# DEVELOPMENT OF VALUE SELECTION METHOD FOR CHOOSING BETWEEN ALTERNATIVE

# SOIL MOISTURE SENSORS

**Final Report**

**March 1997**

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National Program for Irrigation Research and Development

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## Summary

Soil moisture sensors can be used by irrigators to help achieve efficient irrigation schedules. A survey of irrigators in 1993, however, revealed that less than seven percent of irrigators routinely used a soil moisture sensing device of any kind to schedule irrigation. Given the potential benefits accruing from their correct use a project was proposed which could develop an objective, systematic method to aid selection of a device by an irrigator. It was proposed to develop a value selection method in which the key attributes of most value to decision makers could be identified and weighted.

The project asked a range of potential users to identify attributes which are important to them in the selection of a soil moisture sensor. Weights and ranks from the responses were analysed and apportioned to each of the attributes identified. These weights and attributes were then used to develop a value selection method for soil moisture sensors.

An initial list of thirty three attributes was consolidated to nine. A tenth important issue, “total life cost” was included in the evaluation procedure. The respondent group identified accuracy, reliability and ability to operate in the particular soil type of the monitored site, as the most important attributes. Respondents agreed that the cost of the device was secondary to the above.

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# 1. Introduction

The Australian Irrigation Technology Centre (AITC) identified in its 1993 [1] survey of irrigators the low level of adoption of soil moisture sensing devices (less than 7%), despite there being a number of soil water sensors which could be used by irrigators to help schedule irrigation. There is a large range of devices available commercially which make various claims about measuring and monitoring soil moisture status. The operation of these devices is based on a number of different principles. One of the difficulties for any prospective purchaser of a system is to be able to understand exactly what is being measured, what this measurement can be used for and what it means in terms of scheduling irrigation.

Proponents of various systems believe that significant increases (up to 30%) in water use efficiency can be achieved in some cases. There is sufficient empirical evidence to support this claim, however, not all irrigators who have used devices have achieved major benefits. Results from research projects and from field investigations have not yielded uniform results, with different researchers having different experiences with the same device. As a result advice on which device to use has varied, often based on personal preference rather than on the basis of objective, physical performance data. In the longer term this dilemma will only be resolved by the national adoption of a set of testing and definition protocols which clearly describe the functionality and capability of each device. These protocols must use common terminology so that this reason for confusion can be eliminated. The full potential of soil water sensors for irrigation scheduling will only be realised when such a testing and calibration protocol is developed and adopted.

In the short term this research project aimed to develop a tool which can be used by irrigators and their advisers to choose between a range of devices, using a considered systematic attempt to evaluate all of the key features of the devices in question. It was agreed that the tool developed must be able to assist potential purchasers to make informed decisions on the basis of a systematically applied selection methodology.

# 2. Project Objectives

The research defined four key objectives;

1. Analyse how value selection methodology could be used by irrigators to select soil moisture sensors suitable for assisting them to make irrigation scheduling decisions.
2. Establish key attributes which people within the irrigation industry felt were important in the selection of soil moisture sensors.
3 Determine the relative importance of these attributes in different environments to establish, if possible, a weighting for each attribute.
4. Develop a methodology that can be used in a range of situations for the selection of appropriate soil moisture sensors, using the attributes and weighting developed.

# 3. Methodology

### 3.1 Value analysis principles

Value selection or analysis or management is “analysis by function”. It may be defined as “an organised effect directed at analysing the function of hardware, systems and methods with the purpose of achieving the required function(s) at the lowest cost consistent with requirements for performance, reliability and quality.”[2,3]. Value is the minimum amount which must be spent to achieve the appropriate functions.

It is first necessary to identify the function (attribute) and then establish the value of the function by considering the lowest cost of performing that function reliably. Value selection aims at the identification and removal of unnecessary costs which do not provide usefulness, life, quality, appearance or some other aspect of a customer’s needs.

When applied to soil water sensor (*sws*) selection, value analysis calls first for an identification of various attributes expected of *sws* and then examination of each product to see just how each attribute is fulfilled. A product may have a lot of attributes, but some of them may be irrelevant to many of the desired uses, with a resultant low value to potential users. Conversely a product with fewer attributes than those required will also be poorly valued.

An important feature of the value selection method is that users can apply their own weighting to particular attributes and also apply their own definitions to particular attributes. This increases greatly the range of instances in which the methodology can be applied. Some examples of this are discussed in this report.

