SMALL SCALE IRRIGATION DEVELOPMENT

LEVEL-III

MODEL TTLM

Learning Guide- 01

Unit of competency: Measure and apply irrigation water

Module Title: Measuring and applying irrigation water

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Nominal duration: 40Hr

Instruction sheet	Learning guide- 01

This learning guide is developed to provide you the necessary information regarding the following content coverage and topics:–

- Compute the water to be Applied
- Apply a measured amount of water
- Determine soil intake rate
- Identify irrigation measuring device & techniques

This guide will also assist you to attain the learning outcome stated in the cover page. Specifically, upon completion of this Learning Guide, you will be able to –

- Measure soil moisture deficit
- Measure area to be irrigated
- Decide amount of water to be applied
- Predict a predetermined deficit
- Apply irrigation
- Increase appropriate water quantity to ensure leaching
- Select method for intake rate determination
- Make tools &equipment available
- Determine soil moisture holding capacity
- Identify types of irrigation method
- Identify operation feasibility
- Identify site of measurement

Learning Activities

1. Read the specific objectives of this Learning Guide.
2. Read the information written in the "Information Sheets.
3. Accomplish the "Self-check" at the end of each learning outcomes.

4. If you earned a satisfactory evaluation proceed to the next"InformationSheet". However, if you acting is unsatisfactory, see your teacher for further instructions or go back to the Learning Activity.
5. Submit your accomplished Self-check. This will form part of your training portfolio
6. Follow the steps and procedure list on the operation sheet
7. Do the "LAP test" and Request your teacher to evaluate your performance

Information Sheet-1	Compute the water to be Applied

Introduction

All the places of the world do not receive equal rainfall. There exists great variation over space and time. The reason of variation lies mainly with the general circulation of the atmosphere caused unequal heating of various parts of the earth by solar radiation (temperature-variation).Convergence of air currents and their ascending motion cause rainfall. In areas of divergence of flow, particularly, in deep high pressure systems subsidence of air causes clear skies and lack of rainfall. Orography and minor sources of water such as lakes introduce fairly substantial differences in precipitation of local importance.

Hence, Irrigation is defined as application of water to agricultural field artificially to fulfill the biological activity of the crop. But during delivering water to the crop field the amount should be measured wisely certain losses and damage such as occurrence of water logging and salinity formation also to prevent surface runoff& deep percolation. Not only the amount of water but also the pre-condition & type of soil has its own influence on crop water demand and growth. Applying a measured quantity of water to irrigated field depends on soil moisture content, water holding capacity, crop growth stage & growing period.

1.1 Measuring soil moisture deficit

Soil Moisture is rate and quantity of water movement, water storage capacity of soil, Plant water uptake and consumptive use, assessing plant water requirement and scheduling irrigation. Water is life. It originated in water and possibly, if at all its ends, will end in water. The role of water is felt everywhere. Its scarcity causes drought & famine; its excess flood and deluge. Its effects on physical, chemical and biological aspects of life are very complex. Science has not yet answered all the ways of water. Agriculture will remain the foremost user of water. Crops grow in the soil, absorb water and emit it to the atmosphere. It is easy to state this but difficult to quantify. In growing crop large quantities of water is lost in this process. Some are avoidable; some are unavoidable, rather necessary.

Use and misuse of water through irrigation have had its beneficial and harmful effects. Soil colloids, whether organic or inorganic, bear charges on their surface. They are mostly negatively (-) charged. Water is a bipolar. When dry soil is brought in contact with water, some water particles get adsorbed on clay surface by hydrogen bonding and van-der-Waal-London forces and some get adsorbed by exchangeable ions getting hydrated. Number of layers of water that can remain attracted to each depends on type of clay and the cations present. The water molecules in contact with lattice surface form co-valent hydrogen bonds with oxygen in tetrahedral layer. The covalently bonded water molecules are strongly polarized so that a second layer of water molecules can form on the first having the same structural pattern as in the first.

The time extending the films on the soil particle depends on the amount of water entering into the soil called infiltration in turn relay on the type and roughness of the soil. If the soil is highly rough, the intake rate will be much more. Before applying water to the rough soil surface, it is better to visualize the degree of deficit (scarcity) of water present within soil by using a number of techniques:-

Methods of measuring soil moisture deficit are:

- Direct methods :measurement of moisture content in the soil (wetness)
- Indirect methods: measurement of water potential or stress or tension under which water is held by the soil.

Direct Methods

- Gravimetric Method
- Using Methyl Alcohol
- Volumetric Method

Direct Method Formula

- Moisture content Wet weight –Dry weight On weight basis/ Dry weight X 100

This is a short cut procedure but it is not in common use. Soil sample is mixed with a known volume of methyl alcohol and then measure the change in specific gravity of solution with a hydrometer.

2) Using Methyl Alcohol:

The amount of water present in soil sample is estimated by drying it in the oven and calculating by formula. Soil sample is taken with a core sampler or with a tube auger whose volume is known.

3) Volumetric Method Formula

- Moisture content = Moisture content (%) by weight x Bulk Density (%) by volume

Sampling, transporting the method is though accurate and simple it is used mainly for experimental purpose. However, the sampling disturbs the experimental plots and hence many workers prefer indirect methods. Repeated weighing gives errors. It is also laborious and time consuming. The errors of the gravimetric method can be reduced by increasing the size and number of samples.

