Installing and Using the AM400 Soil Moisture Monitor

Prepared for

The Montana Department of Environmental Quality
1520 Sixth Avenue
Helena, MT 59620

Prepared by
The National Center for Appropriate Technology
3040 Continental Drive
Butte, MT 59702

June 2004

Table of Contents

Installing the AM400 Soil Moisture Monitor

Selecting a Site

(M. K. Hansen Company photo)

- Choose a convenient location where it will be easy to check your soil moisture regularly.

- Mount the monitor near eye level on the north (shaded) side of a post. A simple plywood backboard (not shown in the photos on this page) creates extra shading to keep the electronic components cool, and also protects the back of the AM400 from sprinkler spray or rain. Make sure the post is located where it will not obstruct irrigation or harvesting equipment.

(M. K. Hansen Company photo)

- [illegible]ove the snap-on protective cover, the four screws holding on the face plate, and the four screws holding the circuit board in place. Mount the AM400 box securely on the post, then reinstall the circuit board. Leave the faceplate off until you've made all wiring connections inside the enclosure.

- In choosing monitor and sensor locations, we recommend that you *minimize the length of cable runs*. Sensors can be as far as 1,000 feet from the monitor without significant distortions in the readings, but long cable runs mean more work (such as trenching) and increase the cost of installation. 1,500 feet of direct burial cable will cost you as much as purchasing a second monitor.

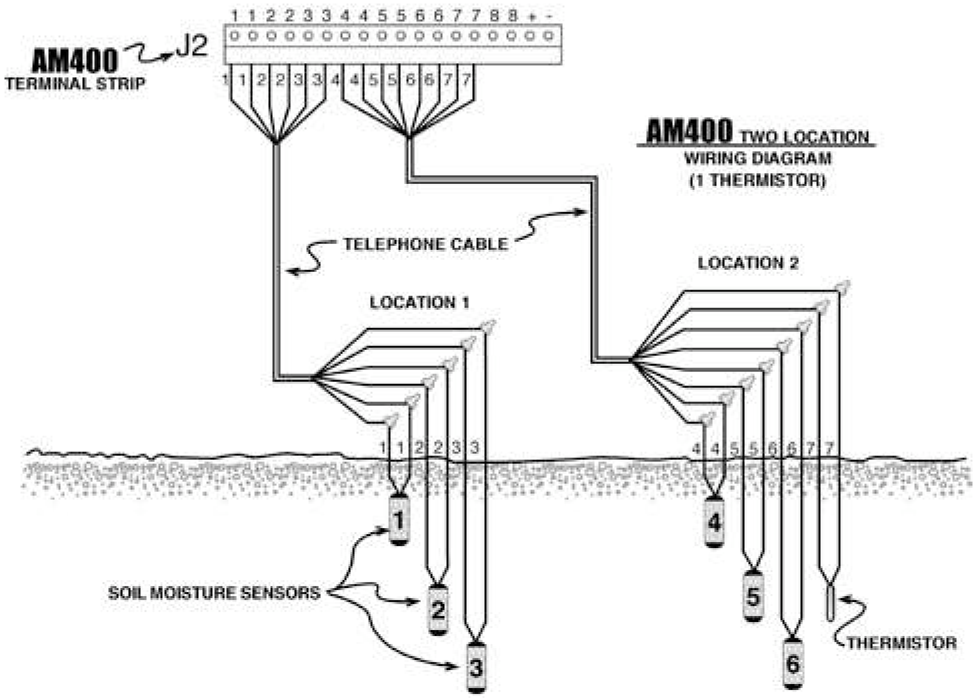
Choosing Sensor Locations

Watermark sensor (NCAT photo)

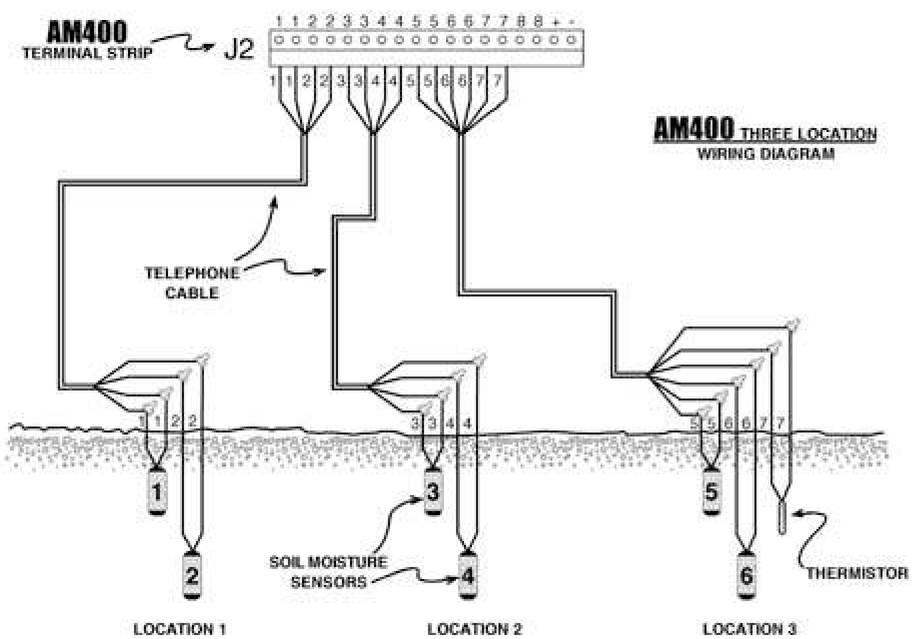
- Choose one or more locations that are representative of your field. It's generally a mistake to choose exceptionally wet or dry areas. For example, if you install sensors in the driest part of the field, the readings may lead you to overwater the rest of your crop.

