Soil Moisture Sensor Protocol Public Comments

March 3, 2008 to June 1, 2008

Week ending March 8, 2008 1 comment

First name: Scott
Last name: Anderson
Job Title:
Organization: Acclima, Inc.
Email: scott@acclima.com
Telephone: 2088871470
Fax: 2088876368

Comments:
Good Job!!!

I suggest a change to the paragraph on the bottom of page 1 to make it consistent with the nature of the testing outlined in the remainder of the document. The paragraph should read something like:

"An important requirement of the sensors is their ability to maintain a stable calibration when subjected to repeated wet/dry cycles with moisture contant values ranging from field capacity to permanent wilt point, with temperatures ranging from 15 C to 35 C and soil EC extractions ranging from 0 to 5.0 dS/m."

Week ending March 15, 2008 No comments

Week ending March 22, 2008

First name: Tom
Last name: Penning
Job Title: President
Organization: Irrometer Co., Inc.
Email: tomp@irrometer.com
Telephone: 951-689-1701
Fax: 951-689-33706

Comments:
During the meeting on January 15, 2008, time ran short and the group never got around to officially discussing the Phase 1 summary report (single page), a sample of which was distributed to those in attendance. I accept the summary as it was presented and spoke with several others in attendance who also agreed to the format. I propose the committee adopt the format and post the single page summary for those sensors that have completed phase one. Water purveyors and others who rely on SWAT reports and wish to make judgments on interim (phase 1) data should be allowed to do so.

Week ending March 29, 2008 No comments

Week ending April 5, 2008 No comments

Week ending April 12, 2008

First name: RAUL O.
Last name: MARQUEZ-HIGGS
Job Title: Irrigation Products Div. Mgr.
Organization: SUPERIOR-ANGRAN, INC
Email: raulomarquezhiggs@supang.com
Telephone: (787) 774-190
Fax: (787) 774-8548

Comments:
Greetings. All these technical aspects for this testing protocols are excellent. I wish to know the final output.

I have only one concern, which could be consider. The idea is that due to thermal and moisture exchanges between the soil and the atmosphere, the soil will continue to remain moist for longer time, specially if the type of soil is clay-type. Under the actual considerations, using a formula which relates two types of moisture contents, if both the atmospheric (air) relative humidity and the soil limit moisture content are not in agreement(one is related to the other), the output for this test might not come out well in the "real" and "daily" applications of this type of sensor. This is to be consider.

Apart from this minor concern, I wish to congratulate you all for this excellent testing protocol. It is clear to read and to understand. Thjank you guys.

Week ending April 19, 2008 **No comments**

Week ending April 26, 2008 **No comments**

Week ending May 3, 2008 **No comments**

Week ending May 10, 2008 **No comments**

Week ending May 17, 2008 **No comments**

Week ending May 24, 2008

Sent: Monday, May 19, 2008 4:37 PM
First name: Dave
Last name: Magner
Job Title: Director - Accessories Division
Organization: Rain Bird
Email: dmagner@rainbird.com
Telephone: 520-741-6118
Fax: 520-806-5625

Comments:
Phase 1 - Section 1.0
Should consideration be given to characterize the performance of the sensor over time? It may be beyond the scope of this initial evaluation but customers and the market will be best served by products that function reliably over time. The SWAT definition of a Smart Controller from August

2007 cited at the beginning of the protocol document requires products that operate "throughout the irrigation season". The proposed testing protocol does not seem to evaluate the equivalent of even a single season.

Phase 1 - Section 2.0 and 4.0 (4.12)
The protocol recognizes sensors capable of estimating both "absolute" and "relative" soil moisture content. However, the relative soil moisture sensor definition seems to counter the definition of a Smart Controller cited at the beginning of the document. The Smart Controller definition requires operation after initial set-up "throughout the irrigation season without human intervention" but the Relative Soil Moisture Sensor definition states the sensor "must be calibrated 'in situ' by an iterative process of adjusting water applications and making observations of turf quality" and during fertilization or other events may "require a change of threshold setting values by the operator". Are those human intervention concepts and definitions compatible in the document's current form?