Indirect Methods

Common instruments

- Gypsum block
- Tensiometer
- Neutron probe
- Pressure plate and pressure membrane apparatus

1. Gypsum block are generally rectangular shaped. Gypsum blocks or plaster of Paris resistance units are used for measurement of soil moisture is situ.
2. **Tensiometers:**

Tensiometers provide a direct measure of the tension at which water is held in soil, and therefore the suction plant roots need to exert in order to extract water. Tensiometers are based on a tried and tested principle that was developed in the 1920's, and they are now the industry standard by which other soil moisture measuring devices are calibrated.

This instrument comprises a water filled tube which is sealed at one end, with a porous ceramic filter at the other end. The specifications of this filter are such that, when buried in soil, it will allow water to flow freely through it, but not air. The suction of the water within the tube provides a direct measure of the suction at which water is being held in the surrounding soil.

The amount of water required to be applied in order to relieve the suction that has built up in soil differs depending on soil type. To estimate the application required, please activate the

3. Soil Moisture Deficit Calculator.

Soil Monitoring Engineering currently manufactures the following types of 22.5mm diameter tensiometers.

4. Gauge Tensiometer:

These robust stand-alone units are favored among farmers and comprise a ceramic filter, high strength transparent polycarbonate body, and a precision stainless steel zero able vacuum gauge. They can be manufactured to any length up to 4m.

Fig1. Septum Tensiometers:

These systems provide a very cost effective and convenient means of assessing soil moisture status at a large number of sites. The top of the tensiometers is sealed with a replaceable silicone rubber septum, and readings are taken using a hand-held hypodermic transducer unit which is used to pierce the septum to take the readings. The septa automatically re-seal once the transducer unit is removed. Tensiometers can be manufactured to any length up to 4m.

Fig2. Remote Tensiometer Systems:

This system has been designed specifically for situations where no instrumentation may be visible above the ground, e.g. football pitches, racecourses and golf greens. The buried tensiometers can be located up to 30m away from the control panels that house the vacuum gauges and are connected to panels through nylon tubing.

5. Neutron probes:-

Soil moisture content can be determined by neutron probe technique. Higher the hydrogen atom in the system more is the moisture content. The lower hydrogen atom in the system indicates moisture deficit.

6. Electrical resistance:-

This method is based on principle that conductance of electricity is directly proportional to moisture content in the medium. The resistance is measured by a conductivity bride or ohm meter. Resistance= 1/conductivity - i.e. higher the resistance lesser is the soil moisture.

7. Volume changed;-

It is a direct method to determine soil moisture content without drying the sample. It is based on volume and weight r/ship of soil.

1.2 Measure irrigated area

The term duty means the area of land that can be irrigated with unit volume of irrigation water. Quantitatively, duty is defined as the area of land expressed in hectares that can be irrigated with unit discharge, that is, 1 cumec flowing throughout the base period, expressed in days. Imagine a field growing a single crop having a base period B days and a Delta mm which is being supplied by a source located at the head (uppermost point) of the field. The water being supplied may be through the diversion of river water through a canal, or it could be using ground water by pumping. If the water supplied is just enough to raise the crop within D hectares of the field, then a relationship may be found out amongst all the variables as:

- Volume of water supplied = B*60*60*24 m^3 Area of crop irrigated = D*104 m^2

- Volume of water supplied per unit area = 10000D 86400 = D 64.8 B

Hence, knowing two of the three variables B, D and the third party may be found out. The duty of irrigation water depends upon a number of factors; some of the important ones are as follows:

• **Type of crop**: As different crops require different amount of water for maturity, duties are also required. The duty would vary inversely as the water requirement of crop.

• **Climate season and type of soil**: Some water applied to the field is expected to be lost through evaporation and deep percolation. Version 2 CE IIT, Kharagpur Evaporation loss has a direct bearing on the prevalent climate and percolation may be during drier seasons when the water table is low and soil is also dry. Percolation loss would be more for sandy soils than silty or clayey soils.

• **Efficiency of cultivation methods**: If the tillage and methods of water application are faulty and less efficient, then the amount of water actually reaching the plant roots would be less. Hence, for proper crop growth more water would be required than an equivalent efficient system. Also, if the water is conveyed over long distances through field channels before being finally applied to the field, then also the duty will rise due to the losses taking place in the channels.

Duty or duty of water is the relation between the areas irrigated, or to be irrigated, and the quantity of water used, or required to irrigate it for the purpose of maturing its crop. When applied to a channel it is the area irrigated during a base period divided by the mean supply utilized in cumecs. It may defined as the area irrigated by unit discharge which means the number of hectares under a particular crop brought to maturity by a constant supply of 1 cubic meter of water per second flowing continuously for the base period. Duty for a channel is usually calculated on the head discharge.

Duty based on discharge passed through the outlet and thus excluding all losses in the canal system is called the outlet discharge factor. Duty is expressed in:-

- Water depth units
- Depth-area units per unit area
- Area per unit rate of flow or per unit volume of water and
- Volume of water or rate of flow per unit area.

In practice duty is expressed in hectares per cubic meter per second & is represented by D. Generally irrigated area can be measured through duty-delta relationship.

1.3. Decide amount of water to be applied

Delta is the total depth of water in cm required by a crop to come to maturity. Or it is an expression used in irrigation practice to mean the depth of water that would result over a given area from a given discharge for a certain length of time. Alternatively, it may be defined as the total volume of water delivered divided by the area over which it has been spread. It is a term equivalent to duty of irrigation water when the latter is expressed in water depth units. Delta depends on the amount of each watering and the interval between successive watering during base period

Delta is stated with reference to the place at which it is measured, that is, delta at farm, delta at outlet, delta at distributor head, and delta at the head of main canal because of the presence of loss. To decide the amount of water in irrigated area it is important to master crop and base period. Crop period is the time that a crop takes water from the instant of its sowing to that of its harvesting.