- Don't install sensors near the edge of a field. Many pivot irrigators find it convenient to put the monitor at the pivot point and run cables outward from the center. This can be a good plan, but keep in mind that the innermost span or two of a pivot are often wetter than the rest of the circle. (Manufacturers tend to oversize these nozzles to avoid clogging.) You might get a better installation – with shorter cable runs to a more typical part of the field – by putting the monitor on a post at the edge of the field or along the access road to your pivot point.

- Up to six sensors can be connected to the AM400. Possible configurations include two sites, with up to three sensors at each site, or three sites, with up to two sensors at each site. You'll also need one thermistor to measure soil temperature.



Two-site configuration.
(M. K. Hansen Company)



Three-site configuration.
(M. K. Hansen Company)

- Place sensors in two or more depths within the soil profile. About 70 percent of a plant's roots are found in the upper half of the plant's maximum rooting depth – often called the *effective root depth*. So for irrigation management purposes, the most important location is probably somewhere near the midpoint of the effective root depth, or at about one quarter to one third of the total root depth.

- A common arrangement is to bury sensors at 6", 18", and 30" deep, to track moisture in the first, second, and third foot of soil depth below the surface. Consult your local NRCS office or county agent if you have questions about where to place sensors for your crops and soils.

Using a bar to dig sensor holes.
(NCAT photo)

- In turf, the most important location is probably just beneath the root zone. The sensors are most useful for detecting overwatering, as evidenced by persistent wet conditions deeper than the roots. Underwatered grass turns brown quickly, so sensors are less essential for detecting underwatering.

Burying Sensors

- Pre-soak Watermark sensors and allow them to dry out thoroughly two or three times before you install them. Always install a wet sensor.

- For shallower sensors, a shovel works OK as a digging tool. The best tool, though, is a soil sampler or digging bar that makes a hole about the same diameter as the sensor. The Irrometer Company (manufacturer of Watermark sensors) recommends using a 7/8" diameter steel rod.

- Make sure that each sensor is in close contact with the surrounding soil. Air pockets will distort soil moisture measurements or even cause the sensor to stop giving readings. We've seen more problems from poor soil contact than any other cause (except perhaps bad splices). These problems are especially common in coarse soil.

Pushing a sensor into a hole.
(NCAT photo)

- It's best to install sensors when the ground is neither too wet nor too dry, to avoid compaction and air pockets. Two to three days after irrigating is an ideal time to install sensors.

- Ideally, you want the soil around each sensor to resemble soils in the rest of the field. You may want to make a mud slurry from water and surrounding soil. Pour a little water into the hole and add a little slurry. After carefully pushing the sensor to the bottom of the hole with a stick, fill with a little more water and more mud slurry or finely crumbled dry soil, packed down gently.

- Ideally, you also want crop canopy near the sensors to resemble the canopy in the rest of the field. Try to minimize damage to crops in the vicinity of sensors.

- Watermark sensors are somewhat fragile and can be damaged during installation. Don't ever force a sensor into a tight hole.

- Once installed, sensors may be left in the ground. Freezing will not damage them, and they should last five to seven years, or even longer. Older sensors should continue to give reasonably accurate readings, although accuracy will gradually decline.

- Bring the green wire leads from each Watermark sensor to the surface. Make sure you know which wires go to which sensors. One marking system is to tie a single knot in the wire leads for the shallowest sensor, two knots for the next sensor, and three knots for the deepest sensor.

- If you've dug a trench for the cable, you may want to install sensors in the side of trench. Measure down from the top of the trench and make a hole in the sidewall at a downward angle of about 45 degrees. This will allow you to pour water in the hole.

- Only one thermistor (temperature sensor) is needed for each monitor, except in unusual circumstances. (For two-thermistor configurations, see "Advanced Settings" at the end of this guide.) Bury the thermistor either near the sensors or near the monitor. The AM400 uses electrical resistance as an indicator of soil moisture, making small corrections based on soil temperature. Soil temperature varies by depth, and the thermistor should generally be buried at an average sensor depth. For example, if your sensors are 6" and 18" deep, your thermistor should be about 12" deep.

- Mark locations or take detailed measurements after the sensors are buried, so you can find them later, if you need to dig them up. Make a detailed map showing sensor and thermistor locations, depths, and what color of wire is connected to each sensor. It's also a good idea to note sensor depths and locations with an indelible marker on the inside of the removable cover.

- Watermark sensors fit snugly inside ½" class 315 PVC pipe. You can glue a section of pipe to the top of the sensor, leaving the pipe extending slightly above ground to mark the sensor location. This also makes it easier to remove the sensor from the ground, and is almost a necessity for annual crops or other situations where you'll need to remove the sensors often.

(NCAT photo)

- After cutting the pipe to the right length, pull the green wire through the pipe and glue the pipe to the sensor collar. Note that PVC glue does not adhere well to the ABS plastic of the Watermark sensor, so look for a glue marked "PVC/ABS."

- A common problem is that the top of the PVC pipe gets broken or cracked, the tubing turns into a funnel, and the sensors give extremely inaccurate wet readings. To prevent this, seal the top of the pipe with silicone caulk to prevent water from running down the pipe. Also make sure the tubing doesn't extend so far above the surface that it will be damaged by machinery.

Choosing and Purchasing Cable

Direct burial cable and indoor phone wire. (NCAT photo)

- There are two main options for connecting sensors to the monitor: indoor phone wire or direct burial cable. Cable with three or four pairs of 18 to 24 gauge wire is easiest to handle and fits best inside the monitor enclosure. Each sensor requires one pair of wires.

