INSTRUCTION MANUAL

HydraProbe Steven's Water Soil Sensor

March 2018

Assistance

Products may not be returned without prior authorization. The following contact information is for Canadian and international clients residing in countries served by Campbell Scientific (Canada) Corp. directly. Affiliate companies handle repairs for clients within their territories. Please visit *www.campbellsci.ca* to determine which Campbell Scientific company serves your country.

To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., phone (780) 454-2505. After a measurement consultant determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. Campbell Scientific's shipping address is:

CAMPBELL SCIENTIFIC (CANADA) CORP.
RMA#_____
14532 131 Avenue NW
Edmonton, Alberta T5L 4X4
Canada

For all returns, the client must fill out a "Statement of Product Cleanliness and Decontamination" form and comply with the requirements specified in it. The form is available from our web site at *www.campbellsci.ca/repair*. A completed form must be either emailed to *repair@campbellsci.ca* or faxed to (780) 454-2655. Campbell Scientific (Canada) Corp. is unable to process any returns until we receive this form. If the form is not received within three days of product receipt or is incomplete, the product will be returned to the client at the client's expense. Campbell Scientific (Canada) Corp.f reserves the right to refuse service on products that were exposed to contaminants that may cause health or safety concerns for our employees.

Precautions

DANGER — MANY HAZARDS ARE ASSOCIATED WITH INSTALLING, USING, MAINTAINING, AND WORKING ON OR AROUND **TRIPODS, TOWERS, AND ANY ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC**. FAILURE TO PROPERLY AND COMPLETELY ASSEMBLE, INSTALL, OPERATE, USE, AND MAINTAIN TRIPODS, TOWERS, AND ATTACHMENTS, AND FAILURE TO HEED WARNINGS, INCREASES THE RISK OF DEATH, ACCIDENT, SERIOUS INJURY, PROPERTY DAMAGE, AND PRODUCT FAILURE. TAKE ALL REASONABLE PRECAUTIONS TO AVOID THESE HAZARDS. CHECK WITH YOUR ORGANIZATION'S SAFETY COORDINATOR (OR POLICY) FOR PROCEDURES AND REQUIRED PROTECTIVE EQUIPMENT PRIOR TO PERFORMING ANY WORK.

Use tripods, towers, and attachments to tripods and towers only for purposes for which they are designed. Do not exceed design limits. Be familiar and comply with all instructions provided in product manuals. Manuals are available at www.campbellsci.ca or by telephoning (780) 454-2505 (Canada). You are responsible for conformance with governing codes and regulations, including safety regulations, and the integrity and location of structures or land to which towers, tripods, and any attachments are attached. Installation sites should be evaluated and approved by a qualified personnel (e.g. engineer). If questions or concerns arise regarding installation, use, or maintenance of tripods, towers, attachments, or electrical connections, consult with a licensed and qualified engineer or electrician.

General

- Prior to performing site or installation work, obtain required approvals and permits.
- Use only qualified personnel for installation, use, and maintenance of tripods and towers, and any attachments to tripods and towers. The use of licensed and qualified contractors is highly recommended.
- Read all applicable instructions carefully and understand procedures thoroughly before beginning work.
- Wear a **hardhat** and **eye protection**, and take **other appropriate safety precautions** while working on or around tripods and towers.
- **Do not climb** tripods or towers at any time, and prohibit climbing by other persons. Take reasonable precautions to secure tripod and tower sites from trespassers.
- Use only manufacturer recommended parts, materials, and tools.

Utility and Electrical

- **You can be killed** or sustain serious bodily injury if the tripod, tower, or attachments you are installing, constructing, using, or maintaining, or a tool, stake, or anchor, come in **contact with overhead or underground utility lines**.
- Maintain a distance of at least one-and-one-half times structure height, 6 meters (20 feet), or the distance required by applicable law, **whichever is greater**, between overhead utility lines and the structure (tripod, tower, attachments, or tools).
- Prior to performing site or installation work, inform all utility companies and have all underground utilities marked.
- Comply with all electrical codes. Electrical equipment and related grounding devices should be installed by a licensed and qualified electrician.

Elevated Work and Weather

- Exercise extreme caution when performing elevated work.
- Use appropriate equipment and safety practices.
- During installation and maintenance, keep tower and tripod sites clear of un-trained or non-essential personnel. Take precautions to prevent elevated tools and objects from dropping.
- Do not perform any work in inclement weather, including wind, rain, snow, lightning, etc.