### 3.2. Identification of desirable attributes

Some people in South Australia with interest in *sws* were contacted to form a reference group. The group was made up of retailers, manufacturers, scientists, consultants, farm extension officers and farmers. A subcommittee of the reference group met to propose a definition for a soil water sensor and an initial set of attributes of sensors was identified.

### 3.3. Ranking and weighting

The proposed definition and identified 34 attributes were distributed among 88 stakeholders throughout Australia, New Zealand and USA. (See appendix 1 for list of participants.)

Respondents were requested to comment on the definition of a sensor and to rank and weight each attribute as appropriate. They were also requested to add, rank and weight any further attributes if the list did not contain all of the attributes they felt should be considered. The most important attribute was ranked 1, the least important as 33 or the number which corresponds to the total number of attributes they identified. Respondents were asked to distribute the weights for each attribute in the order of relative importance, so that the resulting weightings summed to 100.

### 3.4. Analysis of ranking and weighting

Forty-eight (48) out of 91 people replied to the questionnaire. The respondents were classified as agricultural users, consultants, researchers, retailers and manufacturers. Agricultural users are defined as those who use the sensor directly on their farms, gardens, turf etc. Consultants are defined as those who provide advice on equipment usage to any group. Researchers are those who use the equipment for mainly research purposes on farms, gardens, soils, water, laboratories etc.

For each group the analysis determined the average ranking and weighting for each attribute. These averages were combined to obtain the overall average ranking and weighting for all the attributes.

Many respondents indicated that the 33 attributes were too many and that some were similar if not identical. It was also noted that some of the proposed attributes, while important in any purchasing decision, were not direct properties of the sensors, and so should be omitted. Finally it was noted that a simple system should be developed and that the proposed list contained too many attributes. The 33 attributes were therefore condensed to 9 attributes by combining similar attributes and ignoring those which are not direct properties of the sensor or of no significance to farmers. In combining similar attributes, individual ranks and weights were averaged. It should also be noted that an important attribute “total life cost” was removed from the evaluation procedure because it is included in the calculation of cost per annum.

### 3.5. Development of Value Selection Method

The final stage in the development of the method is to combine the attributes with the weightings to derive a “value “for each device. Some basic yes/no questions are answered. These answers are converted into a *one*, *a fraction of one* or *zero* which is multiplied by the corresponding weight to determine the relative importance of the attribute. The exact procedure is outlined in a section 5.1

# 4. Results

## 4.1 Definition of soil water sensor

Most respondents agreed with the original definition of soil moisture sensor as ***"an instrument with a detector which when placed in a soil for a period of time provides information related to the moisture status of that soil."*** One proposed that soil moisture sensor be defined as "***An instrument which provides information related to the water status of a soil".*** This definition is relevant to both present and future technologies of water sensing. As an example of future technologies, soil water sensing by satellites [4] is being field tested.

Accordingly it is proposed that the following definition should be adopted:

***"A soil water sensor is an instrument which when placed in a soil for a period of time provides information related to the soil water status of that soil."***

## 4.2 Definition of Attributes

The original list of thirty three attributes identified by the subcommittee is detailed in Appendix 3. An examination of the list reveals a substantial degree of overlap and interdependence between attributes and, as noted earlier, attributes which are not attributes or properties of the device per se. For example attributes 30, 31, 32 and 33 are all important issues but they are effected by many other issues besides the particular characteristics of the soil water sensor. These attributes were omitted from the final list.

A disadvantage of combining some of the original attributes is the difficulty of developing an attribute term that is unambiguous in its meaning and that covers the range of issues intended to be covered by the particular term. Accordingly a check list of information gathering guidelines to be reviewed when using the procedure has been developed. This list is detailed in section 5.3 below.

The researchers interpretation of respondents attributes is summarised below.

***Effective range of measurement.*** This attribute refers to the ability of the sensor to determine soil water status accurately over a range of soil water conditions from field capacity to a refill point. Respondents were very clear that a device should be able to measure accurately over a wide range of soil water conditions.

***Accuracy.*** The most important attribute according to respondents. Accuracy of measuring devices is determined by comparison with certified devices, under controlled conditions. These conditions are established so that any appropriately qualified workplace can recreate the conditions to test devices using the same procedures. At present, given that there is no standard calibration method for soil water sensors, it is very difficult to make universal claims of accuracy. The AITC believes that a standard calibration procedure for each type of soil water sensor should be developed so that valid comparison between devices can be made. Until such a standard procedure is developed there will continue to be debate about the accuracy of devices.