- Indoor phone wire isn't really intended for this kind of outdoor application, but many people have used it successfully. (In fact, we haven't yet heard of a failure.) It's readily available, easy to work with, and cheap – only four to five cents per foot. If you are careful not to scuff or nick the insulation, this type of cable will probably last for years – unless the area is heavily infested with ground squirrels or gophers. We've had good success with 24-8 indoor phone wire (i.e. four pairs of 24 gauge wire). We don't recommend installing indoor phone wire in the same trench as power supply wiring to a pivot or other alternating current electrical device, because of signal interference problems.

- Direct burial 22-6 cable (i.e. 3 pairs of 22 gauge wire) generally needs to be specially ordered, costs around 25 cents per foot, and is stiffer and harder to work with than indoor phone wire, though direct burial cable is much more durable. You may find it worth the extra money and expense, especially if you are planning a permanent installation. Direct burial cable is shielded – meaning that when you cut it you'll encounter a copper shield – so you'll need a good set of cutters.

Laying Cable from Sensors to Monitor

Burying cable in a shallow trench. (NCAT photo)

- Lay the cable to each of your sites. Determine the amount of cable needed, but (before cutting!) make sure you allow enough length to make connections at both ends. Attach the cable securely to the post (at the monitor end) with cable staples.

- Most people we've worked with have chosen to bury the cable in a shallow trench, and most who left the cable on the surface eventually regretted this decision, when cable was tangled up in machinery or cut during harvest. Some people with access to trenchers have buried the cable deeply enough so that it was below plowing or disking depth.

- It may be convenient to bury the cable in the same trench as three-phase wiring supplying power to a pivot irrigation system. (Check local electric codes to make sure this is allowed.) We recommend that at least six inches of earth separate the monitor cable from the pivot cable to reduce interference or "noise" in the monitor. This will also provide a safety factor.

- Leave extra cable at the sensor end, in case your first splice fails.

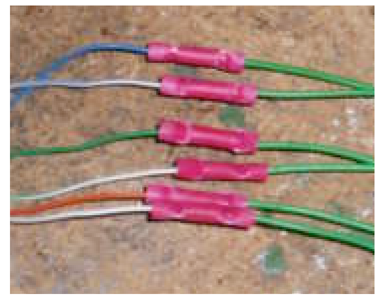
Making Connections

- The most important thing is to make good solid splices that will remain waterproof through repeated soakings. There are many ways of doing this. We've tried the following three:

Twist-on wire nuts
(M. K. Hansen Company photo)

1. Twist-on wire nuts, with a squirt of silicone glue in each nut for waterproofing. This quick and easy way to make splices is suggested by the M.K. Hansen Company. You'll need to use the smallest size (gray) wire nut, and you may need to fold very fine wires in half (doubling the diameter) to get a good grip from the wire nut. Wrap with electrical tape, if you like, for extra waterproofing.

2. Insulated butt connectors. This approach makes a neat straight-line connection, but the wires don't always crimp solidly, it's easy to tear insulation with crimping pliers, and the connectors themselves provide no waterproofing. Heat-shrink tubing over these splices makes a completely waterproof connection, but you have to be extremely careful not to melt delicate insulation on the fine-diameter wires while shrinking the tubing. Our failure rate has been pretty high when heat-shrinking these splices.



Insulated butt connectors
(NCAT photo)

Scotchlok™ UR connectors
(NCAT photo)

3. A third approach (our favorite lately) is to use Scotchlok™ UR or UG connectors. R is for red and G is for green, the color of the dot on the connectors. These are self-stripping, insulated, moisture resistant, and easy to work with. If you use UR connectors you will need to strip the green wires on the sensor and thermistor wires but not the cable wires. If you use UG connectors, you won't need to strip any of the wires. Be sure you test each splice by pulling lightly on the connected wires. For extra waterproofing (and as an alternative to heat shrinking) we wrap our splices in waterproof tape and coat them with fast-drying liquid electrical insulation, available at hardware stores.

- If you are using heat shrink tubing, make sure you slide the tubing over the cable *before* you make your splices. Wrap the wiring in several layers of electrical tape or something similar to give it some protection before heat shrinking. Slide the heat shrink tube back over the connectors, covering the entire length of the splice. Then carefully heat the tubing with a torch until it melts and the sealant oozes out all around the splice. After it cools, bury it. *NOTE*: Before wrapping any splice with tape or heating the heat shrink tubing, make the connections at the monitor and check to see that you are receiving a signal from each sensor.

- To avoid confusion, we always follow alphabetical order, e.g. B, G, O for blue, green, and orange. Blue wires go to the shallow sensor, green wires go to the next-deepest one, and orange wires go to the deepest sensor. (Note that this is not the standard color convention used by phone line installers.)

- To make connections at the AM400, push wires through the plastic cable holder at the bottom of the enclosure and into the box. At the bottom of the circuit board is a terminal strip with pairs of numbers across the top. You'll see a line of small screws across the front of the strip, with small openings at the bottom of the strip. Strip only a small amount of insulation from the ends of the wires (about 3/8"), so no bare wire is exposed when the wires are connected to the terminal strip.

(NCAT photo)

- It's a good idea to squirt some caulk or glue around the wires where they enter the bottom of the enclosure, to keep dust and insects out.
- Secure the cable to the post with cable staples.
- To avoid confusion, we always follow this convention: insert the pairs of blue wires for your shallowest sensor in the holes in the bottom of the strip marked '1'. Insert the next-deepest sensor wires into the holes marked '2'. Continue for all the sensors, and check all connections for tightness. The thermistor wires must always go into the two holes marked '7'.
- Test the monitor again before burying the splices. To test the monitor, press the red button on the monitor (the right-hand button marked S1, if the faceplate is removed). You should see a temperature reading as well as a reading for each sensor installed. If not, check all connections.