Maintenance

- Periodically (at least yearly) check for wear and damage, including corrosion, stress cracks, frayed cables, loose cable clamps, cable tightness, etc. and take necessary corrective actions.
- Periodically (at least yearly) check electrical ground connections.

WHILE EVERY ATTEMPT IS MADE TO EMBODY THE HIGHEST DEGREE OF SAFETY IN ALL CAMPBELL SCIENTIFIC PRODUCTS, THE CLIENT ASSUMES ALL RISK FROM ANY INJURY RESULTING FROM IMPROPER INSTALLATION, USE, OR MAINTENANCE OF TRIPODS, TOWERS, OR ATTACHMENTS TO TRIPODS AND TOWERS SUCH AS SENSORS, CROSSARMS, ENCLOSURES, ANTENNAS, ETC.

WARRANTY AND ASSISTANCE

This equipment is warranted by CAMPBELL SCIENTIFIC (CANADA) CORP. ("CSC") to be free from defects in materials and workmanship under normal use and service for **twenty-four (24) months** from date of shipment unless specified otherwise. ***** **Batteries are not warranted.** ***** CSC's obligation under this warranty is limited to repairing or replacing (at CSC's option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CSC. CSC will return such products by surface carrier prepaid. This warranty shall not apply to any CSC products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CSC is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Return Merchandise Authorization (RMA), contact CAMPBELL SCIENTIFIC (CANADA) CORP., at (780) 454-2505. An RMA number will be issued in order to facilitate Repair Personnel in identifying an instrument upon arrival. Please write this number clearly on the outside of the shipping container. Include description of symptoms and all pertinent details.

CAMPBELL SCIENTIFIC (CANADA) CORP. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover repair costs.

CAMPBELL SCIENTIFIC®

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14532 131 Avenue NW | Edmonton AB T5L 4X4
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HydraProbe Soil Sensor

1. Introduction

The Stevens Water HydraProbe Soil Sensor is a dielectric constant sensor which measures soil temperature, soil moisture, soil electrical conductivity, and dielectric permittivity. It is made with marine grade stainless steel, ABS housing, and a high grade epoxy potting, which protects the internal electrical components from the corrosive and reactive properties of soil.

HydraProbes in an irrigation system can prevent runoff that may be harmful to aquatic habitats, conserve water where it is scarce, and save money on pumping costs. The inter-sensor variability is very low, allowing for the direct comparison of data from multiple probes in a soil column or watershed.

2. Specifications

Power Supply Operating

- 9 - 20 VDC Input Voltage (12 VDC is ideal)

Power Consumption

- Idle: < 1mA
- Active: 10 mA

General

- **Weight**: 200 g (cable 80 g/m)
- **Extended Operating Temperature**: -30°C to +60°C
- **Standard Operating Temperature**: -10°C to +60°C
- **In Soils**: freezing to +55°C
- **SDI-12 Baud Rate:** 1200

Accuracy

- **Temperature:** ± 0.3°C (from -10°C to +60°C)
- **Real Dielectric Permittivity (isolated):** ± 1.5% or 0.2, whichever is typically greater
- **Soil Moisture for Inorganic & Material soil:** ±0.01 wfv for most soils; ±0.03 wfv max for fine texture soils
- **Bulk Electerical Conductivity:** ±0.02% or 0.02 S/m, whichever is typically greater

- **Inter-Sensor Variability:** <± 0.012 wfv (θ m^3 m^{-3})

Note Ideal storage temperature range is -40°C to +55°C.

Dimensions

- **Probe Length**: 12.4 cm (4.9")
- **Probe Diameter**: 4.2 cm (1.6")
- **Tines**: Length: 45 mm (1.77"); Diameter: 3 mm (0.12")
- **Base Plate**: Diameter: 25 mm (0.98")

Communication

- SDI-12

Sensing Volume:

- Length: 5.7 cm (2.2")
- Diameter: 3.0 cm (1.3")

3. Initial Inspection

- Upon receipt of the HydraProbe, inspect the packaging and contents for damage. File any damage claims with the shipping company. Immediately check package contents against the shipping documentation. Contact Campbell Scientific about any discrepancies.
- The HydraProbe is shipped with an informational USB.