***Soil types.*** Some devices available are reputed to work better than others in some soil textures or ranges of moisture content. The ability of the device to measure in the soil conditions prevailing at the site under investigation is important.

***Reliability.*** Users want to be sure that a device works reliably, particularly if it is part of an automatic system. It is recommended that people seek information about reliability from a wide range of sources including other users, the manufacturer or their agent, scientific institutions and research agencies. It is important to distinguish between the reliability of the soil water sensing device itself and the reliability of other parts of the system. If a device is always supplied as part of a total system then one might include all the components in the reliability question. However if the device is sold separately then it's reliability should judged independently of the rest of the system.

***Frequency/soil disturbance.*** Device response time and frequency with which readings can be made may be important to the user. Response time and potential reading frequency may well be related to the manner in which the device is placed in and interacts with the soil profile. The potential impact of the method of placement in soil on the readings of soil water should be considered and the effects and limitations of using a device in a particular soil kept in mind. There is likely to be a significant difference between soil conditions after part of the profile is disturbed to facilitate burial of a device, say a gypsum block, and the soil around an access tube, which has been driven into the soil.

In this project respondents gave this attribute a relatively low rating compared with accuracy, but clearly indicated its importance.

***Data handling.*** Devices available on the market in Australia demonstrate a large range of data handling methods. Some devices indicate soil suction directly but may need to be manually read, while others require the data handling capability of a PC. In all cases it is important that the users clearly understand what the device results mean in terms of soil water status and that the results are presented in a form relevant to the decisions the user is trying to make. The technology should fit the situation. The capabilities of a sophisticated device may be wasted if the operator only has poor understanding of what the device is measuring.

***Communication.*** This attribute relates to the capability of the *sws* to communicate data from the sensor and associated equipment to either a data logging device which may be physically connected to the sensor or by remote communication to a distant processor. This capability becomes more important if there is a large volume of data to be interpreted. An important aspect of this attribute is the capability of any software to produce easily understood and relevant output.

***Operation and maintenance.*** As with other attributes there is a wide variation in the operation and maintenance requirements of devices available commercially. Some devices need the services of a fully trained operator for use as well as ongoing maintenance, whilst other devices are relatively simple to operate.

***Safety.*** This attribute tries to take account of any occupational health and safety aspects relating to the use of the device. The most obvious example relates to the radioactive nature of the neutron probe. Clearly the device is safe to use when new and well maintained, but it could potentially become an issue if proper maintenance is not carried out. It is assumed that all devices are safe in the sense that they meet current occupational health and safety guidelines. However some devices may have more stringent operating requirements to ensure that an acceptable safety level is maintained.

### 4.3 Attribute weights and ranks

The mean rank and weight for each of the ten attributes for each group of respondents are as shown in Tables 1 and 2 and in Figures 1 and 2. The tables show the weighting and ranking given to each attribute by each group of respondents. Respondents were classed as agricultural users (agric), researchers (res), consultants (cons), manufacturers (man) and retailers (ret). The last column in each table details the average of all groups combined.

The following observations may be made about the results detailed in Table 1.

- There are differences between the groups' weightings, although there was general agreement on major issues.
- Agricultural users and Researchers placed most weighting on accuracy.
- Consultants and Manufacturers placed most weighting on reliability.
- Total cost was not as significant an issue for Agricultural users and Consultants as it was for other groups.
- Manufacturers did not place as high a weighting on ease of use and operation as did the other respondents.

While these differences exist the general pattern of weightings was relatively similar over all groups and no particular attribute was rated at greater than 16% which implies that all attributes are important. Potential purchasers of devices expect devices to have all of the functionality described.

All the groups showed positive correlation between the attribute ranks and relative weights. This is an expected result.

The values in Table 1 represent a percentage which indicates the relative importance of the attribute. The larger a number the more relatively important that attribute is considered to be.