Phase 1 - Section 4.0 (4.6) & Phase 2 - Section 4.0 (4.4) Should the definition of field capacity make reference to gravity? A suggestion would be to add the phrase "by the force of gravity" to the end of the currently proposed definition so the drainage concept and time allowed is not so open to potential misinterpretation.

Phase 1 - Section 4.0 (4.9 and 4.18)
Sometimes the document shows a mathematical formula and other times it uses words such as "times" and "multiplied by" to describe a mathematical function. You may want to consider keeping the approach and the use of terms consistent throughout the document.

Phase 1 - Section 8.0
The first sentence states that the sensor "calibration must be stable". However, as indicated in the earlier comment regarding Section 1.0, there does not seem to be an effort to characterize the performance of the sensor over time and address stability.

Thank you for the opportunity to review and comment on these draft protocols. A lot of good work has been done and excellent progress made since the urgent call to action to make this happen quickly during the SWAT meeting at December's IA Show.

Sent: Wednesday, May 21, 2008 11:37 AM
First name: Doug
Last name: Kieffer
Job Title:
Organization: Spectrum Technologies
Email: doug@agmeters.com
Telephone: 815-436-4440
Fax: 815-436-4460

Comments:
On page 3. I'm not sure what is the distinction between Gravimetric Moisture Content (sect 4.7) and Mass Water Content (sect 4.8). I think these definitions can be combined.

On page 7. In the first paragraph, I think the word "discreet" should be "discrete".

Week ending May 31, 2008

Sent: Monday, May 26, 2008 8:30 PM
First name: Don
Last name: Cameron
Job Title: Sales Manager
Organization: AquaSpy Group
Email: dcameron@aquaspy.com
Telephone: +61 (0)419 878 838
Fax: +61 (0)84169901

Comments:
Some soil moisture monitoring products evaluated will be deemed to be "add-on" technology, and are designed to be connected to, and operate in conjunction with existing irrigation controllers. The protocol (item 5.2) suggests that the soil moisture sensor manufacturer specify the make and model of irrigation controller to be used in Phase 2 testing. I suggest that it should be the "feature set" of the controller that should be emphasised here, rather than a particular brand or model, as any controller with the same or higher "feature set" will perform to at least the same efficiency level.
I agree that a specific brand and model would need to be specified by the SMS manufacturer, but suggest that the published reports refer to a "minimum controller feature set" rather than a specific controller brand / model.

The "minimum feature set" may include:
A Minimum Number of Cycle Start Times per Day Station Run Times in One Minute Increments
Multiple Irrigation Programs

Sent: Friday, May 30, 2008 12:41 PM
First name: Tom
Last name: Penning
Job Title: President
Organization: Irrometer Co., Inc.
Email: tomp@irrometer.com
Telephone: 951-689-1701
Fax: 951-689-3706

Comments:
Phase 1:

Table 1 still refers to the terminology "Calibration" instead of the agreed upon terminology of "Testing response" in sections 7.4.2, 7.5.1 and 7.5.2. Similarly the terminology should be corrected in the text of sections 1.0, 7.5 and 8.0.

Section 7.2 describes testing "for the sensor's ability to provide a consistent response between drying cycles and between individual sensors." Since the response between individual sensors is not applicable to the applications for which this protocol is designed to address, it should be stricken. For applications of residential and light commercial landscape irrigation management, response between sensors is not relevant as the same sensor remains in place. How well that

same sensor responds over repeated cycles is relevant, to ensure consistent operation, and section 7.6 was added to address this stability issue.

Phase 2:

In sections 1.0 and 2.0, the terminology "CIMIS" should be changed to "ASCE-EWRI" similar to the terminology used in the climatologically based controllers protocol, so that the protocol is applicable for use in other geographic regions.