Base period on the other hand, is the time in days between first watering of a crop at the time of sowing to its last watering before harvesting, i.e., the number of days in a crop or the number of days over which duty is measured. Base period of a crop is thus slightly less than its crop period, but for practical purposes it is generally taken equal to the crop period.

Table 1.1 indicates the average value of delta for certain important crops.

Crop	delta(cm)	crop	delta(cm)
Rice	125-150	gram	30
Sugarcane	90	cotton	25-40
Tobacco	60	wheat	37.5
Groundnut, maize	45	fodder	22

Now let's see the relationship between duty (D) and delta ( ):

Let D=duty of water (hectares/cumec), B= base period (days), and =delta of water (m).

Volume of one cubic meter flowing for one day=$1 \times 24 \times 60 \times 60 = 86400^{m3}$=8.64 ha m

Volume of one cubic meter flowing for B days = 8.64 B (ha m)

By the definition of duty (D), one cubic meter= 10^4 D m^2 of area supplied for B days matures D hectares of land.

Total depth of water applied on the land= volume/area=86400B/10^4 D

=8.64B/D meter

Here, delta is total depth of water,   =8.64 B/D m

D=8.64 B/   m

D=864 B/   cm

Hence, delta (   ) =864 B/D cm

Calculation of irrigation water requirements

We can decide the amount of water to be added in irrigation area by using another system which is called crop water requirement as follow:

Crop water requirements (CWR) for a given crop, I, are given by:

$$CWR_i = \sum_{t=0}^{T} \left(kc_{i_t} \cdot ET_{o_t} - P_{eff_t} \right)$$ Unit: mm

Where kc_{i_t} is the crop coefficient of the given crop

i during the growth stage t and

T is the final growth stage

Each crop has its own water requirements. Net irrigation water requirements (NIWR) in a specific scheme for a given year are thus the sum of individual crop water requirements (CWRi) calculated for each irrigated crop i. Multiple cropping (several cropping periods per year) is thus automatically taken into account by separately computing crop water requirements for each cropping period. By dividing by the area of the scheme (S. in ha), a value for irrigation water requirements is obtained and can be expressed in mm or in m3/ha (1 mm = 10 m3/ha).

$$NIWR = \frac{\sum_{i=1}^{n} CWR_i \cdot S_i}{S}$$ Unit: mm

Where Si is the area cultivated with the crop i in ha.

The cropping intensity of the scheme can be defined as:

$$\frac{\sum_{i=1}^{n} S_i}{S}$$

1. Effective rainfall was computed according to the "USDA Soil Conservation Service Method" formula

2 Dependable rainfall, the combined effect of dependable rainfall (80% probability of exceedance) and estimated 'losses, due to runoff and percolation, was calculated according to the formula.

Gross irrigation water requirement (GIWR) is the amount of water to be extracted (by diversion, pumping) and applied to the irrigation scheme. It includes NIWR plus water losses:

$$GIWR = \frac{1}{E} \cdot NIWR$$ Unit. mm

Where: E is the global efficiency of the irrigation system.

Self-Check-1	Written Test

Name: ___________________________ Date: ________________

Directions: Answer all the questions listed below.

1. What is the importance of measuring irrigation water during application(5 pt)
2. Differentiate duty, delta, base period and crop period(5 pt)
3. Differentiate Electrical resistance and conductivity relationship(5 pt)
4. What is soil moisture deficit? What are the deficit measuring techniques, explain(10pt)

Note: satisfactory Rating-12.5 and above pts. Unsatisfactory Rating-below 12.5 pts.

You can ask your teacher for the copy of the correct answers

Information Sheet-2	Apply a measured amount of water

2.1 Predict a pre-determined deficit

Once again water is important for irrigation to increase productivity for returning agricultural cost. It is clear irrigation is practiced mostly arid and semi-arid area and during the natural rainfall become ceasing because to make agricultural production continuous for addressing food shortage of a nation through a big science called irrigation. During irrigation neither excess water nor deficit is recommended that is why excess water leads to water logging and high salinity formation, where as in deficit the crop become wilt and the crop cannot achieve its water demand or consumptive use.

When water logging occur due to excess water in agricultural field the crop become out of use because of within the crop root zone air circulation and microbial activity go towards depletion. This drawback of irrigation can be improved by the application of drainage. However, irrigated agricultural field frequently affected by moisture deficit. The amount of water to be applied depends on the degree of this deficit. Before recharging the deficit the following concepts must be visible;

- The rate of evapotranspiration of the area
- The state of wilting point of the crop
- The irrigation period and scheduling
- Topography of the area
- The irrigation season and so on.

2.2 Apply irrigation to replace the deficit

After predicting pre-determined deficit irrigation water then deliver to the specific crop to replace the deficit. If the area is seriously affected by water shortage, it will take large amount of water for full replacement. But in any case the application of water to the deficit field to bring soil moisture content to field capacity.

Field capacity is the amount of water held in the soil after excess gravitational water has been drained i.e. the moisture percentage of the soil expressed on dry weight basis in the field 2 or 3 days after the soil profile is thoroughly wetted by rain or irrigation water, provided there is no water table within capillary reach of the root zone.

