MicroLog SP3

Three-channel datalogger
for soil water potential measurement.

User's manual

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Content:

1 General information

MicroLog SP3 is a small three-channel water-sealed datalogger designed for the resistance measurement using of square wave symmetrical alternating current. It is intended for the measurement of soil water potential with sensors whose electrical conductivity is related to soil water content (gypsum block, Watermark sensor). The temperature of the datalogger is measured for the estimation of the soil or an ambient temperature.

The datalogger case is made from high-density polyethylene allowing its long term leaving in soil. It also survives a temporary immersion to water.

Sensors have to be equipped with 2-pin Switchcraft EN3 connectors connected in a watertight manner.

Data memory can store typically 50,000 readings what means ca 16 months of continuous measurement of soil water potential at three points together with the soil temperature at the depth where the datalogger is buried. One record in memory generally represents the average of more measurement within the storing interval. Both intervals can be set independently.

The datalogger memory (non-volatile type) saves data also under totally discharged or damaged battery. Two ways of memory handling it is possible to choose during datalogger initialization: (i) system stops operation when the memory is full or (ii) it keeps running rewriting the oldest data with the newest ones.

PC with a Windows© system is required for datalogger setting and data handling. The communication between PC and datalogger is wireless, data are transferred by infrared communication by means of a special USB cable. Therefore, the data download does not need to open the enclosure; just to remove the soil covering the datalogger.

Mini32 fancy graphical software with many useful options including base statistics is a part of delivery.

Battery duration of 3.6 V lithium battery reaches up to five years of continuous work in hourly measuring intervals. The battery replacement can be easy done directly in the field.

2 Specifications

Measuring range	0 to 40 kOhm
Measuring frequency	160 Hz
Measuring current (constant)	33 µA
Measuring signal wave form	Square wave, symmetrical
Accuracy:	Better than 0.5 % of reading over the whole temperature range
Operating range:	
- temperature	-20 to 60 °C
- relative humidity	0 to 100 %
Datalogging unit:	
- memory capacity	128 kByte
- measuring interval	10 min to 4 hrs
- averaging (storing) interval	10 min to 4 hrs
- internal clock accuracy (-10 to 40°)	±1 minute per month
- input voltage resolution	16-bit
Battery lifetime:	Lithium LS14250CN 3,6 V; 900 mAh
- storage time/idle run (logging stopped)	8/6 years
- when measured every 10 minutes	2 years
- when measured every 1 hour	ca 5 years
Size (diameter x length)	70 x 52 mm (incl. connectors)
Weight (incl. battery)	110 g

3 Soil water (matrix) potential sensors and their calibration

The above mentioned sensors make use of stable dependence of electrical conductivity on the water content in certain porous matter. Since the soil water potential of sensor body and surrounding soils are equal, the sensor water content can be expressed in terms of water potential. Ion conductivity of water solution inside the sensor which generally influences the electrical conductivity is stabilized by the sensor chemical composition based on calcium sulphate.

3.1 Gypsum block

Delmhorst Instrument Copany, NJ, U.S.A. is one of the most known manufacturer of gypsum blocks. A truncated cone made from gypsum contains two concentric electrodes made from stainless mesh. The electrical conductivity of sulfate solution measured between those electrodes depends also on the temperature and soil structure. See e.g. http://www.emsbrno.cz/Data/Resources/pdf/Dela2001.pdf. It should be mentioned, that there is no common opinion concerning el. conductivity versus soil water potential dependence. The equation offered by Mini32 sensor library was derived from the table issued by producer (see GB 2 data sheet in appendix). The whole measuring range is up to 15 bars.

3.1.1 Conversion formula

Used by Mini32 software (after the KS-D1 manual):

SWP = – 0.0000002566*R^6
+ 0.0000271804*R^5
– 0.0010604163*R^4
+ 0.0183247258*R^3
– 0.1321964809*R^2
+ 0.7618710496*R [bar; kOhm]

3.2 Watermark

Watermark soil sensor is a product of IRROMETER Company Inc., CA, U.S.A. Its design is more sophisticated than by gypsum block. Its stainless steel perforated coat strewed with a textile membrane is inside filled in with silica sand complemented with a gypsum capsule and two concentric stainless electrodes.