4. Cautionary Statements

- Do not subject the probe to extreme heat over +70°C (160°F).
- Do not subject the probe to fluids with a pH less than 4.
- Do not subject the probe to strong oxidizers like bleach or strong reducing agents like formaldehyde.
- Do not subject the probe to polar solvents such as acetone.
- Do not subject the probe to chlorinated solvents such as dichloromethane.
- Do not subject the probe to strong magnetic fields.
- Do not use excessive force to drive the probe into the soil because the tines could bend.
- Do not remove the HydraProbe from the soil by pulling on the cable.

- Use caution not to damage the cable or probe if the probe needs to be excavated for relocation, as the direct burial cable is susceptible to abrasion and cuts by shovels.

- Do not place the probes where they could get run over by tractors or other farm equipment. The compaction of the soil column from the weight of the vehicle will affect the hydrology and thus the soil moisture data.

5. Factory Setup

The HydraProbe has four factory default calibrations that provide excellent performance in most mineral soils, regardless of texture or organics. The calibrations are: Sand, Silt, Clay, and Loam. Loam soil calibration is the default calibration and is suitable for Silt Loams, Loam, Clay Loam, Silty Clay Loam, Sandy Clay Loam, Sandy Loam, and some medium textured Clays.

6. HydraProbe Hardware

The HydraProbe has three main structural components: the cable, sensor, and tines. The marine grade stainless steel tine assembly is the wave guide. The tine assembly is the four metal rods that extend out of the base plate ground plane. Electromagnetic waves are transmitted and received by the center tine. The head or body of the probe contains the circuit boards, microprocessors, and all other electrical components. The outer casing is ABS and the internal electronics are permanently potted with a rock-hard epoxy resin giving the probes a rugged construction. The cable has a direct burial casing and contains the power, ground, and data wires that are all soldered to the internal electronics. The intended use of the HydraProbe is to be buried in soil underground to depths ranging from 5 cm to 2 meters.

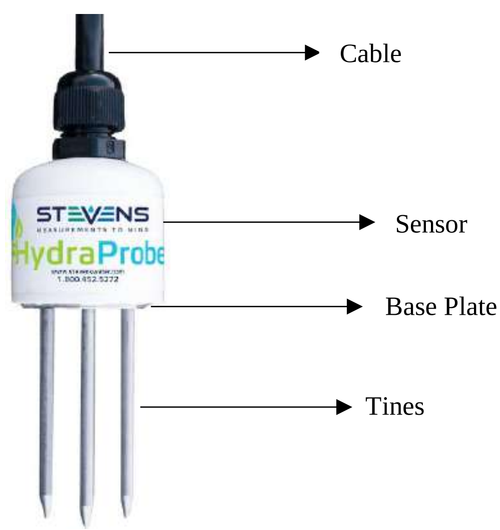

FIGURE 6-1. HydraProbe Hardware

7. SDI-12 Communications

The HydraProbe uses SDI-12 digital communications and can be used with any SDI-12 Campbell Scientific datalogger.

7.1 SDI-12 Transparent Mode

Transparent Mode allows for direct communication with the HydraProbe. This is necessary in order to assign an address to the probe or modify the probe's configuration.

To program the HydraProbe, an SDI-12 compatible device that supports Transparent Mode is required. Campbell SDI-12 dataloggers (see Table 11-1 *HydraProbe Compatibility with Contemporary and Retired Dataloggers*) support Transparent Mode. The SDI-12 protocol is not compatible with common serial data communications, so a device is needed to convert between the two.

TABLE 7-1. How to Connect to SDI-12 Transparent Mode

Steps	Description
1	Connect a Personal Computer (PC) to a datalogger using a standard nine pin serial data communications cable or USB.
2	Ensure the HydraProbe is connected to the SDI-12 port on the datalogger and that power is supplied.
3	Start a terminal program (e.g. Hyper Terminal) on the PC.
4	Issue a command to the datalogger to enter Transparent Mode.

7.2 SDI-12 Command List

The SDI-12 Commands that can be used with HydraProbe are listed in Table 7-2 *SDI-12 Measurement Command List*. Use these commands to communicate with the sensor.