**Table 1. Attribute weighting**

| | | **Weights** | | | | | |
|---|---|---|---|---|---|---|---|
| **Attribute** | **Description** | **Agric** | **Res** | **Cons** | **Man** | **Ret** | **Ave** |
| CA1 | Range | 8 | 7 | 8 | 5 | 9 | 8 |
| CA2 | Accuracy | 14 | 16 | 15 | 13 | 13 | 14 |
| CA3 | Soil Types/Spatiality | 11 | 8 | 10 | 10 | 13 | 11 |
| CA4 | Reliability | 12 | 12 | 16 | 15 | 13 | 13 |
| CA5 | Frequency of use/ soil disturbance | 8 | 9 | 7 | 13 | 5 | 8 |
| CA6 | Data Handling | 9 | 9 | 9 | 5 | 8 | 8 |
| CA7 | Communication | 9 | 8 | 12 | 10 | 9 | 10 |
| CA8 | Total life cost | 9 | 13 | 9 | 12 | 10 | 11 |
| CA9 | Operation and maintenance | 11 | 9 | 10 | 6 | 12 | 10 |
| CA10 | Safety | 8 | 7 | 5 | 12 | 9 | 8 |

Table 2 details the rankings by respondent group and the average for all respondents. Accuracy is ranked first by all respondents. On average, reliability is ranked second and overall the ability of the device to operate in all soil types was ranked third.

Generally the rankings and weightings follow the same trends, with relatively similar weighting given to the attributes. There are exceptions, for example agricultural users ranked cost second but the weighting assigned is less than or equal to that given to the next four lower ranked attributes. As indicated above, this implies that all attributes are of similar importance to respondents.

**Table 2. Attribute ranking**

| | | **Ranks** | | | | | |
|---|---|---|---|---|---|---|---|
| **Attribute** | **Description** | **Agric** | **Res** | **Cons** | **Man** | **Ret** | **Ave** |
| CA1 | Range | 7 | 8 | 7 | 6 | 5 | 7 |
| CA2 | Accuracy | 1 | 1 | 1= | 1 | 1 | 1 |
| CA3 | Soil Types/Spatiality | 3 | 4 | 8 | 4 | 3 | 3 |
| CA4 | Reliability | 6 | 2 | 1= | 2 | 2 | 2 |
| CA5 | Frequency of use/ soil disturbance | 9 | 7 | 10 | 8 | 9 | 9 |
| CA6 | Data Handling | 5 | 5 | 4 | 9 | 6 | 6 |
| CA7 | Communication | 8 | 9 | 9 | 10 | 8 | 8 |
| CA8 | Total life cost | 2 | 3 | 3 | 3 | 7 | 4 |
| CA9 | Operation and maintenance | 4 | 6 | 5 | 7 | 4 | 5 |
| CA10 | Safety | 10 | 10 | 6 | 5 | 10 | 10 |

## 5. Application of Results

Many respondents ranked and weighted heavily some attributes which are not direct functions of the *sws.* These attributes were included in the original list of attributes circulated but were omitted from the selection methodology because they are not totally dependent on the properties of the devices. Attributes like savings in water usage, environmental protection, increased production and added value of production are the key benefits which users expect from the use of *sws*. Many respondents regard the *sws* as a component of "whole farm solutions", not just as a water monitoring tool. Analysis of these "whole farm solutions" attributes reveal that they all relate to the accuracy and reliability of the sensor. Interpretation of the data and consideration of other soil-plant-climate factors are critical points in converting the accuracy and reliability of the sensor into those attributes which are not directly obtainable from the sensor.

As knowledge derived from the information technology industry has been increasingly applied to irrigation control systems, precision irrigation defined as "an equipment and information system permitting ***within field*** site specific decisions for economic and environmental control" [5] is more and more being adopted. Such systems monitor all the soil-plant-climate factors which affect crop water use and integrate the data for specific crops and sites. Precision irrigation potentially permits a more effective and efficient irrigation management than any broad acre approach as it takes account of other soil-plant-climate factors such as (i) soil water holding characteristics (ii) irrigation system (iii) crop requirements and (iv) selection of monitoring sites.

It is therefore essential that the methodology proposed in this report is used as an **aid** to objective selection. The final selection must consider all other factors relevant to the particular site and application.

### 5.1 Evaluation Procedure

The selection procedure is detailed in this section. Table 3 details the questions to be answered in regard to each attribute. Table 4 is a worked example comparing two hypothetical devices, Device A and Device B. It is stressed that a comparison or judgement about devices was not within the scope of this study. Devices A and B are not intended to represent particular devices, merely to demonstrate the value selection methodology.

It is clear that the further adoption of soil water sensing devices is limited by the lack of a universally accepted method of appraisal. In spite of the relative simplicity of the selection method outlined in this paper, there is still scope for people to make their own interpretations and score some attributes incorrectly. This problem would be overcome if a universal test and calibration method for soil water sensors could be developed.

The following steps are used in the evaluation procedure.

1. For each *Yes* or *No* answer score a *one* (1) or *zero* (0) in column B of table . In the operation and maintenance section each answer has a value of a quarter (.25) since there are four answers required.