The 2 bars range fits to agricultural and irrigation purposes – see manufacturer information in appendix.

As for the calibration to soil water potential and temperature, there is more available information yet. The Mini32 sensor library offers four equations of calculation soil water potential from measured a.c. resistance [kOhms]:

- linear (*rough*)
  kPa = (R-500)/135
- acc to Prof. Shock (*Shock 25*)
  kPa=(4.093+3.213*R)/(1-0.009733*R-0.01205*T)
- acc. to Watermark Meter made by IRROMETR company (*Irrometer*)
  $kPa=(p1+p2*R+p3*R^2+p4*R^3+p5*R^4+p6*R^5)*(p7+T\hat{}p8)$ where
  p1 = -0.00121186
  p2 = 0.011105989
  p3 = -0.00026006
  p4 = 2.34E-05
  p5 = -6.37E-07
  p6 = 5.90E-09
  p7 = 368.1438832
  p8 = 1.699405795
- M. K. Hansen Company, WA, U.S.A. compatible (*Hansen*)
  $kPa=(p1+p2*R+p3*R^2+p4*R^3+p5*R^4+p6*R^5)*(p7+T\hat{}p8)$ where
  p1 = -0.066892878
  p1 = 0.196380649
  p1 = -0.018840164
  p1 = 0.001736559
  p1 = -6.30E-05
  p1 = 0.01E-07
  p1 = 28.57229871
  p1 = 0.974296541

Note: In Mini32 software, all equations are implemented for temperature T=25 °C.

4 Operation

MicroLog SP3 datalogger can be used in any environment non-aggressive against polyethylene and synthetic rubber. The operating temperature should not exceed the range -20 to 60 deg.C and the overpressure 0.2 bar (two meters of water column).

MicroLog SP3 has no power switch. It is ready to run immediately after inserting of the battery before dispatching. The system configuration needs a connected PC running the Mini32 software and a special USB/IrDA cable made by EMS.

When it is not in use (operation off), the battery lasts for about six years what is comparable with the total battery lifetime. Nevertheless, remove the battery from the system when the use in next month in not supposed. Note that the system will ask for initialization before next operation. See section After battery replacement or power drop-out.

4.1 Start operation

4.1.1 Basic setting

Make sure that the infrared cable is plugged into a USB port and the communication port is properly configured.

Run Mini32 software.

Put the magnetic head close to the marked point on the sensor lid. The sensor should respond with red light bellow the datalogger lid.

Hold the cable head approximately 10 to 40 centimeters far from the sensor. Make sure that the rounded optical part on the cable head roughly points to the marked point on the sensor lid.

Push "Configuration" button. Set both interval of measurement and two-character device code.

Double click on a channel line opens a channel setting window. Set channel on, choose the sensor type (gauge) and add a description. Set the temperature measurement ON if it is demanded.

Left mouse click on ON/OFF button starts/stops data logging.

Press "Send" button in order to send the configuration to the datalogger.

4.1.2 Advanced setting

Push "More" button in "Configuration" window in order to approach advanced setting screen. This option enables:

- Datalogger reset (initialization). Initializing resets all system variables to default values, changes datalogger time and password, erases all the data from memory and sets the memory operation mode – see General information. System calls for initializing automatically always when the supply voltage has dropped bellow 2.9 Volts, i.e. after battery replacement or its total discharge. In such a case is the user asked for initializing after each communication attempt. Warning – save data always before initializing – they will be erased during initializing!
- Memory erase (RAM clear) should be performed when the memory is full and the data overwriting is disabled and also when the data continuity is senseless or misleading – when the sensor in moved to different location for instance. Make sure the data were successfully saved before memory erasing!
- Hardcopy of memory (HCM). The whole memory content will be saved to file. Use it in case of problem with data conversion after downloading which could be caused by damaged data structure due to external factors. Send the file to producer for free encoding.
- Password. A four-character word can be introduced. Password disables unauthorized changes of configuration.

4.2 After battery replacement or power drop-out

It is necessary to initialize the datalogger always when the battery voltage drops bellow 2.9 Volt. This comes usually after the battery replacement or after its removing. See Advanced setting.

Note: The battery status is continuously calculated since the time of the last system reset. Naturally, the full capacity of the new battery (900 mAh) is supposed. Therefore, the battery duration will be overestimated in case of using a partially discharged battery. See also Battery replacement.