TABLE 7-2. SDI-12 Measurement Command List	
Command	**Response Values**
aM!	• Soil Moisture (wfv) • Dielectric Loss Tangent • Soil Conndunctivity (S/m) • Real Dielectic Permittivity • Real Dielectic Permittivity (temperature corrected) • Imaginary Dielectic Permittivity • Imaginary Dielectic Permittivity (temperature corrected)
aM1!	• Soil Temperature (°C) • Soil Temperature (°F) • Dielectric Loss Tangent
aM2!	• Soil Temperature (°C) • Soil Temperature (°F) • Soil Moisture (wfv) • Soil Conndunctivity (S/m) • Soil Conndunctivity (temperature corrected) • Dielectric Loss Tangent
aM3!	• Real Dielectic Permittivity • Real Dielectic Permittivity (temperature corrected) • Imaginary Dielectic Permittivity • Imaginary Dielectic Permittivity (temperature corrected) • Soil Conndunctivity (S/m) • Diode Temperature (°C)
aM4!	• Voltage 1 (V) • Voltage 2 (V) • Voltage 3 (V) • Voltage 4 (V) • Voltage 5 (V)
aM5!	• ADC Reading 1 • ADC Reading 2 • ADC Reading 3 • ADC Reading 4 • ADC Reading 5

TABLE 7-3. SDI-12 Extended Command List	
Command	**Response**
aXS!	Get soil type
aXS<soil>!	Get soil type
aXP0!	Turn on the probe circuitry
aXP1!	Turn off the probe circuitry
aXM!	Get the default measurement set
aXM=0!	Set the default measurement to 0
aXM=1!	Set the default measurement to 1
aXM=2!	Set the default measurement to 2
aXM=3!	Set the default measurement to 3
aXM=4!	Set the default measurement to 4
aXM=5!	Set the default measurement to 5
aXM=<set>!	Set custom default measure set
aXR!	Reset probe to defaults
aXY<constant>!	Get water constant
aXY<constant><float>!	Set water constant
aXW!	Get probe warmup time
aXW<warmup>!	Set warmup time

8. Cables/Wiring

SDI-12 communication can be used to connect multiple probes to a single port on a datalogger.

TABLE 8-1. SDI-12 Wiring		
Wire Color	**Function**	**Datalogger**
Red	+Volts Power Input	12V
Black	Ground	G
Blue	SDI-12 Data Signal	U1/C1, C3, …

9. Installation

9.1 Installation Precautions

In areas prone to lightning, serge protection and/or base station grounding is recommended.

For maximum protection from lightning, attach a duel dissipater to the top of a lightning rod 3 to 6 meters above the ground. Using at least a 1 cm thick copper cable, connect the dissipater to a buried copper rod 2 cm in diameter. The buried copper rod should be at least 3 meters long and buried horizontally 1.5 to 3 meters deep.

9.2 Installation of HydraProbe into Soil

Note When installing the HydraProbe, it is critical that the soil is undisturbed and that the base plate of the probe is flush with the soil (see Figure 9.1 *Example HydraProbe Installation*).

To install the probe into the soil, first select the depth (see Section 9.5 *HydraProbe Depth Selection*).

TABLE 9-1. HydraProbe Installation Instructions

Step	Directions
1	Address and program the probe (Section 12 *Example Programming*).
2a	Dig a hole using a post whole digger or spade.
2b	If a pit has been prepared for a soil survey, the HydraProbes can be conveniently installed into the wall of the survey pit before it is filled in. Use a paint scraper to smooth the surface of the soil where it is to be installed.
3	Insert tines of the HydraProbe into the soil. Ensure the HydraProbe base plate is flush with the soil. (see figure XX) If there is a gap, the HydraProbe signal will average the gap into the soil measurement and create a bad measurement.
4	Backfill the hole. For every 24 cm (1 foot) of soil put back into the pit, the soil should be compacted. Compaction can be done by trampling the soil with feet and body weight. After the probes are installed, avoid foot and vehicular traffic in the vicinity of the probes.

FIGURE 9-1. Example HydraProbe Installation

9.3 Cable Length

SDI-12 cables can be as short as $\leq$ 1 meter (3 feet) and as long as 310 meters (1000 feet).

9.4 Addressing and Programming

The HydraProbe can be connected in parallel, so that multiple probes can be connected to a single communication port of a datalogger or other device. When multiple probes are connected this way, each probe must be assigned a unique address ***before they are installed*** using SDI-12 Transparent Mode (see Section 7.1 *SDI-12 Transparent Mode*). In addition, the user can select which processing method to use and which data is to be transmitted.

9.5 HydraProbe Depth Selection

Like selecting a topographical location, selecting the sensor depth depends on the interest of the user. Farmers will be interested in the root zone depth, while soil scientists may be interested in the soil horizons.