Section 5.2 makes reference to the manufacturer being required to specify the "make and model" of irrigation controller to be used. Since the specific make and model are not relevant to the ability of the sensor interface system to effectively manage the irrigation application, I propose the terminology be changed to require the manufacturer to specify a minimum feature set that defines the capabilities of the controller they wish to use for purposes of their test. Since controller models will change over time or may not be readily available in all areas where testing may be performed, this approach is less limiting for the testing agency to obtain a controller for testing purposes.

Sent: Friday, May 30, 2008 12:42 PM

First name: Dana
Last name: Lonn
Job Title: Director, Center for Advanced Turf Technology
Organization: The Toro Company
Email: dana.lonn@toro.com
Telephone: 952-887-8204
Fax: 952-887-8695

Comments:
General Comments

. The Toro Company suggests that a more rigorous process be created for the creation and drafting of a testing protocol. Using a scientific advisory committee created that involving technical professionals familiar with and skilled in irrigation to draft and review the protocols would be advisable. An example of this model would be what is used by professional societies like SAE, ASABE, or ASCE for the establishment of their standards. The SWAT committee should consider contacting ASABE (which already has a significant number of irrigation related standards and practices) or ASCE (which has adopted ET standardization) with the objective to adopt these protocols and move them to the formal rigor of a standard or recommended practice.
. The Toro Company recommends that these protocols be revised to make them location independent. All references to CIMIS or CIT as an example need to be removed from the protocols. The protocols need to specify the requirements of the input data or the methods or procedures such that the protocols can be executed at any test facility or geographic locale.
. Editorial comments should be removed from the protocol bodies and moved to a forward or an appendix. The body of the protocols should be very factual and procedural.

Soil Moisture Sensor-Based Controllers

The phase 1 tests are interesting and somewhat useful. However, what is critical to water conservation is that the system (controller mated to sensor) manages soil moisture between wilt and field capacity without over watering to cause excessive runoff. It is possible to develop algorithms that make automatic irrigation systems. By separating the system into two parts it does not allow for creative implementations. It does not truly evaluate the performance of the system to accurately control irrigation.

It is our opinion, that the phase 2 protocol needs to be changed to evaluate the performance of the sensor integrated with the controller. It is not possible to evaluate each component separately and get a true measure of the water saving potential of the system being evaluated.

Phase 1: Indoor Lab Screening tests

. Protocol requires many replications and different test conditions. If a large environmental chamber is not available, it is possible for the test to take nearly a year to execute the complete protocol. Although all of the tests are interesting, the number of tests could be reduced to shorten the test but still allow for testing the limits of performance of the sensor.
. Protocol should suggest the running of one soil wetting and dry down cycle of the soil box prior to running the first test. We have seen that the second test often shows slightly different results than the first test but the third and subsequent tests are similar to the second.
. Changes should be considered to the soil containment boxes. The soil can be very difficult to wet with the current design. Air can get trapped under the false bottom and the volume of water available for wetting the soil is very small.
. This process doesn't necessarily emulate a real use situation as there are no plant roots extracting water from the deeper depths of the soil profile in the containment box.
. The calculated VWC by weighing the containment box is an average of the VWC throughout the soil profile and is not necessarily the VWC of the soil at the depth that the sensor is placed. There is a gradient from top to bottom.
. Overall, this protocol works fairly well. The amount of time to execute the protocol is the main concern.

Phase 2: Operational Test on a Virtual Landscape

. The phase 2 protocol needs to be changed to evaluate the performance of the sensor integrated with the controller. It is not possible to evaluate each component separately and get a true measure of the water saving potential of the system being evaluated.
. All references to CIMIS weather station data should be removed from the protocols. Protocols should be independent of locale. We should specify the requirements of the weather station data not which weather station.
. The specifics of the testing facility computer must be specified in the protocol. The manufacturer needs to know specifically how to design and implement the "data conversion device".
. The discussion of the mode of operation and control for soil moisture sensors on Page 10 should be removed. This is a testing document not a document to educate on how to implement a soil moisture sensor.
. The paragraph on the top of page 11 should be removed for similar reasons. This is a testing protocol and editorial comments should be moved to an appendix if they are in the document at all.
. We do not understand the sentence "The operational concepts also assume that threshold adjustments can be made manually in response to seasonal changes in on-site conditions".
. Irrigation should not be looked at on a daily basis as suggested on the top of page 12. Soil moisture sensors should help controllers manage soil moisture between field capacity and