4.3 Memory capacity

Maximum number of days of the measurement stored in memory can be estimated according to formula

N = 50000/(n*k)

where

n = number of records stored each day

k = number of channels in use

Example: Soil water potential measured by all three sensors and temperature values stored to the memory in hourly intervals will fill up the memory in 610 days.

Note: When storing the data of fewer channels less often, the real memory capacity slightly decreases due to 15 bytes long system information stored into the data memory every day. When measuring in one channel once 4 hours (maximum time period of storing to the memory), the memory lasts for five years "only" instead of theoretically calculated 34 years.

5 Data processing

EMS Mini32 universal software supports also the data handling and processing.

Data download and saving process is activated after pushing "Download" button. All data from memory are saved in the file XY_2005_04_28.hex where XY is device code (see Basic setting) and 2005_04_28 is computer date (YMD). This HEX file contains the stored data and complete configuration information including the last battery voltage and datalogger time in a compressed format suitable for fast transfer to computer. Since this format is not usable for next data processing, the file is subsequently converted to another format - DCV (XY_2005_04_28.dcv). This file contains the same information as HEX one, it is typically four time larger but suitable for fast processing as file mixing and chaining, time averaging, drawing, editing, statistical processing etc. In case of accidental wrong data processing in DCV file it is easy to create the DCV file again after opening the original HEX file. Therefore, please save the original HEX files for archive purposes.

Mini32 software offers a wide range of data operation, mainly:

- connection files of the same configuration coming from different time periods

- mixing files of different systems
- calculation mean values of different time intervals (hours, days)
- drawing selected variables in time with the possibility of easy erasing of irrelevant values
- export of data to text, Excel or Lotus format
- export of graphs to JPG format
- drawing of vertical profiles of variables it a certain time
- printing of graphs
- basic statistical analysis
- regression data analysis
- user defined calculation
- non-linear multi-regression analysis

6 Maintenance

Datalogger *MicroLog SP* does not need any special maintenance except of cable and sensor checking.

6.1 Battery replacement

The battery replacement is easy so it can be done directly in the field (not under rainy condition if possible).

- Screw out the datalogger lid (use original tool supplied by manufacturer)
- Screw-out the battery from the battery terminals
- Short circuit the battery terminals with a metal part (pocket knife) in order to safely reset the battery life counter
- Screw-in a new battery, replace the desiccant bag
- Screw up the lid
- Make system reset. See After power drop-out.

7 Warranty

The producer warrants right function of the measuring system for three years after it is accepted by a customer. All the faults will be removed free of charge during this time, at the measuring device itself as well as at sensors. The producer is not responsible for the faults originated by careless manipulation, incorrect operations, wrong applications or theft. The warranty covers the battery failure for three months only. The fright to producer is paid by customer; the sending back is paid by the manufacturer.

8 Appendix (optional)

- GB 2 brochure (issued by EMS)
- Watermark brochure (issued by EMS)
- Fast data downloading via IrDA connection

Appendix A

Delmhorst Gypsum Block

(after the original Delmhorst factory literature)

1. General information

The blocks are made of gypsum cast around two concentric electrodes. The gypsum acts as a buffer against the effect that the salts might have on the electrical conductivity and the concentric electrodes confine the flow of current to the interior of the block, eliminating the effects of soil conductivity.

When a block is buried in the soil it absorbs moisture from the soil or releases moisture into the soil, until its moisture content approaches equilibrium with the moisture content of the soil. When the block is connected to the meter, current flows between the electrodes and the electrical resistance of the gypsum is measured. Such readings are an indication of the moisture available to the plants.

For irrigation purposes, the water of importance is that amount which can be extracted from the soil by the roots of the plants, and not the percent moisture content (which is related to the weight of the soil). We refer to this reservoir of moisture as available moisture.

Each soil has a different capacity to hold water, depending on its structure and texture. The maximum amount of water available to the plants (called Field Capacity) is the amount held by the soil against drainage by gravity. When virtually all available water has been used (that is when no further moisture can be extracted by the plant) soil moisture has reached the level known as the "Permanent Wilting Point". With soil moisture at this level, plants permanently wilt and die.

