Geoenvironmental
ENGINEERING NEWSLETTER

Measuring Soil Suction

One Hundred Years of Progress

Dr. Gaylon S. Campbell

People have measured the water content of soils and other porous materials for a very long time, and the ideas surrounding that measurement are easily understood. Soil suction is a more recent concept, and, in spite of its importance, is still not well understood by many geotechnical engineers. Edgar Buckingham first described the main component of the soil suction, the matric or capillary suction, over 100 years ago. Buckingham recognized that gradients in suction are the driving forces for water movement in soil, and that components of the total suction could be balanced against each other. He made the first attempts to determine the relationship between water content and soil water suction by balancing the matric suction against gravity in vertical soil columns, which he stood in containers of water. He was correct in assuming that the matric suction would equal the gravitational potential (which he computed from the height above the free water surface) once the columns were at equilibrium. He could not have known then that equilibrium would take decades, because of the low hydraulic conductivity of unsaturated soil.

continued on page 2

DECAGON DEVICES

100 years, continued from page 1

More than a decade passed before significant progress was made beyond Buckingham's experiments. In the 1920's and 1930's two lines of research produced the main tools used by soil scientists and geotechnical engineers for soil suction measurements for the next 70 years. L.A Richards, working in the laboratory of Willard Gardner at Utah State University, and later at the U.S. Salinity Laboratory, developed the idea of using a semi-permeable porous ceramic to balance a pressure against a matric suction. At equilibrium, the matric suction is determined from the pressure. The tensiometer and the pressure plate or axis translation

T5–the smallest available tensiometer on the market

apparatus both came form this work. At about this same time George Bouyoucos at Michigan State University equilibrated gypsum blocks with soil and measured the water content of the gypsum to determine soil suction. He measured the change in water content by measuring the electrical resistance of the gypsum block.

Again, a decade or more passed

Tru Psi soil suction thermocouple psychrometer—precursor to the faster WP4 PotentiaMeter

> ***"Water is H2O, hydrogen two parts, oxygen one, but there is also a third thing that makes it water and nobody knows what it is."***
>
> —D.H. Lawrence (1885-1930). *Pansies*

before there was significant additional progress. In the late 50's two scientists, L. A. Richards in the U.S. and John Monteith in Britain published papers describing a thermocouple psychrometer for measuring suction of soil samples. Those early devices were eventually developed into the TruPsi thermocouple psychrometer system sold by Decagon from 1980 to 2000. They were also the precursors to the new WP4 Dew Point PotentiaMeter now being sold by Decagon. Somewhat later, in the early 70's, Claude Phene and Stephen Rawlins, of the U. S. Salinity Laboratory, invented an improved matric suction sensor. The principle of operation of the sensor was similar to that of the Bouyoucos block, but they used a porous ceramic for the standard matrix, and used heat dissipation or thermal conductivity to

"...and we can save 700 lira by not taking soil tests."

determine its water content. These changes eliminated problems with dissolution and solute sensitivity that plagued gypsum block sensors. C. Calissendorff and myself improved upon both the ceramic and thermal sensor at Washington State University's soil physics laboratory. These sensors were part of Decagon's ThermoLink system for field measurement of matric suction.

The development of accurate and reliable sensors has been a difficult and time-consuming activity, but the dream of a century for geotechnical engineers and soil scientists is finally becoming a reality. The WP4T can measure the soil suction of any sample between 0 and 300MPa (saturated to below air dry) in less than 5 minutes, with an accuracy of ±0.1 MPa from 0 to 10 MPa, ±1% from 10 to 300 MPa. This provides a quick and accurate method for obtaining soil moisture characteristics. The characteristic can be used to determine limits for plant available water or help identify expansive soils. For the wet range (0 to 100 kPa), Decagon offers UMS tensiometers with a resolution of 0.1 kPa, fast response times, a wide range of configurations, and a pressure transducer interface for automatic electronic recording. These are ideal for monitoring flow in unsaturated soil profiles and soil suction for slope stability analyses. A low-cost dielectric soil suction sensor is currently under development and will be available soon. It will operate in both the low and high suction ranges, and will find uses in plant water relations monitoring.