2.3 Increase water quantity to ensure dilution & transport of toxic solutes

Irrigation is the artificial application of water to arid land for growing crops. It is a profession as well as a science. A crop requires certain amount of water at certain fixed intervals throughout its period of growth. Irrigation is not required if this requirement is met with from sufficient rain fall as in summer season. The three essential requirements of plant growth are heat, light and moisture supplemented frequently by artificial of water. Thus, irrigation is supplementary to rain fall when it is either deficient or comes irregularly or at unreasonable times.

In fact the depth of water to be applied in to irrigated field relay on the consumptive use (CU) or the water required by the crop (CWR). CWR or CU is thus the quantity of water required by a crop in a given period of time for normal growth under field conditions. It includes evapotranspiration (ET) and other economically unavoidable waste such as percolation, surface runoff, and application& conveyance losses.

In irrigation applying water to fit only CWR is not recommended since irrigated field often affected by salt formation. Hence, always excess of CWR is advised to leach salt crust. Not only for leaching but also to dissolves mineral nutrients as calcium, magnesium, potassium e.t.c which moves in the plant along with its stem. At the end of the life cycle of a plant, water is also a constituent of the economic product, which may seed, stem, leaf, flower or fruit. In crop production water is also needed sometimes for certain special purposes. The functions of irrigation water in crop production are:

- Triggers activity in a seed, setting a chain of biochemical rxns,
- Dissolves mineral nutrients for their rise from the soil to the plant,
- Promotes chemical action within the plant for its growth,
- Promotes & supports life of bacteria beneficial to plant growth,
- Helps temperature control of the soil as also minimizes the effect of frost &
- At the end of life cycle of the plant , water is still a constituent of the product

Finally the increasing water is necessary for transporting of toxic solutes for instance sodium (Na), Boron, carbonate & bicarbonate concentration.

Self-Check 1	Written Test

Name: ________________________ Date: _______________

Directions: Answer all the questions listed below.

1. What is the reason of applying water in excess of CWR? (6 pt)
2. How can we prevent water logging? explain (3 pt)
3. On what bases applying water partly or full replacement of deficit? (5 pt)

Note: satisfactory Rating-10 and above pts. Unsatisfactory Rating-below 10 pts.

You can ask your teacher for the copy of the correct answers

INFORMATION SHEET-3	Determine soil intake rate

1.1 Select methods for intake rate determination

Intake rate refers the condition of the soil at any given area in which the tendency of water entering in to the subsoil. The concept of intake rate is almost similar to infiltration with element difference i.e. intake rate only express status of the soil taking water with irrespective of water amount & depends on the soil roughness also equal to permeability. Here, permeability is an important quality of soil that enables it to transmit water or air. It is the velocity of flow under a unit hydraulic gradient. It depends on presence of minute openings in the soil as also on the size, shape, and arrangement of such openings. Sandy soils of coarse texture have large pore spaces & hence high permeability. Clayey soils of fine texture have relatively small pore spaces & hence low permeability. Permeability is affected by water temperature, texture and structure of the soil.

Factors Affecting Intake Rates

The most important factors influencing the infiltration rate of water into the soil are:

1. **Soil texture and structure.** The coarser the texture and the more highly structured, the higher the infiltration rates.

2. **Soil surface conditions.** Orientation of soil particles and compaction: after water moves over a soil surface, soil particles are rearranged and the soil surface tends to seal.

3. **Soil moisture content and moisture gradients.** Generally, the drier the soil, the faster the infiltration rate.

4. **Time since the start of irrigation.** Infiltration rate decreases with time until the basic intake rate is reached.

5. **Salt content in the water and soil.** Soils high in soluble salts will typically exhibit higher intake rates than soils from which salts have been leached.

6. **High levels of sodium** on the soil's exchange sites will severely affect infiltration if structure collapses

Infiltration rate of soil is the velocity at which water seeps into it, measured by depth (mm) of the water layer that the soil absorbs in an hour. Infiltration rate is low if it is less than 15 mm/hr, medium if between 15-50 mm/hr and high in case it is more than 50 mm/hr. Infiltration rate is measured by an instrument called ring infiltrometr. But both infiltration and soil intake rate are determined by simple empirical equation:-

1) KOSTIAKOV EQUATION

An early equation used to quantify infiltration rate developed by kostiakov as mathematically;

$I= ct^{\alpha}$ where, I = infiltration by depth (in cm or mm or inches)

T= elapsed time for infiltration in minute

C & α= are empirical constants

2) PHILIP EQUATION

This equation can be derived from theoretical analysis of one dimensional vertical infiltration in to a uniform soil. It is given by;-

$I = sp\,(t)^{0.5} + Co\,(t)$ where   sp=sorptivity constant cm/minute

Co= conductivity constant cm/minute

3) SOIL SCIENCE EQUATION

Soil science department has made a large number of field trials to measure and categorize infiltration rates. This method has used a slightly modified form of kostiakov equation. Infiltration rate in these method computed as;-

$I= at^{b} + c$ c= 0.275 expressed in inches

A and b are given as a function of infiltration factor and can be read from table

3.4 Make available tools &equipment’s

Soil roughness is the appearance of soil in which the first irrigation takes place. It is obvious in any irrigation system the first irrigation period takes large amount of water as compared to the second & third. These clearly shows during first irrigation period the soil of one irrigated agricultural field the soil intake rate much higher than the next with insignificant water wastage. But the amount of water seeping in to the soil including its rate determined by the equation (see 3.1) in each irrigation period. Also there are supportive available tools and equipments to fulfill the soil intake rate requirements. These are include;-

- **Ring infiltrometer,** A double ring infiltrometer requires two rings: an inner and outer ring. The purpose is to create a one-dimensional flow of water from the inner ring, as the analysis of data is simplified. If water is flowing in one-dimension at steady state condition, and a unit gradient is present in the underlying soil, the infiltration rate is approximately equal to the saturated hydraulic conductivity.