Depending on the crop and the root zone depth, in agricultural applications two or three HydraProbes may be installed in the root zone and one may be installed beneath the root zone. Measuring beneath the root zone is important when making decisions about irrigation management.

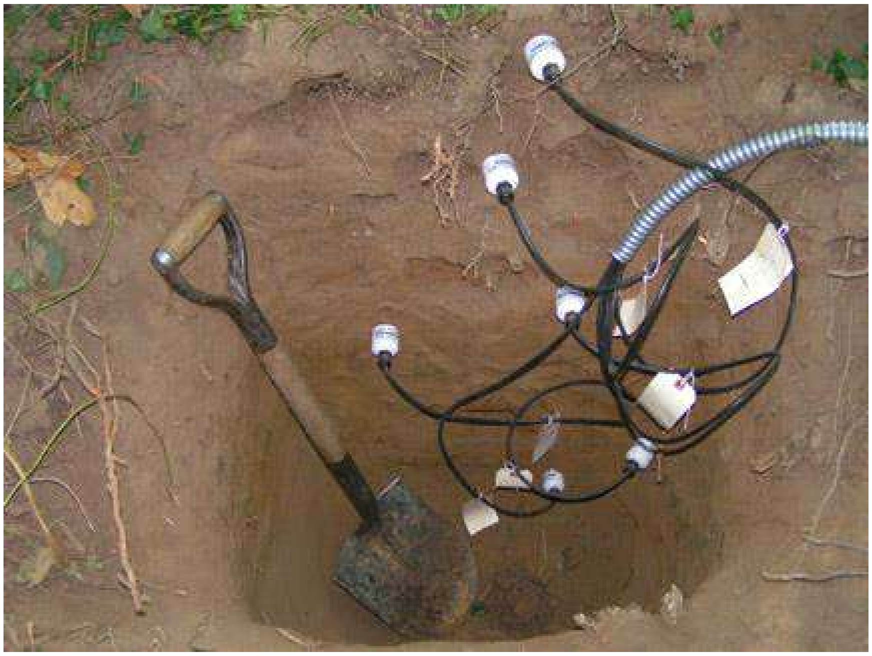

FIGURE 9-2. Six HydraProbes installed into 6 soil horizons

The soil horizons often dictate the depths of the HydraProbes' placement.

10. Measurement Outputs

10.1 Soil Moisture

The HydraProbe provides accurate soil moisture measurements in units of water fraction by volume (wfv or m3m-3) and is symbolized with the Greek letter theta, "θ". Soil moisture is parameter "H" on the digital HydraProbe. Multiplying the water fraction by volume by 100 will equal the volumetric percent of water in soil. Full saturation (all the soil pore spaces filled with water) is soil dependent, but typically occurs between 0.40-0.55 wfv for mineral soil. The unit wfv allows for direct comparison between readings in different soils (0.20 wfv clay contains the same amount of water as a 0.20 wfv sand).

10.2 Complex Dielectric Permittivity

The HydraProbe bases it measurements on the physics and behavior of a reflected electromagnetic radio wave in soil to determine the dielectric permittivity. From the complex dielectric permittivity, the HydraProbe can simultaneously measure soil moisture and electrical conductivity. The complex dielectric permittivity is related to the electrical capacitance and electrical conductivity. The HydraProbe uses patented algorithms to convert the signal response of the standing radio wave into the dielectric permittivity and thus the soil moisture and soil electrical conductivity.

10.3 Soil Temperature

Soil temperature can be measured in Fahrenheit or degrees Celsius. Daily temperature fluctuations between daytime highs and nighttime lows may be observed with the HydraProbe's temperature data. These fluctuations will become less pronounced with depth. Vegetation, tree canopy, and soil moisture are factors that affect daily soil temperature fluctuations. Seasonal trends can be observed in soil temperature data.

10.4 Diode Temperature

The diode temperature is the temperature of the electronics within the HydraProbe housing. Because the electronics produce a negligible amount of heat while taking a reading, the diode temperature is usually very close, if not the same, as the soil temperature. The diode temperature is used by the HydraProbe to make temperature corrections to the electronics.

10.5 Water Potential Measurements

Water potential is highly texture dependent. Clay particles have a larger surface area, thus a higher affinity for water than that of silt or sandy soils. Capillary matric potential is important for irrigation scheduling because it can represent the soil water that would be available to a crop.