Handy Installation Tools

- Bucket
- Small Phillips screwdriver
- Very small straight slot screwdriver
- Lineman's pliers
- Small wire strippers
- Crimpers (for butt connectors)
- Knife
- Dowel or stick, marked at 6", 8", 12", 18", and 24"
- Soil probe
- Digging bar
- Shovel
- Hammer
- Cordless drill
- Propane torch (for heat-shrink tubing)
- Regular sized Phillips and straight slot screwdrivers

Other installation supplies

- Wood post
- ½" plywood backing, approximately 10" by 12"
- Heat-shrink tubing
- Heavy dielectric splicing tape if not using heat shrink tubing
- Fast-drying liquid electrical insulation
- UR or UG phone cable connectors, butt connectors, or fine-diameter (gray) wire nuts
- Silicone caulk
- Electric tape
- AA batteries (2 per unit)
- ½" class 315 PVC piping and PVC/ABS glue, if installing PVC tubing on top of sensors
- Wood screws
- Cable staples

Interpreting Readings from the AM400 Monitor

The AM400 measures electrical resistance inside each Watermark sensor, and – after correcting for soil temperature – converts these readings into centibars (abbreviated ‘cb’), a measure of soil water tension. A centibar is 1/100th of a “bar,” where a bar is roughly equivalent to one atmosphere of pressure. Think of soil water tension as indicating how hard the plant has to work to extract water from the soil. As soil dries, soil water tension increases, the plant works harder to pull water from the soil, and the centibar reading goes up. *Big numbers mean dry soil.*

Soil water tension depends heavily on soil type. The soil water tension of saturated soil varies between 0 and about 10 cb, while field capacity varies between 20 and 33 cb. Coarse soils (from sands to sandy clay loams) have released most of their plant-available water at 80 cb, while many clay and silty soils retain most of their plant-available water at readings drier than 80 cb. *The centibar number alone does not tell you what volume, or how many inches, of water are stored in your soil.*

General Guidelines

Below are some general guidelines. Remember that soil type plays an enormous role in how water is stored and made available to the plant.

Reading	Interpretation
0-10 CB	For fine soils, the soil is saturated and water is draining.
10-20 CB	Most soils are at field capacity.
30-40 CB	Range of irrigation in fine sandy loams.
40-60 CB	Range of irrigation in medium soils.
70-90 CB	Range of irrigation in heavy soils.
> 100 CB	50% available water or less. Plants may be experiencing stress.

While no two irrigated fields are alike, good irrigation management basically involves letting your soils dry out well below field capacity, then irrigating just enough to re-fill the soil profile – or slightly under-filling the soil, to leave room for precipitation.

- Don’t read too much into the information, or get hung up on small variations in the numbers you are seeing. The AM400 is intended to be a practical farming tool, not a research tool. Ignore small upward and downward changes in the reading, which may simply indicate day/night differences in soil temperature and evapotranspiration.

- When you look at the graph on the AM400 screen, you’ll see an upward spike every time you irrigate or it rains, then a downward-sloping line as the soil dries out. Pay attention to the slope of this line, since it indicates how quickly your soil is drying.

- Make sure you are aware of the scale, shown in the numbers to the left of the graph. The graph re-scales itself to accommodate higher readings. If the graph is only showing you the range from 0 to 25 centibars, changes may look much bigger and more important than they really are. Remember that soil at 25 centibars is still very close to field capacity.

- At various times during the irrigation season, take soil samples at various depths (with a shovel or soil sampling probe) and feel them in your hands. Note how these samples correspond to the moisture readings on your monitor. The AM400 is a sophisticated device, but getting your hands dirty is still the best way to develop confidence in what the readings really mean.

- On a hot windy day, take a reading in the morning and one in the evening to get an idea of how quickly the soil is drying.

- Take a reading when you start irrigating over a sensor location. Check the same location four, six, eight, and 12 hours later. The profile may be filling faster or slower than you had thought.

Centibar Reading and Soil Moisture Correlations

The charts below give correlations between centibar readings and the amount of water remaining in the soil. Use these numbers with caution. They are for uniform, non-rocky soils and are not adjusted for crop type or effective rooting depth.

Sandy Soils

Centibar Range	Inches of Water per Foot of Soil
10 cb or less	0.8
11-30 cb	0.6
31-50 cb	0.4
51-65 cb	0.2
>65 cb	0

Sandy Loam Soils

Centibar Range	Inches of Water per Foot of Soil
10 cb or less	1.4
11-20 cb	1.2
21-30 cb	1.0
31-40 cb	0.8
41-50 cb	0.6
51-60 cb	0.4
61-70 cb	0.2
>70 cb	0

Silt Loam/Clay Loam Soils

Centibar Range	Inches of Water per Foot of Soil
10 cb or less	1.9
11-20 cb	1.6
21-30 cb	1.4
31-40 cb	1.2
41-50 cb	1.0
51-60 cb	0.8
61-70 cb	0.6
71-80 cb	0.4
81-85 cb	0.2
>85 cb	0

Loam Soils

Centibar Range	Inches of Water per Foot of Soil
10 cb or less	1.8
11-20 cb	1.6
21-30 cb	1.3
31-40 cb	1.1
41-50 cb	0.9
51-60 cb	0.6
61-70 cb	0.4
71-75 cb	0.2
>75 cb	0