2. For each attribute multiply the point in column B with the weight in column A to obtain column C. Column C is the relative importance.

3. Total all the numbers in column C to obtain total relative importance T.

4. Calculate C, the total estimated life cost of the sensor, by estimating capital, installation, running and maintenance costs for the expected life of the sensor.

5. Divide C by L, the expected life of the sensor in years, to determine A, the annual cost of the sensor.
A = C/L

6. Divide the total T with the annual cost of the sensor to obtain the value V [6] of the sensors.
V = T/A

7. The lowest valued sensor may be more suited to your needs and gives you the best value for money expended.

**Table 3. Evaluation procedure table.**

| ATTRIBUTES | Weight(A) | Point (B) | Score (C) |
|---|---|---|---|
| **Effective range of measurement** | **8** | | |
| *Is sws able to measure all ranges of soil water of interest to you?(Yes =1; No =0)* | | | |
| **Accuracy** | **14** | | |
| *Is sensor accuracy enough for your purpose? (Yes =1; No =0)* | | | |
| **Soil Types (For use with range of soils)** | **11** | | |
| *Is sensor's accuracy affected by the soil type?(Yes=0; No =1)* | | | |
| **Reliability** | **13** | | |
| *Do you have any personal, other users' or literature based idea of the reliability of sensor and is the failure rate satisfactory to you? (Yes =1; No=0)* | | | |
| **Frequency/soil disturbance** | **8** | | |
| *Can the sensor provide quick or frequent readings in undisturbed soil?(Yes=1; No=0)* | | | |
| **Data Handling** | **8** | | |
| *Will you have difficulty in reading or interpreting data? (Yes = 0; No =1)* | | | |
| **Communication(For remote data manipulation)** | **10** | | |
| *Does sensor provides data logging and down loading capabilities and a friendly software for analysing & interpreting the data? (Yes =1; No =0)* | | | |
| **Operation and Maintenance**<br>*Is sensor calibration universal?*<br>*Does sws have long life (> 5yrs)?*<br>*Is sensor maintenance free?*<br>*Is sensor easy to install?*<br>*Give sensor ¼ for each Yes answer.*<br>*Total* | **10** | | |
| **Safety** | **8** | | |
| *Does use of sensor entail any danger? (Yes =0; No = 1)* | | | |
| **Total** | | | |

**Table 4. Evaluation procedure example.**

| | | Device A | | Device B | |
|---|---|---|---|---|---|
| **ATTRIBUTES** | Weight (A) | Point (B) | Score (C) | Point (B) | Score (C) |
| **Effective range of measurement** | **8** | | | | |
| *Is sws able to measure all ranges soil water of interest to you?(Yes =1; No =0)* | | 0 | 0 | 1 | 8 |
| **Accuracy** | **14** | | | | |
| *Is sensor accuracy enough for your purpose?<br>(Yes =1; No =0)* | | 0 | 0 | 1 | 14 |
| **Soil Types (For use with range of soils)** | **11** | | | | |
| *Is sensor's accuracy affected by the soil type?(Yes=0; No =1)* | | 1 | 11 | 0 | 0 |
| **Reliability** | **13** | | | | |
| *Do you have any personal, other users' or literature based idea of the reliability of sensor and is the failure rate satisfactory to you?<br>(Yes =1; No=0)* | | 0 | 0 | 1 | 13 |
| **Frequency/soil disturbance** | **8** | | | | |
| *Can the sensor provide quick or frequent readings in undisturbed soil?(Yes=1; No=0)* | | 1 | 8 | 0 | 0 |
| **Data Handling** | **8** | | | | |
| *Will you have difficulty in reading or interpreting data? (Yes = 0; No =1)* | | 1 | 8 | 1 | 8 |
| **Communication(For remote data manipulation)** | **10** | | | | |
| *Does sensor provides data logging and down loading capabilities and a friendly software for analysing & interpreting the data?<br>(Yes =1; No =0)* | | 0 | 0 | 1 | 10 |
| **Operation and Maintenance**<br>*Is sensor calibration universal?*<br>*Has sws got long life (> 5yrs)?*<br>*Is sensor maintenance free?*<br>*Is sensor easy to install?*<br>*Give sensor ¼ for each Yes answer.*<br>*Total* | **10** | *¼*<br>*¼*<br>*0*<br>*¼*<br><br><br>¾ | <br><br><br><br><br><br>7.5 | *¼*<br>*0*<br>*¼*<br>*0*<br><br><br>½ | <br><br><br><br><br><br>5 |
| **Safety** | **8** | | | | |
| *Does use of sensor entail any danger?<br>(Yes =0; No = 1)* | | 1 | 8 | 0 | 0 |
| **Total** | | | **42.5** | | **58** |

