and 2 below).

1.1.3.1 The GS3 has a relatively small volume, which is best for small containers.

1.1.3.2 The TEROS 12 has a larger one-liter measurement volume, which has the advantage of averaging over more of the slab.

1.2 **Automated band saw** for cutting slabs (1)

1.3 **Permanent marker** for labeling slabs (1)

1.4 **Stone wool slab(s)** (4 to 5)

1.4.1 Slabs for calibration (1 to 2 depending on expected EC levels [see 2.1.1.1])

1.4.2 Slabs for a water column (3 to 4)

1.5 **Large scale** (1)

1.5.1 Make sure the scale used to weigh the slab sample can accommodate the mass of the saturated slab, the sensor, and the reader/logger.

1.5.2 The scale should have a resolution of 0.1 g or better for best possible calibration.

1.6 **Calipers or measuring stick/tape** to measure dimensions of the slab (1)

1.7 **Data acquisition system** (1)

1.7.1 Use whatever data acquisition system will be used in the greenhouse (ProCheck, ZL6, EM60G, EM50, EM5B, Campbell Scientific data logger, etc.).

1.8 **Containers** (2)

1.8.1 One container for saturating calibration slab(s) in EC solution

1.8.2 One container large enough for saturating 3 to 4 water column slabs

1.9 **Sodium chloride** for creating electrical conductivity (EC) solutions

1.10 **EC meter** for verifying the EC of your solution (or use a GS3/TEROS 12) (1)

2. Create EC solution(s)

2.1 Create one to two water solution(s) with electrical conductivities (EC) that span the expected range of irrigation water.

2.1.1 It is generally acceptable to conduct the calibration with a solution at one EC level unless the EC in the slab will change dramatically during growing operations.

2.1.2 If this is the case, create a calibration curve for two different slabs in two different solutions (one at the highest expected dS/m and one at the lowest expected dS/m), and average.

2.2 Add sodium chloride in small amounts to a container of water until the solution reaches the desired EC level.

2.3 If two solutions are created, label the containers with the corresponding dS/m value.

2.4. Verify solution EC levels with an EC meter or a GS3/TEROS 12 soil moisture sensor.

2.5 Let the solution come to room temperature.

3. Slab preparation

3.1 **Calibration slab**

3.1.1 Cut a piece of slab.

3.1.1.1 Slab(s) should be the appropriate size for the sensor selected (see Figures 1 and 2 below), the scale used for mass measurement, and the container used for saturation (15 cm x 15 cm is a common size).

3.1.1.2 An automated band saw works best for cutting the slab. A precise cut will make dimension measurements easier and more consistent.

3.1.2 Obtain a permanent marker to label the slab with the intended dS/m value, the mass of the slab, and its dimensions.

3.1.3 Measure the exact slab dimensions (length, width, height) with calipers or a measuring tape.

3.1.4 Record dimensions in Table 1 (see downloadable spreadsheet below) and on the slab.

3.1.5 Weigh the dry slab (m_{slab}) and sensor, including the cable (m_{cable}).

3.1.6 Record the weight values in Table 1 (downloadable spreadsheet) and on the slab.

3.1.7 Soak the calibration slab in the EC solution for 30 minutes to one hour until fully saturated.

3.2 **Water column slabs**

3.2.1 Fill a large container with tap water. Let the water come to room temperature.

3.2.2 Cut 3 to 4 slabs, each approximately the same size as the calibration slab.

3.2.3 Soak all of the slabs at once in the water for 30 minutes to one hour until fully saturated.

3.2.4 Once slabs are saturated, remove slabs, and drain the water from the container.

3.2.5 Return slabs to the container, stacking them into a tower, one on top of the other. This water column will be used to help drain water from the calibration slab.