An inner ring is driven into the ground, and a second bigger ring around that to help control the flow of water through the first ring. Water is supplied either with a constant or falling head condition, and the operator records how much water infiltrates from the inner ring into the soil over a given time period. The ASTM standard method[2] specifies inner and outer rings of 30 and 60 cm diameters, respectively.

Figure 3.1 double ring infiltero meter

- **Siphon,**Theword **siphon**is used to refer to a wide variety of devices that involve the flow of liquids through tubes. In a narrower sense, the word refers particularly to a tube in an inverted 'U' shape, which causes a liquid to flow upward, above the surface of a reservoir, with no pump, but powered by the fall of the liquid as it flows down the tube under the pull of gravity, then discharging at a level lower than the surface of the reservoir from which it came.

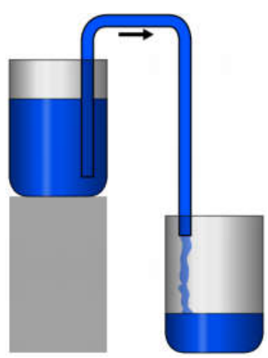

Figure 3.2 siphon

- Flumes,is a human-made channel for water in the form of an open declined gravity chute whose walls are raised above the surrounding terrain, in contrast to a trench or ditch. Flumes are not to be confused with aqueducts, which are built to transport water, rather than transporting materials using flowing water as a flume does. Flumes route water from a diversion dam or weir to a desired materiel collection location.
-

Figure 3.3 flume

- Auger, core sampler,Soil core sampling equipment is used to collect virtually undisturbed soil core samples for soil profiling and environmental investigations.

Figure 3.4 auger/core samplers

- Spatula, Unique spatula both scoops material and instantly displays weight. Balance with digital display is located in the easy-grip handle. The weighing range is 0 to 300.0 grams and 0 to 10.580 ounces. Readability is 0.1 gram and 0.005 ounce. Level position repeatability is 0.1 gram and accuracy is. An **analytical balance** (often called a "lab balance") is a class of balance designed to measure small mass in the sub-milligram range. The measuring pan of an analytical balance (0.1 mg or better) is inside a transparent enclosure with doors so that dust does not collect and so any air currents in the room do not affect the balance's operation. This enclosure is often called a draft shield.

- **Computer software,** oven, Major components of the system consist of a microwave oven, at. Electronic balance, a small 64-Kilobit computer, a monitor, and a printer as well as a program cartridge (which can be detached from the computer) on which system-controlled **software** is stored.
- **Cylinder and hose,** Each regulator is designed to fit a specific type of cylinder valve and a regulator that fits one type of valve will not fit any of the others. The valve on Propane cylinders has a screw thread and only accommodates Propane regulators. Butane is supplied by Flogas under two brands, Flogas and Ergas. The Flogas Butane cylinders are yellow and always use a "Jumbo" valve. There are two types of Ergas Butane cylinders: the orange ones have the same "Jumbo" valve as the Flogas cylinders, but the blue/green cylinders have a much narrower "Compact" valve. High-pressure regulators have a much narrower nozzle than that fitted to low-pressure regulators and use a much narrower hose
- **Tensiometer,** may refer to one of a number of devices. The two most common are:

✓ Tensiometer (surface tension) an instrument used to measure the surface tension of liquids

✓ Tensiometer (soil science) an instrument to determine matric water potential

- Stop watch is a handheld timepiece designed to measure the amount of time that elapses between its activation and deactivation. A large digital version of a stopwatch designed for viewing at a distance, as in a sports stadium, is called a **stopclock**. In manual timing, the clock is started and stopped by a person pressing a button. In fully automatic time, both starting and stopping are triggered automatically, by sensors.

- Current meter, pressure apparatus, the pressure meter PCE-DMM 50 is suitable for stationary and mobile pressure measurement. The pressure meter PCE-DMM 50 is used in mechanical and plant engineering, laboratory technology and environmental technology. This pressure meter is battery powered. The measuring range of the pressure meter reaches up to 600 bar.

- Max. 600 bar / 8702 psi
- Rotating display
- For hygienic applications
- Media: water, oxygen, fuels and oils
- Print: absolute or relative (user selectable)
- Diaphragm: Ceramics
- Accuracy class: 0.2

3.3 Determine soil moisture holding capacity

Soil moisture holding capacity is the amount of water required to fill all the pore spaces between the soil particles by replacing the entire air held in pore spaces. It is the upper limit of possible moisture content. One of the main functions of soil is to store moisture and supply it to plants between rainfall or irrigations. Evaporation from the soil surface, transpiration by plants and deep percolation combine to reduce soil moisture status between water applications. If the water content becomes too low, plants become stressed. The plant available moisture storage capacity of a soil provides a buffer which determines a plant's capacity to withstand dry spells.

Forms of Soil Water Storage

Water is held in soil in various ways and not all of it is available to plants.