Finely textured soils such as fine sandy loams and clay loams hold a greater amount of water at field capacity then coarsely textured soils such as coarse sandy loams. The available soil moisture can be measured either in percent of the total potential reserve or in the terms of suction necessary to draw the moisture from the soil particles. Such suction is referred to as soil moisture tension.

2. Installation of blocks

- Soak the blocks in water for 2 to 3 minutes.
- Dig a hole in the ground with 1" soil auger or better, a 7/8" soil probe.
- Make a soil and water slurry of creamy consistency and place 1 or 2 tablespoons of the slurry in the hole.
- Push the block to the bottom of the hole, forcing the slurry to envelop the

block. The block can be pushed by using a tube (plastic or aluminum will suffice) or a slotted rod.

- Back fill the hole and tamp in small increments.
- Install only one block in each hole and fasten the leads to a stake so that they can be kept clean and are easily located for reading. Identify the lead wire according to the depth of the blocks. This can be accomplished by a colored tag or by making a knot on the shallow block, 2 knots on the deep one (3 knots on the next, if three blocks are used in the same station).

NOTE: It is recommended that the blocks be soaked in water for 1 hour and allowed to dry as soon as received. This additional wetting-drying cycle will improve their uniformity. Before .planting the blocks, they should be soaked again for 2 to 3 minutes to improve contact with the soil.

3. Where to place blocks

It is not possible to give precise instructions, which apply to all cases. The location and depth of the blocks depends on the nature of the crops, its potential root zone, the type of soil with regard to texture and subsurface formation, and the profile of the field. However, there are some guidelines to be followed: (A "string" of blocks 2, 3, or 4, depending on the depth to be reached, is called "station").

Locate the stations in the representative areas of the field. Don't place the blocks in low or high spots or near changes in slope of the irrigation run unless you wish to measure variability in water penetration caused by such differences. Select a station location where the plant population is representative of the field. Keep the soil around the stations from becoming compacted when taking readings especially where blocks are planted near the surface. Don't walk in furrows in which soil moisture readings are being measured. Walk in the next furrow. Mark each "walk" furrow when installing the blocks. When using sprinkler systems, make sure the blocks are set so they will not be damaged when the sprinkler is moved. Inaccurate readings can also result if the blocks are placed too close to the sprinkler head.

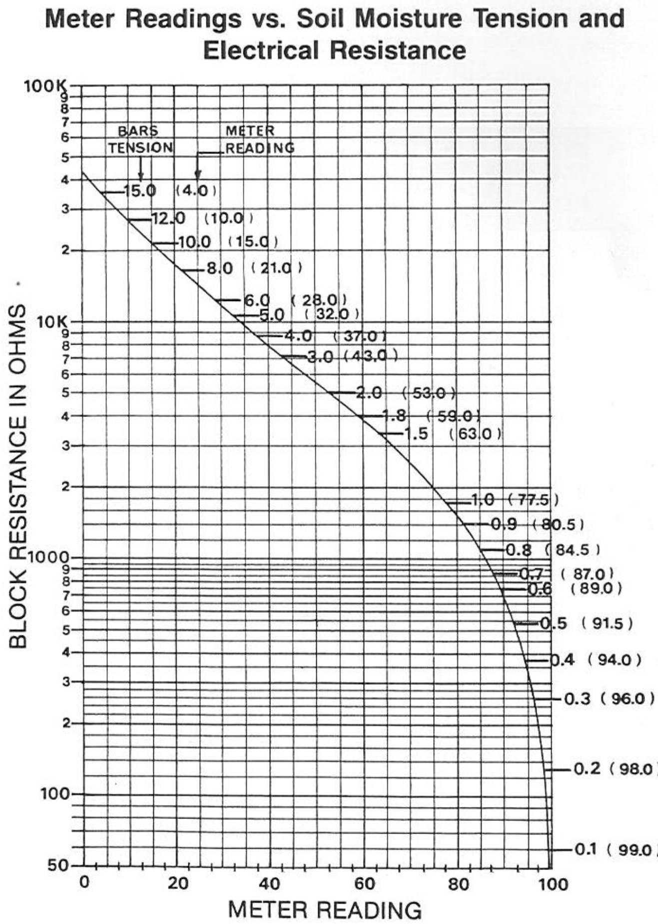
The blocks should not be shielded by any low hanging branches nor in an area that may be flooded by run-off. In the case of row crops, the blocks should be located directly in the row. As for orchards, the blocks are located at the drip line of a tree. It is also suggested that a second “string” of a few blocks be placed in the ground not far from the first - 10" to 20" apart. This will serve as a control on the blocks and on other factors. If the readings of two adjacent blocks at the same depth show a significant discrepancy, the cause should be determined. It may be poor distribution of water from the sprinkler system, or difference in sprinkler distribution caused by wind, differences in root concentration surrounding the block installations, or difference in the soil.