Sample + Sensor(s) + Container Weights		Water wt	Calculated VWC	Sensor Measurements		
				GS3 Raw		Average
Drying Points	g	g	$m^3\ m^{-3}$	2.5 cm	7.5 cm	RAW
Saturation	2539.7	2084.9	0.92	1726.1	1724.9	1725.5
Point 2	2395.3	1940.5	0.86	1731.2	1739.6	1735.4
Point 3	2278	1823.2	0.81	1720	1692.5	1706.25
Point 4	2140.3	1685.5	0.75	1685.7	1583.6	1634.65
Point 5	1997.1	1542.3	0.68	1670.6	1503.1	1586.85
Point 6	1828.4	1373.6	0.61	1618.1	1443.2	1530.65
Point 7	1644.9	1190.1	0.53	1554.5	1391.2	1472.85
Point 8	1496.8	1042.0	0.46	1518.2	1350	1434.1
Point 9	1384.1	929.3	0.41	1466.7	1307	1386.85
Point 10	1279.1	824.3	0.37	1411.2	1271.5	1341.35
Point 11	1182.3	727.5	0.32	1365.7	1244	1304.85
Point 12	978.6	523.8	0.23	1258.8	1198.8	1228.8
Point 13	891	436.2	0.19	1201.2	1178.2	1189.7

Table 1. Example of a partial data collection table for slab-specific METER sensor calibration. Download the full spreadsheet below.

Download this excel spreadsheet (with cell operations) for your own use.

4. CALIBRATION PROCEDURE

4.1 Remove the calibration slab from the EC solution, and set it on the counter.

4.2 Quickly insert the soil moisture sensor into the saturated slab.

4.2.1 The sensor should be inserted into the exact same vertical position and orientation for measurements in the field/greenhouse as they were inserted when collecting raw data for the calibration.

4.2.2 The sensor can be inserted into the side or top of the slab, but be mindful of spatial variability in slab water content. At mid to high water content levels, there will be a large gradient in water content from the top of the slab to the bottom.

4.2.3 To measure EC more accurately, insert the sensor midway or lower.

4.2.4 It is possible to calibrate multiple sensors at multiple depths. If desired, use multiple sensors and a data logger to take simultaneous readings in the same slab.

4.2.5 Sensor pins should be fully covered by the slab material. At a minimum, the material should fill the area outlined in Figure 1 or Figure 2 below.