Chemical water; - is an integral part of the molecular structure of soil minerals. It can be held tightly by electrostatic forces to the surfaces of clay crystals and other minerals and is unavailable to plants. The rest of the water in the soil is held in pores, the spaces between the soil particles. The amount of moisture that a soil can store and the amount it can supply to plants are dependent on the number and size of its pore spaces

Gravitational water; - is held in large soil pores and rapidly drains out under the action of gravity within a day or so after rain. Plants can only make use of gravitational water for a few days after rain.

Capillary water; is held in pores that are small enough to hold water against gravity, but not so tightly that roots cannot absorb it. This water occurs as a film around soil particles and in the pores between them and is the main source of plant moisture. As this water is withdrawn, the larger pores drain first. The finer the pores, the more resistant they are to removal of water. As water is withdrawn, the film becomes thinner and harder to detach from the soil particles. This capillary water can move in all directions in response to suction and can move upwards through soil for up to two meters, the particles and pores of the soil acting like a wick. When soil is saturated, all the pores are full of water, but after a day, all gravitational water drains out, leaving the soil at field capacity. Plants then draw water out of the capillary pores, readily at first and then with greater difficulty, until no more can be withdrawn and the only water left are in the micro-pores. The soil is then at wilting point and without water additions, plants die.

The amount of water available to plants is therefore determined by the capillary porosity and is calculated by the difference in moisture content between field capacity and wilting point. This is the total available water storage of the soil. The portion of the total available moisture store, which can be extracted by plants without becoming stressed, is termed readily available water. Irrigators must have knowledge of the readily available moisture capacity so that water can be applied before plants have to expend excessive energy to extract moisture. The amount of soil water available to plants is governed by the depth of soil that roots can explore (the root zone) and the nature of the soil material. Because the total and available moisture storage capacities are linked to porosity, the particle sizes (texture) and the arrangement of particles (structure) are the critical factors. Organic matter and carbonate levels and stone content also affect moisture storage.

Poor structure, low organic matter, low carbonate content and presence of stones all reduce the moisture storage capacity of a given texture class. Clays store large amounts of water, but because they have high wilting points, they need significant rain to be able to supply water to plants. On the other hand, sands have limited water storage capacity, but because most of it is available, plants can make use of light showers regardless of how dry they are before the shower.

Plants growing in sand generally have a denser root system to enable them to access water quickly before the sand dries out.

Table3.1: Water holding capacity (mm/cm depth of soil) of main texture groups. Figures are averages and vary with structure and organic matter differences.

Where, FC= field capacity, WP= wilting point AW= available H_2O

Texture	FC	WP	AW
Coarse sand	0.6	0.2	0.4
Fine sand	1	0.4	0.6
Loamy sand	1.4	0.6	0.8
Sandy loam	2	0.8	1.2
Light sandy clay loam	2.3	1	1.3
Loam	2.7	1.2	1.5
Sandy clay	2.8	1.3	1.

loam			5
Clay loam	3.2	1.4	1.8
Clay	4	2.5	1.5
Self-mulching clay	4.5	2.5	2

Measuring soil water Holding Capacity

Firstly, establish the depth of the root zone, either by observing the depth to which roots from the previous crop have extended, or by noting the depth to a restrictive layer. The roots of most annual field crops occur in the top 120cm of soil, if there are no restrictive layers. Some perennial species may extend roots to 600cm or more if soil conditions are ideal and moisture is present.

Secondly, use table3.1 to calculate the water holding capacity of each soil layer in the root zone. For example, 25cm of clay loam with an available water of 1.8mm water per cm of soil, can store 45mm of available water. The water holding capacity of a soil is calculated by summing the capacity of each layer in the root zone.

Finally soil water holding capacity can be measured using the following methods and sensors

ML2x ThetaProbe

• High performance soil moisture sensor – true ±1% accuracy

With the ThetaProbe it's easy to make reliable, accurate soil moisture measurements. Simply insert the probe into the soil, connect to your data logger or meter, and within seconds you can be logging soil moisture. ThetaProbes are robust, buriable and maintenance free.

SM300 Soil Moisture Sensor

New research grade sensor
Soil moisture AND temperature

The new SM300 achieves ±2.5% accuracy and offers outstanding performance in all soil types. The SM300 is a versatile, high quality, research grade sensor that offers convenience and cost saving by combining soil moisture and temperature measurement in a single probe.

PR2 Profile Probe

Measure soil moisture above and below the root zone
Dual function - instant measurements with HH2 or long term monitoring with DL6 recorder
Accurate measurements - low sensitivity to temperature and salinity

The PR2 uses newly patented sensing technology making it possible to measure soil moisture content profiles in a range of soil types and across a wide range of nutrient levels. The Profile Probe is uniquely able to provide both portable measurements (attached to a meter) as well as long-term records when attached to a data logger.

WET-2 WET Sensor

Accurate soil moisture and pore water EC monitoring within the root zone

The WET Sensor is unique in its ability to monitor Water content, pore water EC and Temperature directly within the soil or plant growing medium. It is an invaluable tool enabling horticultural growers to monitor and optimise the growing conditions directly within the substrate.

EQ2 Equitensiometer

Maintenance-free, wide range dielectric tensiometer -50 to -500 kPa

The Equitensiometer is an innovative sensor for measuring soil water potential (soil matric potential) based on the ML2x ThetaProbe. Being maintenance free, (i.e. no refilling, degassing or topping up required) and low power, the EQ2 can be conveniently used at remote sites. It is not harmed by frost or by long term burial.