## 5.2 Practical Considerations

As has already been noted there is no standard test or calibration procedure for soil water sensing devices. Prospective purchasers find it difficult to obtain reliable, accurate information about the devices they are considering. Usually the only source of information is the seller of the equipment. There are a number of factors affecting the final operating performance of sensors and many of these are beyond the control of the equipment provider. It is very common for buyers to complain about the erratic operation of equipment with the result that almost no piece of equipment has an unsullied *commercial* reputation, and even fewer have attracted unequivocal technical support. It is likely that many of the operating problems are due to factors other than the capability of the sensors per se. However since all of the equipment is associated with the sensor it is the sensor that is most easily blamed.

To try to assist potential users a series of information gathering guidelines have been noted below. If these guidelines are followed and used in conjunction with the value selection method, purchasers of soil water sensors are likely to make much better decisions.

## 5.3 Information Gathering Guidelines

Information is required to ensure that the sensor purchased is fit for the job that is required.

1. It is important that the reason for using sensors is clear and that sensors represent the best alternative. If that is accepted the purchaser needs to assemble as much independent evidence as possible to support working claims. Such evidence could come from research agencies, Government field stations, scientific literature, other users and Government departments. The information that each can provide will vary and a cross section should be approached.

2. Have a very good understanding of the location where the sensor will be installed including physical, chemical and biological data about the soil, crop and water quality.

3. Obtain all relevant technical information possible about the operation of the sensor; how it works, what it measures, what calibrations have been carried out and what supporting evidence is available to back up any claims.

4. Look for information on the actual operations of the sensor, people and skills required to operate, data outputs and handling. Does the data output meet the needs of the person using the data to schedule irrigation?

5. Check the capabilities of the device with the characteristics of the site in which it is to be used. There is little value in buying a unit that works exceptionally well in sandy soil if it is required for a heavy cracking clay. Will the device be affected by the salinity of the irrigation water, by temperature etc?

In general it is important that purchasers adopt a systematic approach to data gathering about devices. In this regard developing a good understanding of what is required from the sensor is the critical first step, the importance of which cannot be stressed enough. Any person involved with the use of soil water sensors should continually increase their knowledge of the soil plant water complex if they wish to understand and take advantage of the data generated by the sensor.

## References


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[4] Rao, K.S *et al*; *Computer aided Brightness Temperature Map of Indian Subcontinent-interference on Soil Moisture Variations*, India; Remote Sensing of Environment, v20 n2 Oct 1986, p 195-207

[5] Peter Buss, *The Fourth Agricultural Revolution - The Australian Solution*; Sentek Publication

[6] M. Larry SHILLITO & David J. DE MARLE: *Value Its Measurement, Design & Management*. John Wiley & Sons, Inc New York, 1992

## APPENDIX 1. LIST OF RESPONDENTS

The following individuals and organisations contributed to the development of the list of attributes and the relative importance of each attribute.