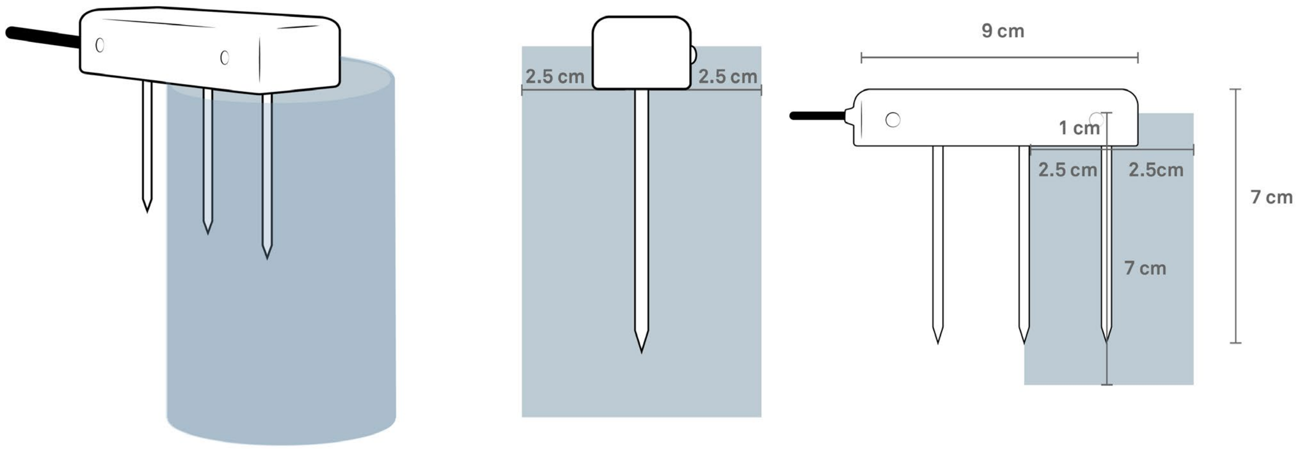

Figure 1. Idealized measurement volume of METER GS3 sensor

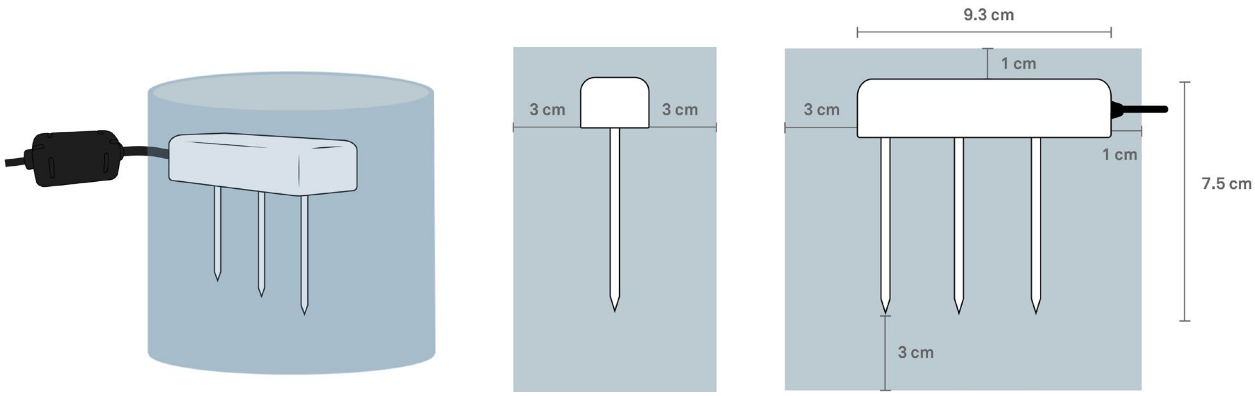

Figure 2. Idealized measurement volume of METER's TEROS 12 sensor

4.3 Place the saturated calibration slab (with sensor inserted) onto the scale.

4.4 Quickly collect a raw sensor reading in the slab using a Procheck or data logger.

4.5 Record the weight (m_{total}) and the raw sensor value in Table 1.

4.6 Pick up the calibration slab (with sensor inserted), and place it on top of the water column tower for approximately three seconds. The stack of saturated slabs will begin to pull water out of the calibration slab.

4.7 Return the calibration slab to the scale.

4.8 Take another raw sensor reading.

4.9 If the water content has lowered 10 to15%, record the new weight and raw sensor value in Table 1.

Note: Use a column in the Table 1 spreadsheet to automatically calculate the decrease in water content percentage each time a reading is entered. This will make it easier to judge when to record the next reading.

4.10 Repeat steps 4.6 to 4.9 at ever increasing time intervals (every 3 seconds at first, then 4 seconds, 5 seconds, 10 seconds, 30 seconds...eventually reaching intervals of 2 hours to 24 hours, or more, as the slab dries).

4.11 Record raw sensor readings and weights in Table 1 each time the water content in the calibration slab decreases by 10-15%. Do this until the slab is completely dry.

> 4.11.1 If the water content stops decreasing, the water column may not be tall enough. Add another saturated slab.

4.11.2 Alternatively, the halt in decrease may be due to a dry water column. If this is the case, resaturate the water column slabs, and continue the procedure.

5. Calculations

The volumetric water content is defined as the volume of water per volume of slab

$$\theta = V_w / V_t$$

Equation 1

Where θ is volumetric water content (cm³/cm³), V_w is the volume of water (cm³), and V_t is the total volume of the slab (cm³). V_t of your sample is easily calculated because you measured the dimensions of the slab. To find V_w, take the total weight measured in section 4 (combined slab, sensor, and water weight) and subtract the slab and sensor weight.

$$m_w = m_{total} - m_{slab} - m_{sensor}$$

Equation 2

$$V_w = m_w / \rho_w$$

Equation 3

Where m_w is the mass of water, m_{total} is the mass of the wet and sensor together(g), m_{slab} is the mass of the dry slab, m_{sensor} is the mass of the sensor, and ρ_w is the density of water (~1 g/cm³).