4. Depth of installation

The active root zone of the crop determines the depth at which to place the blocks. Type of crop, soil depth, and state of growth should also be considered. When seeds are first planted, irrigation is necessary to assure quick and uniform seed germination. Visual inspection of the soil near the seeds will indicate whether irrigation is needed at that time. A minimum of two blocks per station is recommended; one shallow, one deep. The table below gives recommended depths for setting the blocks according to soil depth or active root zone. Recommended depths for placing electrical resistance blocks according to soil depth or active root zones.

Soil depth or active root zone (Inches)	**Shallow blocks (Inches)**	**Deep blocks (Inches)**
18	8	12
24	12	18
36	12	23
48	18	36

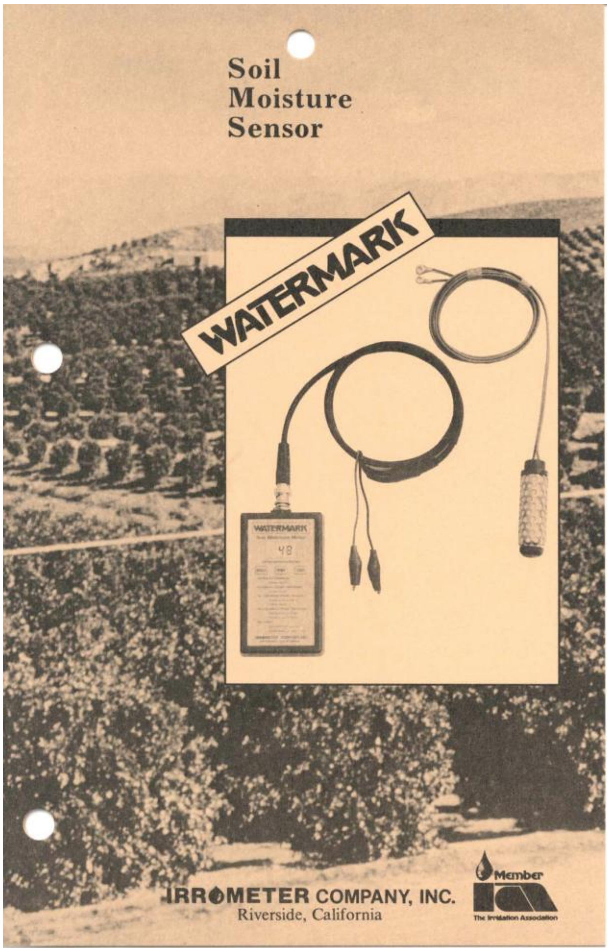
5. Delmhorst conversion graph (from KS-D1 Moisture Tester)



Appendix B

Watermark brochure

(Irrometer factory literature)



WATERMARK SOIL MOISTURE SENSORS

For over sixty years, plant scientists have verified the value of actual soil moisture measurement as the most effective method for precise irrigation scheduling. These in-field measurements allow an irrigation manager to know exactly how fast the soil is being depleted of moisture, and **WHEN** to initiate an irrigation cycle to replenish soil moisture for maximum plant growth. By obtaining soil moisture readings in different areas of the field, and at different depths in the root zone, the manager can also establish **HOW MUCH** water to apply, from experience and good record keeping. This "Irrigation to Need" can result in:

- ☑-Lower Water Cost
- ☑-Lower Energy Bills
- ☑-Prevent Excessive Leaching of Fertilizers
- ☑-Better Crop Quality
- ☑-Better Crop Yields