permanent wilting point. The best irrigation for plant health is to irrigate as infrequently as possible while maintain the soil moisture within the limits required by the plant material to be healthy.

. The same paragraph on page 12 refers to consumptive use. That appears to be a calculated ET value. A calculated value cannot determine the true consumptive use and is therefore not a valid means of determining the ability of a soil moisture sensor to make a good irrigation decision.

. In order for soil moisture sensor based controllers to be effective, it is necessary for the controller to understand field capacity and plant wilting point. The protocol should evaluate how those limits are established. Is input required from the customer or is the controller smart enough to determine the limits on its own?

. We are not sure that this virtual test is valid to evaluate the system performance. We think that it would be better to determine whether a system maintains the soil moisture between field capacity and wilting point.

Sent: Saturday, May 31, 2008 6:40 PM
First name: Tom
Last name: Reynolds, CID, CLIA, CSWP
Job Title: Water Manager/Designer
Organization: Water Balance, LLC
Email: tomrinaz@cox.net
Telephone: 602-463-5072
Fax:

Comments:
Congratulations on moving forward and making progress on this important opportunity.

Ph.1, 8.0 I believe we move into Ph 2 with the statement "..conditions that cover a significant portion of the.market." I do not read anywhere in the protocol where real conditions (i.e. compaction, roots, or soil fauna) s included. These are laboratory conditions. It is a protocol to test the sensors in precise ranges of differences in soil texture, salinity, temperature, and repeatability through s wet/dry cycles. Could we just say "essentially static, laboratory conditions so as to focus on basic sensor performance?"

Ph 2, 1.0, last Parag. Excellent. Suggests that yesterday's data has value for an adaptive management approach. See Gregory et al.(2006), Richards (2004) and Harris and Heathwaite (2005) regarding adaptive management strategies for conservationists. Where "modeling is combined with empirical data collection to cope with uncertainty and develop more parsimonious predictions that might inform adaptive management." ((Harris and Heathwaite, 2005)

Ph 2 Table 1-A We basically have a series of conditions that are full cover, fully wetted. Zone #5 does not stand up to the rigor of the other conditions. I hope that the subsequent "re-validation testing" in 3 years will tackle the condition where shrubs and trees may only receive irrigation to 40% - 60% or their basal canopy, thus showing the need for these technologies to account for wetted volumes. I had hoped it would be considered now, rather than try and reconcile this ever more popular landscape condition later, and have to rewrite so much code.

Received by June 3, 2008

Sent: Sunday, June 01, 2008 11:25 PM
First name: Michael
Last name: Dukes
Job Title: Associate Professor
Organization: University of Florida
Email: mddukes@ufl.edu
Telephone: 352-392-1864
Fax: 352-392-4092