10.6 Soil Salinity and Soil Electrical Conductivity

Soil electrical conductivity (EC) is parameter "O" and the temperature corrected electrical conductivity is parameter "J" on the digital HydraProbe. EC is also referred to as specific conductance and is measured in Siemens/meter (S/m). The HydraProbe will measure EC up to 1.5 S/m. The accuracy of EC parameters in soil are highly soil dependent, the HydraProbe's EC measurements in slurry extracts, water samples, and aqueous solutions are accurate (<±1%).

Electrical conductivity and the imaginary dielectric permittivity are highly sensitive to changes in temperature. The raw and temperature corrected parameters are offered from both EC and the imaginary permittivity.

TABLE 10-1. HyrdaProbe Parameters

Parameter Name	Digital Parameter Assignment
Raw Electrical Conductivity	O
Temperature Corrected Electrical Conductivity	J
Raw Imaginary	M
Temperature Corrected Imaginary	N
Soil Moisture	H

Theoretically, as temperature increases, the molecular vibrations increase making it more difficult for electricity to propagate through a material, thus electrical conductivity goes down with temperature. The temperature corrections are based on a saline water solution's EC/temperature relationship to provide an output of what it would be at 20°C. This would allow the user to make reasonable comparisons of different EC values at different temperatures.

11. Datalogger Compatibility

As shown in Table 11.1 *HydraProbe Compatibility with Contemporary and Retired Dataloggers*, the HydraProbe is compatible with several contemporary and retired Campbell Scientific dataloggers.

TABLE 11-1. HydraProbe Compatibility with Contemporary and Retired Dataloggers

Contemporary Dataloggers	Retired Dataloggers
CR200/200X	CR510*
CR300	CR10X*
CR800/850	CR23X*
CR3000	
CR6	
* Must be the -2M versions and must use the PakBus® operating	

12. Example Programming

In the following example, the HydraProbe will measure the soil moisture (wfv), soil temperature (°C), and soil electrical conductivity (S/m), along with other optional parameters.