| | | | |
|---|---|---|---|
| ADAMS | Tony | Mr | Primary Industries |
| ADDIS | Tony | Mr | Urban Irrigation Consultants |
| ALLEN | Warwick | Mr | "Quiprite Pty Ltd," |
| ATKINSON | Ian | Mr | Nursery Industry Ass. of Aus |
| AUGHTON | David | Mr | Rubicon systems australia P/L |
| AUGUST | Wayne | Mr | Automatic Irrigation Co Ltd |
| AZHAR | Aftab | Mr | Victoria University of Technology |
| BARTER | Stephen | Mr | Golden Mile Orchards |
| BARTETZKO | Mark | Mr | Primary Industries |
| BELL | Ian | Mr | DPIF(TAS) |
| BOLAND-LAUDEN | AM | Ms | Agriculture Victoria |
| BOSWORTH | Lisa | Ms | IMT & Associates |
| BUSS | Peter | Mr | Sentek |
| BUSS | Peter | Mr | Sentek |
| CAMPBELL | Hugh | Mr | Riverina Irricad Design Services |
| CHAPPELL | David | Mr | PPI Corporation P/L |
| COLE | Phil | Mr | Primary Industries |
| CONNELLAN | Geoff | Mr | Burnley College |
| CULL | Peter | Dr | Neutron Probe Services |
| CUMING | Ken | Mr | Watermatic Controls P/L |
| CUMMING | Mark | Mr | Ted Finchett P/L |
| DALE | Mark | Mr | Sunraysia Horticultural Centre |
| DAWSON | Noel | Mr | LWRRDC |
| DILLON | Peter | Dr | CSIRO Centre for Groundwater Studies |
| DOWNING | Alec | Mr | Neutron Probe Services |
| EASTHAM | Judy | Dr | CRC for Soil & Land Management |
| EWENS | Tim | Mr | Yandilla Park |
| FERBER | Darren | Mr | Hardie Toro |
| FERGUSON | Karen | Ms | Geoflow |
| FINCH | Trevor | Mr | Research Services New England |
| GATTO | Rick | Mr | Sentek |
| GIBSON | Rob | Mr | Southcorp |
| GIDDINGS | Jeremy | Mr | Agriculture Victoria |
| GLADIGAU | Lance | Mr | IRRITECH |
| GRAETZ | Brian | Mr | Graetz Irrigation |
| GRANSBURY | John | Mr | Hydro-Pan Pty Ltd |
| HALES | Ralph | Mr | IMT & Associates |
| HICKEY | Tony | Mr | Sunraysia Horticultural Centre |
| HILL | Stuart | Mr | City of Adelaide |
| HISCOX | Ralph | Mr | Amiad Australia |
| HOCKNEY | Ian | Mr | Farrell Hockney |
| HODGKINS | Tim | Mr | Amiad Australia |
| HOPE | Meredith | Ms | CSIRO/CSU |
| HORTON | Tony | Mr | Dept of Natural Resources |
| HUMPHREYS | Liz | Dr | CSIRO/Water Resources |
| JONES | Lindsay | Mr | Soil Solutions Pty Ltd |
| KNIGHT | Rob | Mr | DRW Water Management |
| LACEY | Adrian | Mr | Olney Almonds |
| LINDSAY | David | Mr | Namoi Cotton Co-operative |
| LIPMAN | Ashley | Mr | Primary Industries |
| LOVE | R | Mr | Irrigear Stores Pty Ltd |

| | | |
|---|---|---|
| LUITJES Kym | Mr | IMT &Associates |
| LYSTER Maurice | Mr | Casuarina Valley Orchard |
| MATSCHOSS Shawn | Mr | IMT & Associates |
| McBEATH Neil | Mr | Agriculture Victoria |
| McCARTHY Mike | Mr | CRC Viticulture |
| McMASTER Lewis | Mr | Lewis McMaster Consulting |
| McNALLY Gary | Mr | Newcastle Irrigation |
| MEYER Wayne | Pr | ofCSIRO/CSU |
| NORTON Scott | Mr | Primary Industries |
| PEADON Brian | Mr | Western irrigation |
| PECK Steve | Mr | Hydroscapes Aust Pty Ltd |
| PHILCOX Martin | Mr | Primary Industries |
| RAINE Steven | Dr | University of Southern Queensland |
| READ Tony | Mr | Kinhill Engineers |
| RIDGEWAY David | Mr | Dunalbyn Gladiolus |
| ROBINSON Nigel | Mr | Sentek |
| RODECK Peter | Mr | Environdata Aust P/L |
| ROLFE Chris | Mr | NSW Agriculture |
| ROSENBAUM David | Mr | NSW Agriculture |
| SAWKINS Geoff | Mr | N/A |
| SCHACHE Maxine | Ms | Sunraysia Horticultural Centre |
| SHARLEY Tony | Mr | Primary Industries SA |
| SHORT Andrew | Mr | Irrigation Consultant |
| SKEWES Mark | Mr | Primary Industries |
| SLUGGET Trevor | Mr | Yandilla Park |
| STRANGE Pam | Ms | Scholefield Robinson Horticultural Services |
| SWINTON Richard | Mr | NSW Agriculture |
| TANKARD Henry | Mr | Sunrise 21 |
| TAYLOR Anthony | Dr | Irricon consultants |
| TENBUREN Michael | Mr | Irrigation Design Consultant |
| THOMPSON Chris | Mr | Serve-Ag Pty Ltd |
| THOMSON Tony | Mr | Primary Industries |
| VAN LEEUWEN J | Mr | John Van Leeuwen & Assoc |
| WATSON Keith | Mr | IMT & Associates |
| WIGG Fiona | Ms | Southcorp Wines |
| YOUNG Michael | Mr | Shepparton Regional Development Board |
| ZANDER Ben | Mr | Orlando-Wyndham Group |

## APPENDIX 2. Letter to Respondents

The Australian Irrigation Technology Centre (AITC) is undertaking a project on behalf the Land & Water Resource and Research Development Corporation (LWRRDC) with the aim of **developing a value selection method for choosing between alternative soil moisture sensors (*SMS*).** The following seven broad stages have been perceived in the project implementation schedule.