Comments:
Phase I

1. Generally, the document needs to be proof read to eliminate incomplete sentences and sentence fragments. For example, page 14 under 5.3 "Communicate with the soil moisture-based system controller manufacturer the starting time/date of the test run, the source of the real time weather data" appears to be two sentences. Other examples can be found on page 18 in the paragraph at the bottom of the page, such as "Access the valve runtime monitors to determine the runtimes per valve as specified by the manufacturer's system." and "Use the runtimes, the specified precipitation rate, and application efficiency to calculate the net application" both appear to be awkward and would read better if written in third person.
2. I recommend using accepted definitions in section I don't believe the definition for "Field Capacity" under section 4.6 is a standard definition. This definition should be more specific. For example, what does ".drain away" mean. For how long will drainage occur and how does this point in the soil moisture regime relate to soil water pressure or some other quantitative measure? This same comment applies for "Permanent Wilting Point". Check all definitions against standard and accepted terminology. For example, the definition for "field capacity" in the Soil Science Society of America glossary is: "field capacity, in situ (field water capacity) The content of water, on a mass or volume basis, remaining in a soil 2 or 3 days after having been wetted with water and after free drainage is negligible. See also available water." (https://www.soils.org/sssagloss/index.php).
3. In definition 4.12, should the word "turf" be replaced with "plant" or does this imply that this process can only be determined on turfgrass.
4. In definition 4.18, "volumetric water ratio" is not defined in the protocol. Should the term be "volumetric water content"?
5. For the lab test and specifically how will soil moisture content be determined from the sensor output of the relative sensors (see section 7.2.1)? To develop a regression curve fit, the observed soil moisture content and the sensor determined soil moisture content are both necessary. This part of the protocol could be clarified to address this question. Or, will the protocol determine the relationship between observed soil moisture content and sensor output (i.e. mV or mA signals)? If this is the case, how will the sensor be judged as accurate?
6. In section 8.0. Are "correlations" really going to be reported or are curves fitted to the data being reported? If curves are being reported, I suggest statistical comparisons such as comparing slopes of linear fits to determine if curves are different across different testing conditions since different curves from one soil to another hold a significant implication to irrigation scheduling.
7. In table 2, it would be helpful to specify the particle size distribution of the soils so that confusion is eliminated in the future when test results are compared and in particular across different labs or even different testing events should that become necessary.
8. Near the end of section 7.2.1, the protocol indicates that 32 readings will be collected during the test. Later under Table 2, the protocol indicates that 10 "uniformly spread" data points will be used to determine a relationship between the sensor reading and the soil moisture content. In some soils; however, a "uniform spread" of data points may not capture the dynamic aspect of the

soil moisture regime important to plants. For example, in coarse sandy soils evenly spaced points would miss the evolution of water from close to field capacity at 10 kPa tension to nearly field capacity at 20 kPa.

9. In section 7.6 it is unclear to me why a manufacturer determined "dry point" would be used when in Phase II the "dry point" is implicit within the RZWWS amount which is analogous to readily available water.

Phase II

1. In the second paragraph, clarify "their".
2. I recommend specifying the particle size analysis and soil moisture release curves for each soil of Phase II testing.
3. For all testing, time clock settings need to be standardized across controllers to eliminate bias in results due to differences in time clock settings by individual manufacturers. Accordingly, there is no reason to allow the manufacturer to select a particular time clock unless that clock is inherently part of the soil moisture sensor control system. I recommend a standard time clock be used for all testing.
4. At the end of all tests, specific time clock schedules and settings as well as soil moisture sensor controller settings should be reported so that tests are repeatable.

Comments for the week ending June 7, 2008

Sent: Tuesday, June 03, 2008 3:59 AM

First name: Mike
Last name: van Bavel
Job Title: President
Organization: Dynamax Inc
Email: mikevb@dynamax.com
Telephone:
Fax:

Comments:
In January the Soil Sensor manufacturing group meeting two controller-testing methods were discussed and voted upon. Both (a) the soil-based lab simulation controller test (70 % agreed) and (b) a software-hardware simulation, "virtual test" (90 % agreed); were agreeable to the group.

After the virtual testing was introduced,

1) CIT (Ed Norum) stated he did not know how to build the "black box" interface required to perform the testing.
2) Some other manufacturers introduced the idea stated they have never built such a "black box"
3) CIT (Dig) was stating the computer model soil simulation would be provided, and that he would provide the protocol and the means to communicate soil water status and the simulated data to the "black box" hardware. Each manufacturer then provides the soil moisture sensor emulation to their controllers for the test.
4) The manufacturing group agreed that the simulation updates from the soil model would be updated once per minute for signaling to each black box..