CRBasic Example 12-1. Program-CR300

```
'==================Credentials and Contacts====================
'Title of Program: Stevens HydraProbe

'Created for: In House Testing Stevens HydraProbe

'Created By: Campbell Scientific (Canada) Corp.
'Website: www.campbellsci.ca
'Address: 14532 - 131 Ave NW Edmonton, Alberta T5L 4X4
'General Phone Number: 780-454-2505
'E-mail: dataloggers@campbellsci.ca

'Output type: SDI12 Address: 0

'==================== Settings =============================
'  Stevens HydraProbe is set to default and returns nine measurement: HJFGOKMLN
' H  ------------------------  Soil Moisture (wfv)
' J ------------------------  Soil Conductivity (temp. corrected)(S/m)
' F ------------------------  Soil Temperature (Deg C)
' G  ------------------------ Soil Temperature (Fahrenheit)
' O ------------------------ Soil Conductivity (S/m)
' K ------------------------  Real Dielectric Permittivity
' M  ------------------------ Imaginary Dielectric Permittivity
' L ------------------------ Real Dielectric Permittivity (temp. corrected)
' N  ------------------------ Imaginary Dielectric Permittivity (temp. Corrected)
```

```
'====================Wiring ============================

' Red -----------------------------------> SW12V
' Black ----------------------------------> G
' Blue ------------------------------------> C1 (SDI12)

'======================Constants========================
'Start of Constants Customization Section
'Program Scan Rate
Const Scan_Rate = 10
'===================== Declarations=======================
'Diagnostic Parameters
Public Battery_Voltage
Units Battery_Voltage = Volts
Public Panel_Temperature
Units Panel_Temperature  =Deg C
'================= Stevens HydraProbe Declaration ================

Public Hydraprobe_Data(9)
Alias Hydraprobe_Data(1) = Soil_Moisture
Units Soil_Moisture = wfv
Alias Hydraprobe_Data(2) = Temp_Corrected_Soil_Conductivity
Units Temp_Corrected_Soil_Conductivity = S/m
Alias Hydraprobe_Data(3) = Soil_Temperature_C
Units Soil_Temperature_C  = ˚C
Alias Hydraprobe_Data(4) = Soil_Temperature_F
Units Soil_Temperature_F  = Fahrenheit
Alias Hydraprobe_Data(5) = Soil_Conductivity
Units Soil_Conductivity  = S/m
Alias Hydraprobe_Data(6) = Real_Dielectric_Permittivity
Alias Hydraprobe_Data(7) = Imaginary_Dielectric_Permittivity
Alias Hydraprobe_Data(8) = Corrected_Real_Dielectric_Permittivity
Alias Hydraprobe_Data(9) = Corect_ImaginaryDielectric_Permittivity
Dim M1_Data(3)
Public  Dielectric_Loss_Tangent
Dim M3_Data(6)
Public  Diode_temperature
Units Diode_temperature = ˚C
Public Current_Settings As String
Public Soil_Type As String
Public Warm_Up_Time
Units Warm_Up_Time = mSeconds
Public Troubleshooting_Flag As Boolean
'===================== Data Tables=======================

'Diagnostics Data Table (should be collected on a daily basis)
DataTable(Diagnostics,True,365)
  DataInterval(0,1440,Min,0)
  Maximum(1,Battery_Voltage,FP2,False,False)
  Minimum(1,Battery_Voltage,FP2,False,False)
  Maximum(1,Panel_Temperature,FP2,False,False)
  Minimum(1,Panel_Temperature,FP2,False,False)
  Sample(1,Status.OSVersion,String)
  Sample(1,Status.SerialNumber,UINT2)
  Sample(1,Status.StartTime,String)
  Sample(1,Status.StationName,String)
  Sample (1,Status.ProgName,String)
  Sample(1,Status.RunSignature,UINT2)
  Sample(1,Status.ProgSignature,UINT2)
  Sample(1,Status.SkippedScan,UINT2)
  Sample (1,Status.WatchdogErrors,UINT2)
  Sample (1,Status.VarOutOfBound,UINT2)
  EndTable

DataTable (FifteenMinute,1,-1)
  DataInterval (0,15,Min,10)
  Sample (9,Hydraprobe_Data(),FP2)
```

```
EndTable

DataTable (Hourly,1,-1)
  DataInterval (0,60,Min,10)
  Sample (1,Dielectric_Loss_Tangent,FP2)
  Sample (1,Diode_temperature,FP2)
  Sample (1,Current_Settings,String)
  Sample (1,Soil_Type,String)
  Sample (1,Warm_Up_Time,Long)
EndTable

'======================Main Program=====================
BeginProg
  ' power the sensor through SW12
SW12 (1)
  '======================Main Scan========================

  Scan(Scan_Rate,Sec,3,0) 'scan rate is set as a constant

    '==================Diagnostics Information===================
    'Datalogger Battery Voltage measurement
    Battery(Battery_Voltage)
    'Wiring Panel Temperature measurement
    PanelTemp(Panel_Temperature,_60Hz)

    ' Return Maintenance and Trouble Shooting Data every Hour
    If TimeIntoInterval (0,60,Min)Then Troubleshooting_Flag = true

      If Troubleshooting_Flag  = false
        ' Return 9 measurement: HJFGOKMLN
        SDI12Recorder (Hydraprobe_Data(),C1,0,"M!",1.0,0)
      EndIf

      ' More addtional and optional measurements
      If Troubleshooting_Flag  = true
        '  Return 3 measurement: FGI
        SDI12Recorder (M1_Data(),C1,0,"M1!",1.0,0)
        ' Dielectric Loss Tangent
        Dielectric_Loss_Tangent = M1_Data(3)
        '  Return 6 measurement: KLMNOP
        SDI12Recorder (M3_Data(),C1,0,"M3!",1.0,0)
        ' Diode temperature
        Diode_temperature = M3_Data(6)
        ' Return the current settings
        SDI12Recorder (Current_Settings,C1,0,"XM!",1.0,0)
        'length = Len (Current_Settings)
        Current_Settings = Mid(Current_Settings,2, Len (Current_Settings))
        ' Returns the current soil type .
        SDI12Recorder (Soil_Type,C1,0,"XS!",1.0,0)
        Soil_Type = Mid(Soil_Type,5, Len (Soil_Type))
        '  Returns Warm Up Time .
        SDI12Recorder (Warm_Up_Time,C1,0,"XW!",1.0,0)
        Troubleshooting_Flag = false
      EndIf
      CallTable (FifteenMinute)
      CallTable (Hourly)
      CallTable (Diagnostics)
    NextScan

  EndProg
```

13. Maintenance and Troubleshooting

Please ensure the physical wires from the probe to the datalogger are connected before proceeding.