Improving ECH_2O, Soil Moisture Probe, Field Performance

Decagon introduced the model EC-20, a 20 cm, soil moisture probe in the spring of 2001. Since that time, the ECH_2O probe line has been continually tested and modified to improve its performance in the field. Issues that have received considerable attention recently are the ECH_2O probe's sensitivity to differences in electrical conductivity (EC), soil texture, and temperature.

Electrical Conductivity, Soil Texture, and Temperature

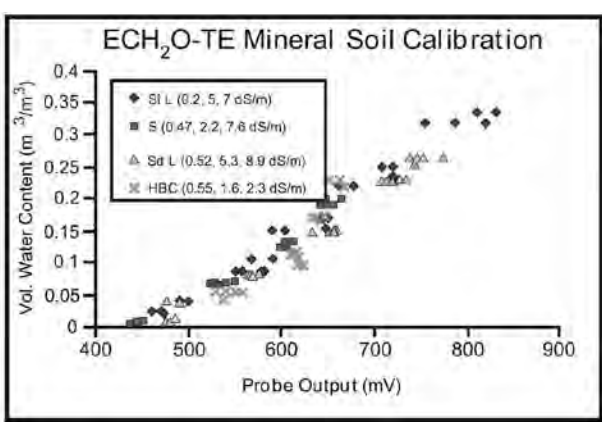
While the current EC-20 and 10 cm probes are adequate for most field applications, some research and commercial project needs are not being met because of these issues. Thus, there has been considerable interest in developing a probe that has lower sensitivity to variations in electrical conductivity, soil texture, and temperature while maintaining the qualities that have made the ECH_2O probe so widely accepted.

Increasing Measurement Frequency

There has been considerable discussion in the scientific literature regarding how increasing measurement frequency improves the salinity, soil texture, and temperature stability of soil moisture sensors. With this in mind, we changed the measurement frequency of one of our current probes, a 10 cm-long (EC-10) and two new 5 cm-long ECH_2O probes (ECH_2O-TE and EC-5) to see if we could improve the response of the probes.

Figure 1 illustrates the improvement that increasing the measurement frequency has made in the EC-10 sensor. The performance of the two new sensors (ECH_2O-TE and EC-5) is similar to that of the EC-10 (Fig. 2).

At the new measurement frequency, users can expect ±3 VWC accuracy in any soil type/salinity with no user calibration.



The two sand calibrations best illustrate the considerable decrease in scatter at the 72MHz level compounds to 10MHz.