SWT-4 and SWT-5 Water Filled Tensiometers

Loggable, water-filled, pressure transducer tensiometers to measure soil water potential in many different soil environments.

HH2 Moisture Meter

Holds multiple user-defined soil types

Stores up to 2000 time-stamped readings

Includes PC data collection software

SWT-MR Manual Readout Unit

Multi-function handheld readout unit

- Automatic offset corrections
- Memory for 220 readings

For use with Soil Water Tensiometers, such as SWT4 and SWT5 models

DL2e Data Logger

High specification research logger

15 to 62 differential analogue channels

Battery powered, rugged, weatherproof case

Easy programming with Ls2Win Software (software included)

The DL2e is compatible with almost every type of sensor that gives an output in terms of DC voltage, resistance, count, frequency or status.

Delta-T Logger (Ls2Win s/ware). Includes DL2e Logger PC Software Ls2Win, "Getting Started",user guide, Software & Manuals CD and RS232 Cable LRS1.

DL6 Soil Moisture Logger

Dedicated soil moisture logger

Optimised for use with Profile Probes &ThetaProbes

6 differential analog channels plus temperature and counter inputs

IP67 weather-proof case and battery power

The DL6 can be used with combinations of ThetaProbes, Profile Probes and SM300s, and also accepts rain gauge and soil temperature inputs.

GP1 General Purpose Logger

High accuracy 7 channel data logger

• Ideal for Delta-T soil water content sensors
• Memory for >600,000 readings
• Smart irrigation control capability

The GP1 supports a full range of 0 to 2.5V environmental sensors.

Self-Check-3	**Written Test**

Name: ___________________________ Date: ________________

Directions: Answer all the questions listed below.

1) Define soil moisture holding capacity (5pt)
2) Differentiate forms of soil water (5pt)
3) How can we measure infiltration rate of soil? (5 pt)

Note:-7.5pt and above stay in satisfactory if not put under un sat

Information sheet-4	**Identify irrigation measuring device & techniques**

4.1 Identify type of irrigation method

Generally, irrigation may broadly be classified in to the following band:-

i) Surface
ii) Sub-surface &
iii) Pressurized irrigation method

Surface irrigation method – is the application of irrigation water from the surface and it wets the soil surface. This method of irrigation may further be classified in to:-

a) Flow irrigation   b) lift irrigation

Flow irrigation occurs when the water is available @ a higher level, & it is supplied to lower level, by the mere action of gravity.

Lift irrigation; - if the water is lifted up with some mechanical or manual means, such as by pumps etc and then supplied to the crops root zone for nourishment.

Flow irrigation has two forms as-

i) Perennial
ii) Flood (inundation) irrigation

Perennial irrigation –in this system of irrigation constant and continuous water supply is assured to the crops in accordance with the requirement of the crop throughout the crop period. Also water is supplied through storage canal head works and canal distribution system.

Flood irrigation –also called inundation or submergence. In this method of irrigation soil is kept submerged & thoroughly flooded with water, so as to cause Saturation of the land.

Sub-surface irrigation method –it is termed as sub surface because in this type of irrigation, water does not wet the soil surface. The underground water nourishes the plant root by capillarity. It may be divided in to the following two types;-

a) Natural
b) Artificial sub surface irrigation method

Natural sub surface irrigation method;-by natural agents like rainfall. Leakage water from rivers, channels etc goes to underground and during its passage through the sub soil, it may irrigate crops sown on lower lands by capillarity. Sometimes leakage water causes the ground water to rise up which helps in irrigation of crops by capillarity.

Artificial sub surface irrigation method;-when a system of open jointed drains is artificially laid below the soil, so as to supply water to the crops by capillarity then it is known as artificial sub irrigation. It is a very costy process & it may be recommended only in some special cases with favorable soil condition and for cash crops of very high return

Pressurized irrigation method

This is the other type of irrigation in which water is delivered to the crop root zone by the agent of pressure. Mostly the water moves from the lower to higher elevation supported by pressure generated device such as water. It contains two groups but we will look at on the other session as;-

i) Sprinkler
ii) Trickle/drip irrigation

4.2 Identify operation feasibility

Feasibility studies aim to objectively and rationally uncover the strengths and weaknesses of the existing business or proposed venture, opportunities and threats as presented by the environment, the resources required to carry through, and ultimately the prospects for success. its simplest terms, the two criteria to judge feasibility are cost required and value to be attained. As such, a well-designed feasibility study should provide a historical background of the business or project, description of the product or service, accounting statements, details of the operations and management, marketing research and policies, financial data, legal requirements .Generally, feasibility studies precede technical development and project implementation.

Operational feasibility: Operational feasibility is a measure of how well a proposed system solves the problems, and takes advantage of the opportunities identified during scope definition and how it satisfies the requirements identified in the requirements analysis phase of system development

4.3 Identify site of measurement

Irrigation water is measured at various points in the system: at the source, in the conveyance channels and at field intakes.

- At the source: water is measured at this point in order to know the water supply or water available from the source. This is important to decide direct withdrawal if supply, say stream flow rate is greater than demand or construction of water reservoirs and dams if supply less than demand.
- In the conveyance channels: water is measured at this point for proper distribution of the required amount of water.
- At field intakes: for design and operation of the distribution system, the supply requirements of the individual fields will need to be expressed in inflow rates or stream size, Q. i.e.