WHY WATERMARK

The **Watermark** is a solid state, electrical resistance type sensor, in use since 1978. Unlike other electrical resistance sensors, the patented **Watermark** provides accurate readings from 10 centibars to 200 centibars, which covers the entire soil moisture range required in irrigated agriculture, even in the heavier clay soils. They require no water, or vacuum gauge, which makes them maintenance free. The **Watermark** does not dissolve in the soil which generally occurs with a gypsum block in a short period of time. However, this sensor includes internally installed gypsum which provides some buffering for the effect of salinity levels normally found in irrigated agricultural crops and landscapes. Because they are unaffected by freezing temperatures, they do not require removal during winter in cold climates. And, they can be used with sophisticated data loggers to automatically record and chart the readings. In automatic irrigation systems, the **Watermark** can be used to control or interrupt irrigation cycles which are not needed. See Page 7.

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WHAT DO THE READINGS MEAN?

The **Watermark** readings reflect soil water tension or suction. The meter internally converts the electrical resistance reading of the sensors to this tension or suction value. This major physical force of soil water is a direct indicator of how hard the plant root system has to work to extract water from the soil. The drier the soil, the higher the reading. As a general guideline the interpretation of these readings is listed below and has been found practical for use under field conditions.

Soil Suction	Interpretation
0-10 centibars	Saturated soil. Occurs for a day or two after irrigation.
10-20 centibars	Field capacity. Soil is still wet in all but coarse sands where water is beginning to become depleted. This range is usually maintained in drip irrigation 12"-18" from the emitter.
30-60 centibars	Usual range for irrigation in most soils. Irrigate at the lower end of this range in hot dry climates and with the lighter soils. Irrigate at the upper end of this range in cool humid climates and with the higher water holding capacity soils. Observe crop response closely.
70-100 centibars	In heavy clay soils and crops requiring a greater dry down between irrigations, irrigation can be delayed until this range. Exercise caution in the 90-100 range.
100-200 centibars	Dry conditions. Proceed with caution and knowledge.

By reading your sensors 2-3-times between irrigations you will notice the rate at which the soil is drying out. The "rate of change" is as important as the actual reading in determining when to irrigate to avoid moisture stress. See Figure 2 on page 5. Readings are best taken in the morning. The **Watermark** meter has a soil temperature compensation feature. This allows for greater accuracy as electrical resistance readings vary 1% per degree of Fahrenheit encountered in the soil. On a day to day basis, this will not have a major effect, but on a seasonal basis (spring vs. summer) it needs to be taken into account.

DETERMINING WHEN TO IRRIGATE

Figure 1 shows how variations in soil affect the ability of the soil to store water (water holding capacity). Heavier clay soils store much more water than sandy soils. But even more important, the plant cannot readily extract all of this stored moisture, only the "available" portion. The general rule of thumb is that irrigation should commence before you reach 50% of the "available" portion being depleted. From Figure 1 you can see what the soil moisture tension is at the 50% level of available moisture.

Assuming your soil was in the middle, this 50% level would occur at about 60-70 centibars. While determination of the proper irrigation point is largely dependent on soil type, you must also consider the crop and your irrigation method. Sensitive crops may require irrigation sooner, less sensitive crops may not need water until later. Surface irrigation may allow you to apply water much more rapidly than a drip system, thus you need to consider how quickly your system can react in order to avoid moisture stress. See Figure 2.

DETERMINING HOW MUCH TO IRRIGATE

Your own record keeping system, and experience with your crop, soils and irrigation method are essential with any good management system. With **Watermark** Sensors properly placed in both the top (eg. 12") and bottom (eg. 24") of the crop root system, your readings will tell you whether it is the shallow or deep moisture which is depleted. If your shallow reading is 60 and your deep reading is 10, you know you only need to apply enough water to rewet the top 12". If the readings are reversed, with 40 for the shallow and 60 for the deep, you may need to apply twice as much water. The local farm advisor or SCS can be of great help to you in determining your individual soils and how much water they store. This will lead to your use of the **Watermark** Sensor readings to effectively control your irrigation scheduling and to prevent excessive leaching of plant nutrients. See Figure 2.