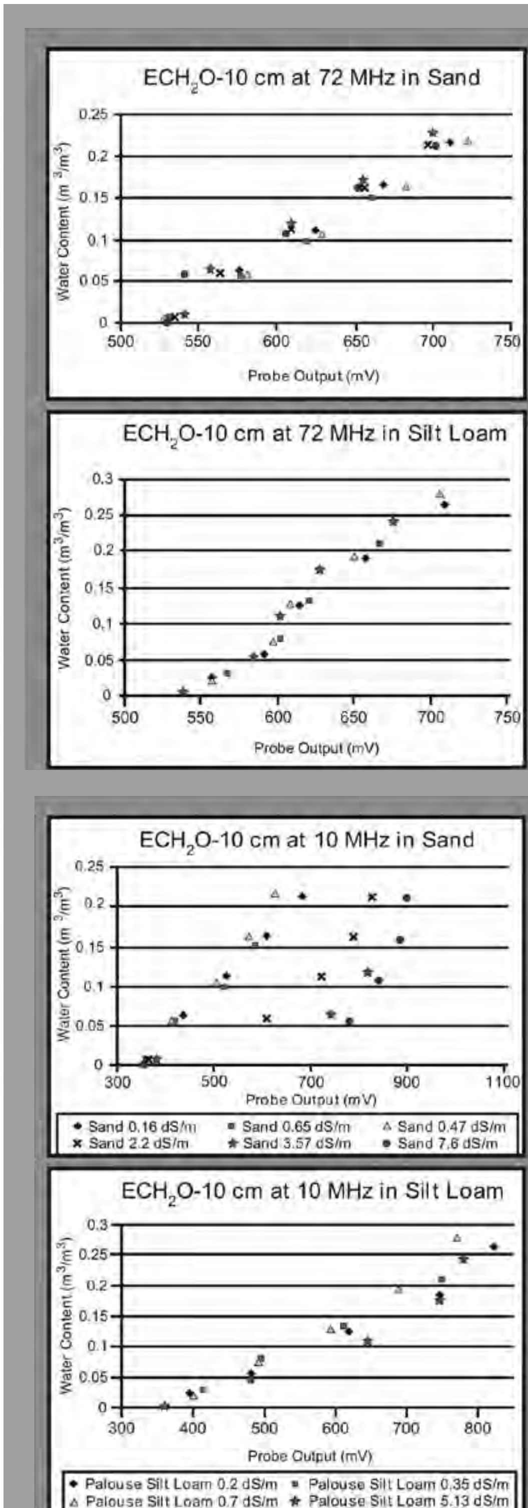


Fig. 1 EC-10 probe output running at two frequencies in sand and silt loam at several solution electrical conductivities and water contents.

Fig. 2 Two ECH20-TE probes calibrated in four soil types at varying salinities up to 8.9 dS/m (S - sand, Sd L - sandy loam, Si L - silt loam, HBC - Houston black clay).

Guide to soil suction units

DECAGON DEVICES
2365 NE Hopkins Court, Pullman, Washington 99163
phone 509-332-2756, support@decagon.com

	kPa or J/kg	MPa	Bar	cm of H2O	Relative Humidity	Freezing pt. C	Osmolality mol/kg	pF	pore diam microns
	1	0.001	0.01	10	0.999993	-0.0008	0.0004	1.01	290.08
	10	0.01	0.1	102	0.999926	-0.0076	0.0041	2.01	29.01
FC	33	0.033	0.33	337	0.999756	-0.0252	0.0135	2.53	8.79
	100	0.1	1	1020	0.999261	-0.0764	0.0410	3.01	2.90
	1000	1	10	10204	0.992638	-0.7635	0.4105	4.01	0.29
PWP	1500	1.5	15	15306	0.988977	-1.1453	0.6157	4.18	0.19
	10000	10	100	102041	0.928772	-7.6352	4.1049	5.01	0.03
air dry	100000	100	1000	1020408	0.477632	-76.3519	41.0494	6.01	
oven dry	1000000	1000	10000		0.000618		410.4939	7.01	

FC *- a typical value for the drained upper limit of soil suction.*
PWP *- a typical value for the lower limit of plant available water in soil.*
air dry *- this value varies with atmospheric humidity.*
relative humidity *- computed assuming an air temperature of 293 K.*
pF *- is the base 10 logarithm of the soil suction in cm.*
Osmolality *- milliosmoles/kg is osmoles/kg multiplied by 1000.*
pore diameter *- the bubble pressure or diameter of the largest water filled pore at each indicated potential.*

Outstanding Innovation Award

▲ ***The annual AE50 award honors companies that overcome engineering challenges to bring innovation to the marketplace. Products receiving the AE50 award are selected by a panel of experts in the agricultural, food and biological systems industries for the ability of a new product design to save producers time, cost and labor while improving user safety and operating in an environmentally-friendly fashion.***

The Decagon Research Team

Gaylon Campbell

Dr. Gaylon Campbell is the Vice President of Decagon Devices, Inc. He taught Soil Science for 30 years at Washington State University. Gaylon has authored several books and many research papers related to soil physics and environmental physics.

Colin Campbell

Dr. Colin Campbell is the Research and Development Director at Decagon Devices, Inc. He is also an adjunct professor at Washington State University teaching Environmental physics. Colin has a Ph.D. from Texas A&M in Soil Physics.

Doug Cobos

Dr. Doug Cobos is the lead scientist/engineer working with the Jet Propulsion Lab to develop a sensor designed by Decagon Devices on the 2007 Mars Phoenix Mission to measure water and other surface properities on Mars. He is also an adjunct professor at Washington State University. Doug has a Ph.D. in Environmental Biophysics from the University of Minnesota.