$Qt = Ad$

=A (MAD * TAW)*Drz

=A *NIR/€a

Where, Q = size of stream, m^3/hr

t =time required to irrigated the area, hr

A= area to be irrigated, m^2

€a= application efficiency

d = depth of irrigation, m

Self-Check-4	Written Test

Name: ___________________________ Date: ________________

Directions: Answer all the questions listed below.

1) What is the difference between the three forms of irrigation method? (10pt)
2) Why necessary irrigation water measurement at different site? (8pt)

Note: **Satisfactoryrating–9 pointsandabove Unsatisfactory-below9points**

Youcanaskyourteacherforthecopyofthecorrectanswer

Operation sheet-1	Measuring infiltration rate of soil

Objective: Measure infiltration rate of the soil

- ✓ **Use the following steps and procedure**

1. Place the inner ring with the cutting edge facing down on the ground. Remove small obstacles such as stones or twigs. When measuring below the ground surface, a profiled pit should be made.
2. Put the driving plate on top of the inner ring. Depending on its diameter the ring will fit over, between or within the pins located on the bottom side of the driving plate.
3. Use the impact-absorbing hammer to insert the infiltration ring about 5 cm vertically into the soil. Make sure to disturb the soil as little as possible. In stiff soils have someone stand on the driving plate while another person drives it in? Remove the driving plate from the inserted infiltration ring.
    - Keep the depth of placement as limited as possible so as not to disturb the top layer. Insert the rings inany case to below a particular top layer, such as a disturbed or crusted top layer or layer with macro-pores.
    - In the case you should encounter any play between the ring and the ground, push the ring back in its place. A disturbed crust can be healed using bentonite or other soil material.
4. Place the outer ring with the cutting edge facing down around the inner ring and put the driving plate on top of it.
5. Repeat step 3. The shape of the driving plate will ensure adepth identical to that of the inner ring.
6. The standard double ring infiltrometer set allows simultaneous measuring in threefold. Place the rings 2 - 10 m apart, depending on the field situation, and repeat steps 1 to 5.
    - Place all rings at a similar depth to allow comparison of the results. Differing ring diameters are not supposed to produce differing results.
7. Place the measuring bridge with measuring rod and float on the innerring. Remove, without disturbing the soil structure, any vegetation thatmay hamper free movement of the float or affect the measuring.
8. Fill the outer ring with water, then the inner ring, to approximately 5 - 10 cm. Start measuring immediately to determine the infiltration curve (see paragraph 3.2).

- The water level within the infiltration rings should be as low as possible to ensure vertical infiltration.The rings should not go dry. It is recommended to fill to 5 - 10 cm.
- To protect the ground surface when pouring the water, use plastic foil, a jute cloth, sponge or a 1-2 cmlayer of sand or gravel. It is also possible to pour the water via your hand on the ground.
- Make sure to have sufficient water at hand. Filling one set of rings requires approx. 25 litre.

Some remarks:

 To measure only the infiltration capacity of saturated soil it will suffice to saturate the soil (by pouring water in the rings) without measuring.

 To obtain optimal results in determining the infiltration capacity, use water of a similar quality and temperature to that of the real system you are examining.

LAP Test/ Job Sheet	**Practical Demonstration**

Name: _______________________________ Date: _________________

Time started: __________________________ Time finished: _________________

Instructions:

You are required to perform the following:

- **Measuring**

1. Start the measuring by noting the time and the water level in the inner ring (reference level) as indicated on the measuring rod. Use columns A and B on the field list. When carrying out synchronic measuring, use several field lists.

- **Always use copies of the field list; use the original only for reproduction.**

2. Determine the drop in the water level in the inner ring during a certain interval. Note the time and the water level in column A and B on the field list. Start with short intervals (for instance 1-2 min) and conclude measuring with a longer interval (20 - 30 min, depending on the type of soil).

- Make sure the infiltration rings do not godry during measuring. Add water when only a few centimeters of water are left in the rings. Write the new levels in column B of the list.

- Keep the water in the inner and outer ringat a similar level. A higher water level in the outer ring will lead to a decreasing infiltration rate in the inner ring. A lower water level in the inner ring will cause the buffering against lateral spreading to decrease.

3. Stop measuring only if the infiltration rate has reached a constant value. A change of < 10% in a certain phase is often considered as constant. Depending on the type of soil this may occur within 1 or 2 hours, in exceptional cases only after a day.

4. Remove the rings using the pull-out hooks.

5. Rinse the rings, make sure no earth sticks and sets to the rings. Proper maintenance will prevent unnecessary disturbance of the soil upon installation.

- **After measuring computation of the measuring data**

1. Calculate the cumulative time and time steps in columns C and D using the data in columns A and B. Determine the infiltration in column E by calculating the water level differences between intervals in column B.
2. Calculate the infiltration capacity (mm/min) in column F by dividing for each interval the infiltration (column E) by the time step (column D). If necessary, convert the infiltration capacity to e.g. [m/hour] in column G.
3. The tabulated data can be used to determine the infiltration curve. Plot out the calculated infiltration capacity (column F or G) on the y-axis of a graph and the cumulative time (column C) on the x-axis.
4. The near-saturated hydraulic conductivity equals the more or less constant infiltration capacity established toward conclusion of the measuring. Use multiple measurements to calculate a reliable mean value for a certain type of soil or landscape unit.
5. Determine, if necessary, the cumulative infiltration for a certain period. The cumulative infiltration is the total amount of water infiltrating over a certain period of time (L, for instance mm). Fill in column H of the field list by adding the total infiltration (column E) for each interval from the starting of measuring on.

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