Clay Soils

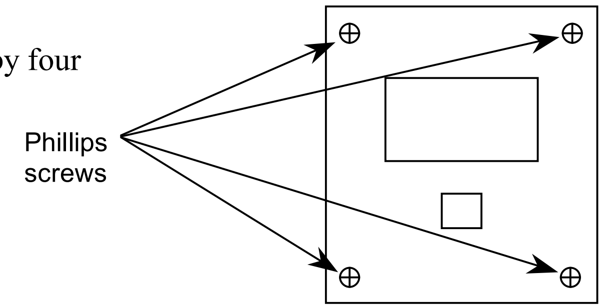
Centibar Range	Inches of Water per Foot of Soil
10 cb or less	2.1
11-20 cb	1.9
21-30 cb	1.6
31-40 cb	1.4
41-50 cb	1.2
51-60 cb	1.0
61-70 cb	0.8
71-80 cb	0.6
81-90 cb	0.3
91-95 cb	0.2
>95 cb	0

Adapted from guidelines developed by Dr. Jim Bauder, Department of Land Resources and Environmental Sciences, Montana State University, Bozeman, MT.

Removing the Circuit Board from the AM400 Monitor

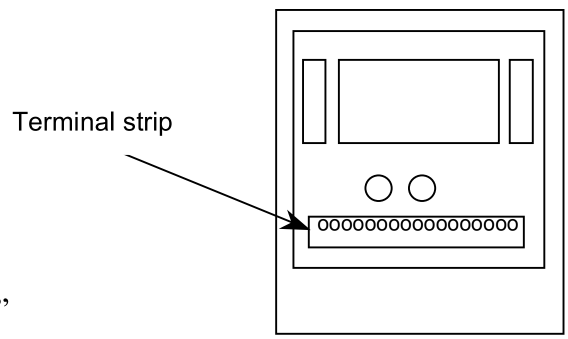
You may have occasion to remove the circuit board either to store indoors over the winter, to download data directly to a computer, or for repairs.

1. Remove the face plate (held on by four small Phillips screws).



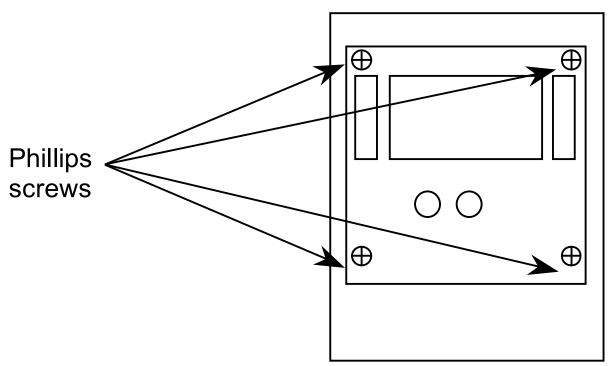
Face plate

2. Remove the black plastic terminal strip (the thing with all the tiny screws in it) from the bottom of the circuit board. Do NOT disconnect or cut any of the individual wires. Just pull gently on the terminal strip with your fingers and you'll be able to work it free from the pins and remove it. You may need to do a little prying or rocking to get it free, but of course don't use a screwdriver or do anything violent. While you are removing the terminal strip you may find that it "breaks" in half. Don't worry, the parts easily slide and snap back together again.



Circuit board

3. Remove the circuit board (held on by four small Phillips screws).

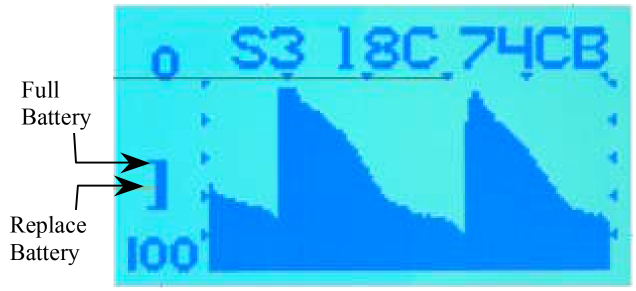


4. Do NOT remove the batteries unless you are planning to clean the circuit board, since these power the internal clock that enables you to assign dates and times to the soil moisture readings stored in memory. Re-insert circuit board screws and reattach the face plate so you won't lose any screws.

Maintenance

The AM400 doesn't require much in the way of maintenance and should function virtually trouble-free for years. There are, however, a few items that should be addressed or inspected periodically.

Batteries: Check the battery indicator on the left side of the screen. When the bar starts to drop, replace with two AA batteries.



(M.K. Hansen Company)

Cleaning: Normally there is no need to clean the circuit board or enclosure, unless you notice a buildup of dirt and debris. To clean the monitor, remove the circuit board and wipe the inside of the enclosure with a damp rag. To clean the circuit board, remove the batteries and gently wash the circuit board with mild soap and lukewarm water, being careful to avoid getting water on the LCD display. Make sure the soap is thoroughly rinsed off and allow the board to dry completely before reinstalling the batteries and replacing the circuit board in the enclosure. Reseal any openings with caulk.

Winter Storage: While the monitor can generally be left outside during the winter months, removing and storing the circuit board inside a heated building is recommended and may extend the monitor's life.

Troubleshooting

Nearly all problems encountered during installation are caused by bad splices. Occasionally, the cable itself will be damaged. Bad WaterMark sensors are also a (rare) possibility.

Symptom: *No display whatsoever appears on the screen.*

Make sure batteries have been installed and that they aren't dead. Install or replace as necessary.

Symptom: *One or more sensors give no reading during installation. (You see a dashed line.)*

Make sure that:
1. The sensor wires are connected to the correct slots on the terminal strip;
2. The terminal strip is firmly attached to the circuit board and correctly aligned on the pins;
3. The wires aren't broken; and
4. The screws holding the wires on the terminal strip are tight.