The calculations above are most easily done in a spreadsheet program such as MS Excel. The previous Table 1 shows the above calculations performed.

6. Finding and using the calibration function

If the above calculations are performed in a spreadsheet program, then finding the calibration function is quite easy. Simply make a scatter plot with the sensor output on the X-axis and the calculated VWC on the Y-axis (Figure 1). Then use the trendline or curve-fitting function to construct a mathematical model of the relationship. This relationship is often linear, as shown below, but it is sometimes best fit with a quadratic equation.

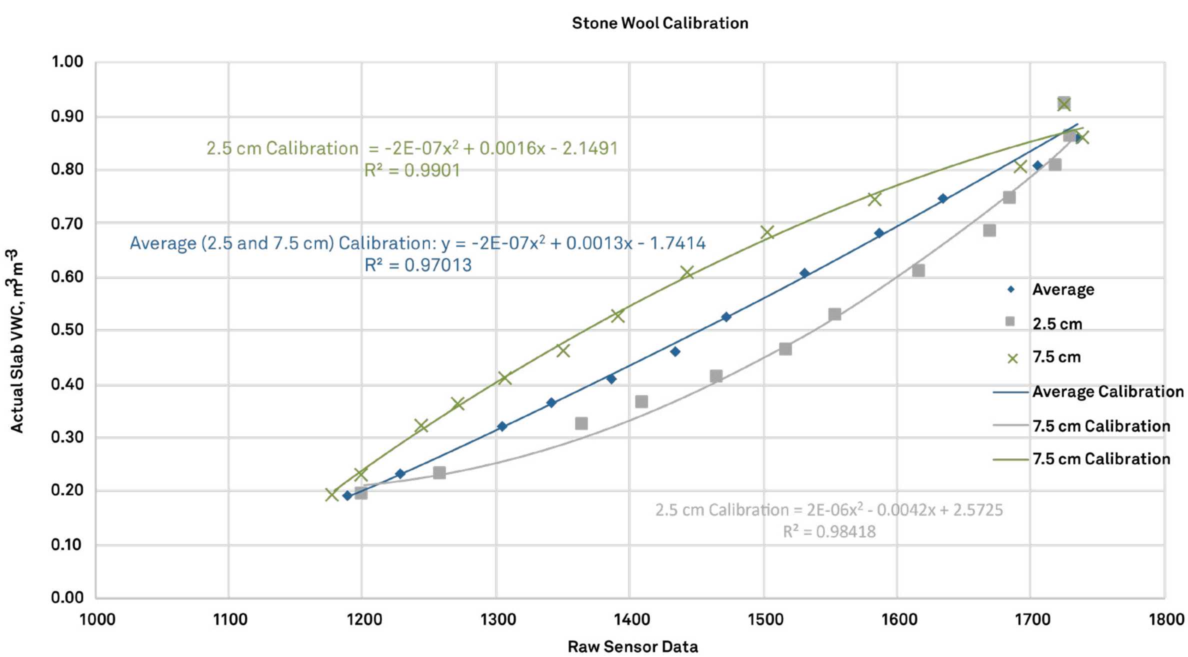

Figure 1. Stone wool calibration graph

Once the calibration function is constructed, apply it to the METER sensor data. When logging data with the ZL6, EM60G, EM50, and EM5B data loggers, apply this equation to the raw data downloaded from the logger. If using ZENTRA Cloud software, apply the calibration function under the System Settings tab in the Calibration Settings. Simply click the Add Calibration button and type in the coefficients. Remember to apply enough significant figures to the equation. If using the DataTrac software package, apply the calibration function under the setup tab. If using Campbell Scientific data loggers, apply the calibration in the data logger program or during post-processing.