1. Identify Broad Selection Criteria (BSC) and propose measurement procedures(MP).
2. From list of identified BSC and MP prepare a Draft Selection Criteria (DSC) and MP.
3. Circulate DSC and MP amongst stakeholders for comments and reviews.
4. Receive and collate comments and reviews.
5. Develop Value Selection Method draft document
6. Communicate draft document for comments and reviews on formatting and presentation.
7. Prepare Final Report

On the 3rd of May, 1996, a meeting of some *SMS* experts in SA was held at the Levels Campus to identify suitable set of criteria which may be used as basis for **developing a value selection method for choosing between alternative soil moisture sensors (*SMS*)**. On the following sheets of paper, you will find a proposed definition of *SMS* and list of some of the attributes identified. In order to involve as many stakeholders as possible in the value analysis process, you are being invited to contribute towards the definition and identification processes. In making both contributions, please bear in mind that definitions and criteria which are objective (ie can lead to measurable quantities) are more helpful in developing standards for the industry.

Definition of a *SMS*: ***an instrument with a detector which when placed in a soil for a period of time provides information related to the moisture status of that soil.***

1. Do you agree with the definition of *SMS*?
   (i) Yes
   (ii) Yes, but with some changes. I propose the following changes:......

   (iii) No. I don't agree with the definition. I propose the following definition(s)

2. From the list below, please rank and weight each attribute as you deem fit for your operations. You may add, rank and weight more attributes if the list below does not adequately express your operational requirements. Rank the most important attribute as 1, the least important as 33 or the number which corresponds to the total number of attributes you have come up with. On a basis of 100%, distribute your weights for each attribute in their order of relative importance to you.

## Appendix 3. Original Attribute List

| | CRITERIA | RANK | WEIGHT |
|---|---|---|---|
| 1. | Range (Applicable range of input and output values) | | |
| 2 | Span (Maximum variation in input and output ranges) | | |
| 3 | Sensitivity (Rate of change of output with respect to input) | | |
| 4 | Linearity and Non-linearity of response | | |
| 5 | Is *SWS* sensitive to Hysteresis? | | |
| 6 | Does *SWS* take account of Environmental effects which may modify or interfere with results | | |
| 7. | Accuracy (What is the degree of accuracy of *SWS*) | | |
| 8. | Soil Ranges applicable (Can sensor be applied across all soil types?) | | |
| 9. | Reliability (How often does the sensor fails?) | | |
| 10 | Multiplicity of use (After one data reading, how early can another data be taken and can the same site be used?) | | |
| 11 | Spatial variability of results (How does the sensor handles differences in moisture status in adjacent soils) | | |
| 12 | Results Display format and resolution | | |
| 13 | Rate at which results are made available | | |
| 14 | Ease of interpreting the results | | |
| 15 | Tolerance limits of *SWS* | | |
| 16 | Repeatability of results | | |
| 17 | Data logging and down loading capabilities. | | |
| 18 | Total life time cost (Initial capital, delivery, installation and commissioning costs, running, maintenance measurement error and calibration costs) | | |
| 19 | Calibration (Site specific or universal?, frequency of ~) | | |
| 20 | Longevity (How durable is the sensor under normal working conditions) | | |
| 21 | Simplicity of Use (Does *SWS* use require any specialised training?) | | |
| 22 | Installation Time | | |
| 23 | Convenience of power requirements( Battery, solar panel, etc) | | |
| 24 | Ease and Degree of PC linkage) | | |
| 25 | Software data concurrence and compatibility | | |
| 26 | Does the *SWS* lead to consistency and predictability of plant response? | | |
| 27 | Is the sensor appropriate for determining plant stress? | | |
| 28 | Is the sensor appropriate for automation purposes? | | |
| 29 | Does *SWS* lead to savings in water usage? | | |
| 30 | Does *SWS* lead to environmental protection? (Drainage, salinity, soil health, debilitation of plant growth etc) | | |
| 31 | Does *SWS* lead to increased production? | | |
| 32 | Does *SWS* lead to added value?. | | |
| 33 | Safety of use | | |