If all of this checks out, the problem is most likely a bad splice. If re-splicing doesn't solve the problem, the cable may have some type of damage.

Symptom: *One or more sensors stop giving readings. You see a dashed line on the display screen.*

If the graph shows a recent downward (drying) trend, dropping off the display screen, the sensors may simply be so dry that they are unable to register a reading.

If the readings stop abruptly (with no previous downward trend), make sure that:
1. The sensor wires are connected to the correct slots on the terminal strip;
2. The terminal strip is firmly attached to the circuit board and correctly aligned on the pins;
3. The wires aren't broken; and
4. The screws holding the wires on the terminal strip are tight.

If all of this checks out, the problem is either the splice or some damage to the cable connecting the sensors. Redo the splice or repair the cable.

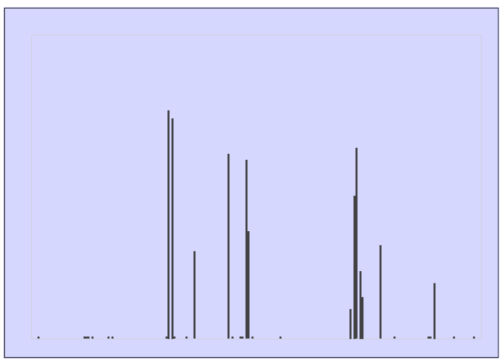
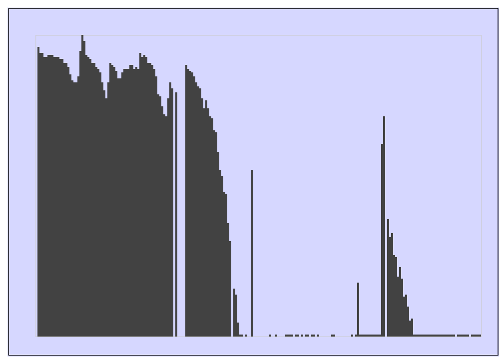
Symptom: *The temperature reads 25^o C.*

25^o C is a default reading indicating that there is no thermistor input. If you're certain that this reading is wrong (equivalent to 77^o F), the thermistor is not connected correctly. (Note that on a warm summer day, a thermistor sitting in the sun may be quite warm.) Make sure that:

1. The thermistor wires are connected to the two slots on the terminal strip labeled '7';
2. The terminal strip is firmly attached to the circuit board and correctly aligned on the pins;
3. The wires aren't broken; and
4. The screws holding the wires on the terminal strip are tight.

If all of this checks out, the problem is most likely the splice. If re-splicing doesn't solve the problem, the cable may be damaged.

Symptom: *The display graph shows upward spikes or breaks, as in the illustration below.*

First, make sure the sensor wires are connected to the correct slots on the terminal. Check for tight connections at the terminal strip and make sure the wires aren't broken. Inspect the enclosure for dirt, debris, water, and insect-related goo or scum. Debris on the circuit board can cause odd readings, and moisture can cause corrosion on the circuit board, especially on battery terminals.

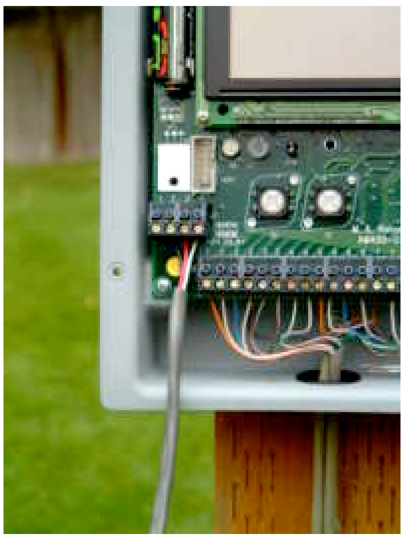
If *only one* sensor is showing spikes, the problem is most likely either the splice or some damage to the cable. Redo the splice or repair the cable.

If *more than one* sensor is showing spikes or breaks, and these are on different cables, the problem could still be caused by bad splices or cable damage. If re-splicing and replacing cables does not solve the problem, and you've made sure that the circuit board and battery terminals are clean and dry, you may need to consult the manufacturer.

Downloading Data from the AM400 Soil Moisture Monitor

The AM400 stores 10 months of data that can be downloaded, imported into a software program or spreadsheet, and graphed. You can download data two ways: 1) directly from the circuit board to a laptop computer, or 2) from the circuit board to a personal digital assistant (PDA) and then to a computer. Either way, you need connectors and cables.

A downloading cable is included with your purchase of AM400 Chart graphing software from the M.K. Hansen Company. Alternatively, you can order a special black plastic plug that fits over the four pins on the circuit board[1] from Control Design Supply in Seattle, phone # (253) 804-0715. The part number is LMI9245.102.01. You would then need to construct a connecting cable using a serial cable, the plastic plug, and a serial connector. For a cable to connect to a Palm Pilot refer to Oregon State University's website. (See below.)



Downloading cable connected.
(M. K. Hansen Company)

Downloading directly to computer, using Windows 98 or 2000[2]

No special software is needed, since Windows 98 and 2000 come pre-loaded with a downloading program called HyperTerminal. Download in the field, using a laptop, or you can remove the circuit board and bring it inside to download data. Follow the three steps below:

Step 1. Create the connection description using HyperTerminal

Prior to the first data download, create a "connection description" for the AM400. This task is best performed prior to taking the laptop computer into the field.