Here are some distinct questions we believe need to be answered so that we can proceed with this new testing standard:

1) When will the black box interface be specified? Will there be a deadline to have this working and verified?
2) What parameters are going to be included in the "black box" soil sensor emulator?
3) The protocol implied that these parameters are expected to be responding to the software simulation in the CIT computer, so which parameters are assigned to the simulation (computer generated) and which will be signaled to the "virtual interface (black box):
A) Moisture level?
B) Temperature?
C) Salinity?
D) Soil Type?
E) 95 % confidence level of noise?
F) Sensor repeatability?
G) Rainfall?
H) Eto - with Kc simulation?
I) Exposure?
J) Slope?

It seems that A) to F) (first six parameters) are the responses that the sensor generates for the controller from the "black box", and that we need to clarify that the CIT software modeling will provide these parameters to the "black box".

4) Will the "black box" or the soil water balance computer model be tested, and who will determine if it is accurate or not?
5) Will the black box need to have an accurate simulation, or will a manufacturer be able to select an ideal sensor interface which has no variability included in the signal from the sensor/soil environment, or the various noise and repeatability test results?
6) Since six zones will be simulated, it assumes all six are independently modeled by the CIT simulation, then does that mean each controller test can require up to six "black boxes" to run the tests?
7) If the manufacturer stipulates only one sensor can run all zones, will he choose the zone and supply only one black box to emulate only this zone?
8) Are the watering times in the controller test, the water balance of the soil for evaluation of the efficiency and the adequacy only depending on the soil simulation of the soil water content?
9) If the CIT cannot supply a black box water balance protocol and the manufacturers are not able to provide a working emulator within the time limit, should we have CIT prepare an alternative option for a lab-based in-soil testing for the controls?
10) If the independent laboratory, which may also implement this testing protocol, needs the black box to perform the test, should the black box design and the implementation be shared with the independent lab, or is this not intended for other manufacturers or for peer review?
11) The whole issue of "black box" interface and soil simulation seems to boil down to this: We are accepting a number of statistics from a sensor report, with averages, trends, and linear or other best bit curves, and then providing the average/trend/math model to a controller via the "black box interface", so all sensors then look the same (all are average), have the same response (same trend for all) to soil, and likely not straying from a best fit curve (no variability or noise). This test is a simplification that makes a perfect result almost guaranteed, no matter how poorly the calibration of the sensor reflects the soil conditions, or how noisy/ variable/non repeatable the sensor is in the actual sensor testing. We submit that an international panel of experts also have some opportunity to review and comment and offer a more realistic solution.

Sent: Tuesday, June 03, 2008 4:37 AM

First name: Mike
Last name: van Bavel
Job Title: Presedent
Organization: Delta-T c /o Dynamax
Email: mikevb@dynamax.com
Telephone:
Fax:

Comments:
8.0 Results- Interpretation AND DATA PRESENTATION are fairly clear now, and concise. Also the protocol language that was submitted in the fifth draft was cleared of a significant number of errors, and subjective editorial that conflicted the goals.
Now can SWAT agree that the CIT should proceed to publish the earlier test results from Phase 1, submitted to Delta-T October of 2006 with these same corrections, clarifications, and consensus for data analysis? Delta-T has requested the review not to be postponed further, and to present a final manufacturers report to IA and SWAT.

We have also seen the latest suggestions on how to present the protocol results to SWAT, and it should be clear now that the Section 8.0 was agreed, and should be prepared without watering down the summary information. In this section we should clarify in the definitions section that the Correlation 8.1-8.5 is not only the curve or regression equation and the R2, but also the 95% confidence limits, and the standard error. We believe that the interested parties can become familiar with basic statistics, 1:1 charts and proper interpretation of a test report with a little glossary / Statistics 101 help guide. Can we add this clarification there?

PUBLIC COMMENT PERIOD ON PROPOSED DRAFT PROTOCOLS CLOSED ON JUNE 3, 2008 10:00 AM