13.1 Troubleshooting the HydraProbe Outputs

To verify that the HydraProbe is functioning properly, perform the following commands:

TABLE 13-1. HydraProbe Functional Test

Step	Directions
1	Place the HydraProbe in distilled water in a plastic container. Ensure the entire probe is submerged.
2	In transparent mode and with the third parameter set (aM3!), type “1M3**!**” followed by “1D0**!**” (with a probe address of 1 for this example).
3	The typical response of a properly functioning HydraProbe is “1+77.895+78.826+2.462”.
4	From this example, the real dielectric permittivity is 77.895, the temperature corrected dielectric constant is 78.826, and the imaginary dielectric permittivity is 2.462.
5	According to factory specifications, the dielectric constant should be from 75 to 85 and the imaginary dielectric permittivity should be less than 5.
6	Optional: After probe verification, reset the probe back to the default parameter or any other parameter set.

13.2 Causes of Unexpected HydraProbe Results

Possible causes of unexpected HydraProbe results.

- Void spaces between the tine assemblies can occur from changing soil conditions. Shrink/swell clays, tree roots, or pebbles may introduce a void space.

- Water in the soil will be pulled downward by gravity; however, during dry periods or in arid regions, the net movement of water is up toward the surface.

- Sandy soils drain better than soils that are clay rich. In general, the smaller the soil particle size distribution, the slower it will drain. Sometimes silt may have the same particle size distribution as clay, but clay will retain more water for longer periods of time.

- Soil horizons have different densities. In general, the greater the soil density, the less water it will hold and the slower water will move through it. Occasionally, water will stop or slow down and rest on a dense, less permeable layer of soil.

- Shrink/swell clays have a large ion exchange capacity and will shrink/swell seasonally with water content. The seasonal expansion and contraction homogenizes the top soil and the subsoil. As the clay shrinks during a drying period, the soil cracks open and forms large crevasses or fissures. If a fissure forms in the measurement volume of the HydraProbe, the probe will signal average the fissure and potentially generate biased results. If the fissure fills with water, the soil moisture measurement will be high. If the fissure is dry, the soil moisture measurement will be lower than expected. If the HydraProbe measurements are being affected by shrink/swell clays, it is recommended to relocate the probe to an adjacent location.

- Never use excessive force to insert the probe into the soil. Some soils will have pebbles. If a pebble finds its way between the probe's tines, it will create an area in the measurement volume that will not contain water. The probe will signal average the pebble, which lowers the soil moisture measurement. If the pebble is an anomaly, relocating the probe will provide more representative soil measurements. However, if it is revealed from the soil survey that there exists a random distribution of pebbles, a pebble between the tines may provide realistic measurements.

- Organisms such as plants and burrowing animals can homogenize soil and dislodge soil probes. If the HydraProbe's tine assembly becomes home to organisms, the soil moisture measurements will be affected. After the animal vacates, the soil will equilibrate and the soil measurements will return to representative values. The cable leading to the probe may be chewed by some animals. If communication between the datalogger and the probe fails, check the cable for damage.

- If the electrical conductivity reaches 1 S/m, the soil moisture measurements will be significantly affected. The HydraProbe is less affected by salts and temperature than TDR or other FDR soil sensors because of the delineation of the dielectric permittivity and operational frequency at 50 MHz. The salt content will increase the imaginary dielectric constant and thus the soil electrical conductivity.

- Water preferentially travels between peds on soil. This is evident by clay film coatings that develop around a ped. Often, the clay film delays the infiltration of water into the ped, thus as the wetting front moves down into the soil, the regions between the peds become the preferential water pathway. As the wetting front moves through the soil column, the soil moisture measurements may be temporarily biased by the peds. Likewise, if the sensing volume is residing between several peds, the soil moisture measurements will reflect the movement of water between the peds. During installation, if a horizon has thick clay films around the peds, the user may want to use daily averages of soil moisture readings to accommodate soil moisture variations in the peds.

- The HydraProbe can also be used to determine if soil is frozen. Once ice reaches 0°C, it will begin to thaw and the real dielectric permittivity will increase from 5. However, temperature alone may not indicate whether or not the soil is frozen. As the soil begins to thaw, the soil moisture and the real dielectric permittivity should return to values similar to what they were before the soil froze.