Click on the Windows **Start** button. Select, in order: *Program* menu, *Accessories* menu, and *Communications* menu. Click on *HyperTerminal* on the *Communications* menu. Double click on the *HyperTerminal* icon.

In the *Connection Description* window, enter "AM400" in the *Name* field and then select an icon from the menu. This icon will be used in the future to select the AM400 connection description prior to downloading data. Click *OK*.

In the *Connect To* window, select **Direct to Com1** in the *Connect Using* field. Click *OK*. In the *COM1 Properties* window, enter the following:

Bits Per Second: **9600**
Data Bits: **8**
Parity: **NONE**
Stop Bits: **1**
Flow Control: **NONE**

Click on the *Advanced* button and make sure that the **Use FIFO Buffers** box is checked. Click *OK* two times. Close the *AM400 - HyperTerminal* window. Click *Yes* to disconnect. Click *Yes* to save the session.

[1] Some AM400 models may have an external port for downloading.
[2] Procedures will vary for other operating systems.

Step 2. Setup prior to data download

Make sure the computer system date and time are correct. Click the Windows *Start* button. Select in order: *Program*, *Accessories*, and *Communications*. Click *HyperTerminal* on the *Communications* menu. Double click on the *AM400* icon. Hit any key to turn on the *COM* port. Select *Transfer*. Click *Capture Text*. Click *Browse* in the *Capture Text* window. In the *Select Capture File* window, use the *Save In* field to specify the directory where the data file is to be placed. In the *File Name* field specify the name of the data file where the captured data is to be stored. A new data file name must be used each time data is downloaded.

Click *Save* but DO NOT click *Start* in the *Capture Text* window until after the serial cable has been connected to the AM400 and the AM400 has been powered up.

Step 3. Download data

Remove the AM400 face plate. Connect the serial cable from *COM1* of the computer to the AM400 printed circuit board, as shown in the figure on the previous page. Make sure the white wire connects to the right-hand pin. Power up the AM400 by pressing the S1 button. Click *Start* in the *Capture Text* window on the computer. Press S1 to begin the download. You should see text scrolling down the computer screen. When the text stops scrolling, close the *Text* window. Click *Yes* to disconnect.

A note on file format

Data files downloaded from the AM400 directly to a computer are in comma-delimited ASCII format. Each file consists of records (or lines of data) made up of eight numbers. The numbers within each record are separated by commas. Records (or lines) are separated by carriage returns. A record contains the data recorded at a specific eight-hour interval. The first six numbers in each record provide soil moisture readings in centibars. The first reading corresponds to sensor number 1, the second corresponds to sensor number 2, and so on. The seventh and eighth numbers correspond to soil temperature readings in degrees Celsius from thermistors connected to channels seven and eight respectively. Records are downloaded in time order with the most recently recorded data first. When viewed using a text editing program, the most recently recorded data appears at the top of the file. You can import the text files into Excel and then create graphs from the data.

For more information on data downloading, visit www.mkhansen.com.

Downloading to a Palm Pilot and then to a computer, using Windows 98 or 2000 [3]

Clint Shock at Oregon State University (OSU) has developed downloading software to use with a Palm Pilot. The software and instructions are at www.cropinfo.net/downloads/soilwater.html. Some general directions are given here:

Step 1. Get necessary hardware and software.

You will need the following software and hardware before you can install OSU's software program on your computer and Palm Pilot:

- Palm Desktop, Version 4 or above, from Palm, Inc.
- WinZip
- Any Palm Pilot, from Palm, Inc.
- An appropriate data cable (see OSU website for list of data cables)

[3] Procedures will vary for other operating systems and Personal Digital Assistants other than the Palm Pilot.

Step 2. Set up OSU Water Potential software.

- Download the OSU Water Potential Software onto your computer from www.cropinfo.net/downloads/SoilWater.zip.
- Using WinZip, un-Zip SoilWater.zip. This creates a folder that you can put anywhere on your computer. The developers suggest placing it under c:\Program Files\.
- Create a shortcut in the Start menu or on the desktop to OSU.bat. Depending on where you put the folder, it might be in c:\Program Files\SoilWater\OSU.bat. Because different versions of Windows do this differently, consult the manual that came with Windows or your computer.

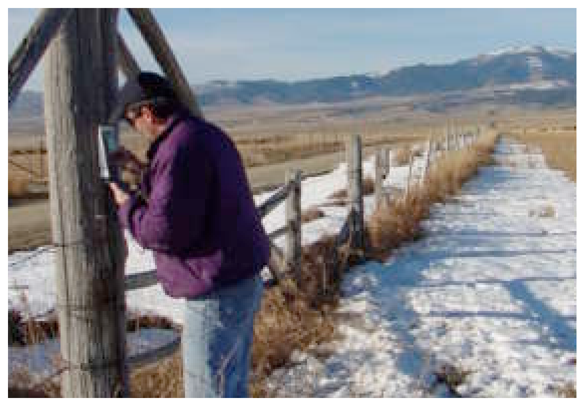
Step 3. Install Palm Pilot Software.

- On your computer, run the Palm Desktop Install Tool. Click *Add*.
- Select all of the .prc files in c:\Program Files\SoilWater\ and click *Open*. You should now see three programs listed in Install Tool. Press *Done*.
- Connect your Palm Pilot to the computer and press the *HotSync* button.

The necessary software should now be installed on both your Palm Pilot and your computer.

Step 4. Download data.

- Connect the Palm Pilot to the circuit board with the special cable.
- Run the Soil and Water Potential program.
- Enter a name for the monitor, or select it from the list.
- Press *Collect Data*.
- Press the S1 button on the AM400 monitor. If data does not begin to download, press the button again. When the data collection is complete, the number of characters collected will stop increasing. (These numbers increase very quickly.)
- Press *Done*.
- You can collect data from multiple AM400s.