SENSOR INSTALLATION

The basic procedure is to make a hole with a 7/8" diameter rod to the desired sensor depth. With coarse or gravelly soils, it is sometimes difficult to get a snug fit between the sensor and the soil. With this situation, making an oversized hole (1" - 1 1/4") may be necessary. Then prepare a "grout" of the soil and water and pour it down into the bottom of the hole. Push the sensor down to the bottom of the hole (a piece of 1/2" class 315 PVC pipe is handy) to ensure it bottoms out and snugly fits into the soil. If desired, the 1/2" class 315 PVC can be solvent welded to the sensor collar to provide a permanent stake. If the PVC is not left in place after sensor installation, carefully backfill the access hole and tamp the soil down sufficiently to prevent water channeling down the hole to the sensor. Specific instructions are included with each shipment.

SENSOR MAINTENANCE

Once the sensors are installed, there is no further need for maintenance. With permanent crops such as trees and vines, the sensors may be left in place all winter, providing your cultural operations would not disturb them. With annual crops, where field operations are required, removal of the sensors prior to harvest is a standard practice. If the sensors are removed, simply clean them off and store them in a dry area until spring.

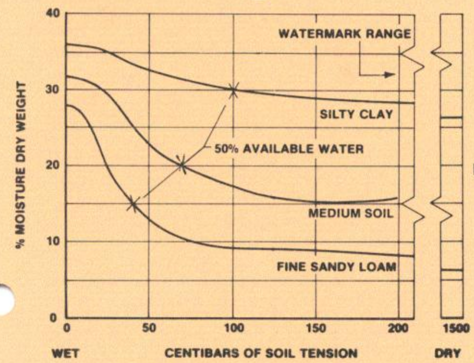

Fig. 1

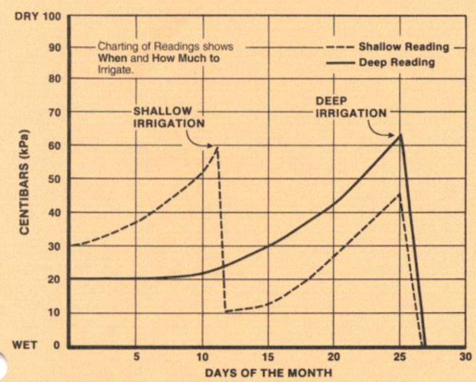

Fig. 2

HOW THE WATERMARK WORKS

The patented **Watermark** Sensor consists of two concentric electrodes buried in a special reference matrix material that is held in place by a stainless steel case. The matrix material has been selected to reflect the maximum change of electrical resistance over the growth range of production crops. In operation, soil moisture is constantly being absorbed or released from the sensor. As the soil dries out, the sensor moisture is reduced and the electrical resistance between the electrodes is increased. This resistance is read by the **Watermark** Meter. The sensor is manufactured from non-corrosive parts and lasts for years. It is $^7/_8$" in diameter by two-inches long.

If the sensor is being used with a data logging device, sensor excitation current is 5 VAC, 100 — 120 H_z (square wave) and sensor output is 500-30,000 ohms of electrical resistance which equates to 0-200 centibars of soil water suction (non-linear).

The **Watermark** Meter Model 30KTCD-NL gives a digital readout in centibars (kPa) of soil water suction (calibrated). Using an AC bridge circuit powered by a nine-volt battery, the meter converts the electrical resistance reading of the sensor to the centibar (kPa) value. It also has the capability of inputting the soil temperature (˚F or ˚C), which helps compensate for the effect which soil temperature has on the reading ("fine-tunes the data").

In operation, follow the instructions which are on the face of the meter, and in the pamphlet included with the meter. Pushing the "READ" button "wakes up" the meter - you will see "--". It stays "awake" for 5 seconds - or for 60 seconds if you immediately push "READ" a second time. While the meter is "awake," you can take readings and check or change the temperature setting. The reading is held for 60 seconds, which allows time to record it.

YOU — THE MANAGER

The concept of soil moisture measurement in managing irrigation schedules to meet crop "need" has been demonstrated for many decades. It's not just simply a matter of conserving water and energy, although this has become a most critical factor. When you irrigate precisely, you can indeed achieve these savings, but the real bonus from good management comes in the area of better production and healthier, longer living, ornamental plants and turf. These results however, are not achieved by guesswork; the key ingredient is You — The Manager! Tools such as the **Watermark** give you the extra advantage needed to be successful. Why not ask your irrigation advisor to help you add soil moisture measurement to your management program?