Downloading to a Palm Pilot. (NCAT photo)

Step 5. Transfer the data to the computer.

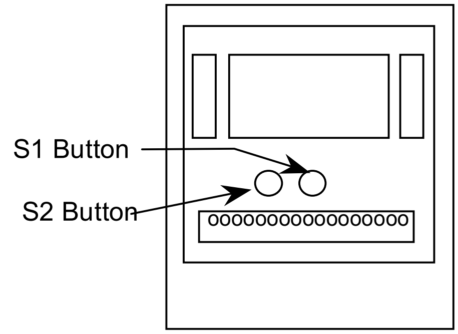
- Connect Palm Pilot to the computer and press the *HotSync* button. Note: Once you download data to your Palm Pilot and to your computer, the original files are still on the Palm Pilot until you delete them.

Step 6. Convert data into text format.

- On your computer, run the OSU Soil Water Potential program. If you have trouble finding it, it is called OSU.bat.
- Select the file to open. This is the data you collected with the Palm Pilot. It will be found in your Palm Pilot user's backup directory. This is usually c:\Program Files\Palm\LastF\backup\, where LastF is your last name and first initial. The file name will start with the name you gave to the particular AM400 monitor when you downloaded the data and will be appended by -Day.pdb, where Day is the day of the year (1-366) that it was downloaded.
- Select a place to save the output file, which will be in comma delimited ASCII format. This file will contain the data collected from the field in a usable text format. This data file can be imported into any graphing program such as Excel, Lotus 1-2-3, or Quattro Pro.

Advanced Settings for the AM400 Monitor

Reset the time setting
The AM400 samples soil moisture three times during each 24-hour period, eight hours apart. If you want the AM400 to sample at a specific time, you can reset the sample clock by this method:



1) Remove the face plate.

2) Wake the unit up by pressing the S1 button. The S1 button is the one that is used during normal operation. With the face plate off, it's the button on the right.

3) Press the S2 button twice. The S2 button is to the left of the S1 button. You'll see something in hexadecimal format, similar to this:

```
01 _ _ _ 01_ _ _
01 42.5 01_ _ _
01 14.0 01_ _ _
0    0.5    _ _ _
```

4) Press the S1 button to reset the sample clock to 0. You should hear the monitor make a fluttering noise. If you want to sample at midnight, go out to the unit at 4:00 PM or 8:00 AM, and reset the sample clock to 0.

Switch temperature units (for units manufactured in 2004 or later)
Newer units allow the user to switch between degrees Celsius (C) and degrees Fahrenheit (F). The default is F. To switch to C:

1) Remove the face plate.

2) Wake the unit up by pressing the S1 button. The S1 button is the one that is used during normal operation; with the face plate off, it's the one to the right.

3) Press the S2 button twice. The S2 button is to the left of the S1 button.

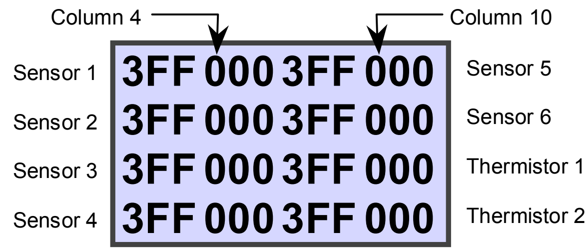
4) Press the S1 key.

Noise filtering
The AM400 has special digital filtering to filter out 60 Hz noise. You should encounter few "noise" problems as long as the cable to the sensors is at least six inches from any AC power cable. However, if you think that noise may be a problem, and your sensor cables are near an AC power cable, the AM400 has a display showing the relative amount of noise on each channel. Before running this test, make sure you have connected a wet sensor or thermistor to each pair of wires that you'll be using. You need to run the test twice, with the AC power source both on and off. To run the diagnostic test:

1) Remove the face plate from the monitor.

2) Wake the unit up by pressing the S1 button and then press the S2 button four times to access the A/D diagnostic display with the letter "T" in the lower right hand corner.

3) Once the A/D diagnostic is displayed, press the S1 button. Single digit hexadecimal numbers representing the relative noise on each channel will appear in the fourth and tenth columns of the display. (Your display may look slightly different.)



Hexadecimal numbers indicating amount of noise.

A "0" in the fourth or tenth columns represents no noise. An "F" in the fourth or tenth columns represents high noise. Column 4 shows noise on channels 1 through 4 from top to bottom. Column 10 shows noise on channels 5 through 8 from top to bottom. (Channels 1 through 6 correspond to sensors 1 through 6; channels 7 and 8 correspond to thermistors 1 and 2.)

Using a second thermistor

The AM400 uses electrical resistance as an indicator of soil moisture, making small corrections based on soil temperature. Shallow sensors are more affected by the diurnal temperature fluctuations than deep sensors, but the resulting variations in soil moisture readings are generally not very significant for the practical purposes of irrigators. So normally, installations include only one themistor, connected to the pair of terminals marked ‘7’ on the terminal strip, and buried at an average sensor depth.

The AM400 does have the capacity, though, to assign the shallow sensors their own thermistor, allowing more accurate soil temperature corrections where the greatest temperature fluctuations are occurring. While few irrigators need this slight improvement in accuracy, a second thermistor can be connected to the terminals marked ‘8’ on the terminal strip. When a second thermistor is installed at the 8 position, the monitor will use soil temperature readings from this thermistor to correct for sensors 1 and 4 (presumed to be shallow). The thermistor at the 7 position will correct for sensors 2, 3, 5, and 6.