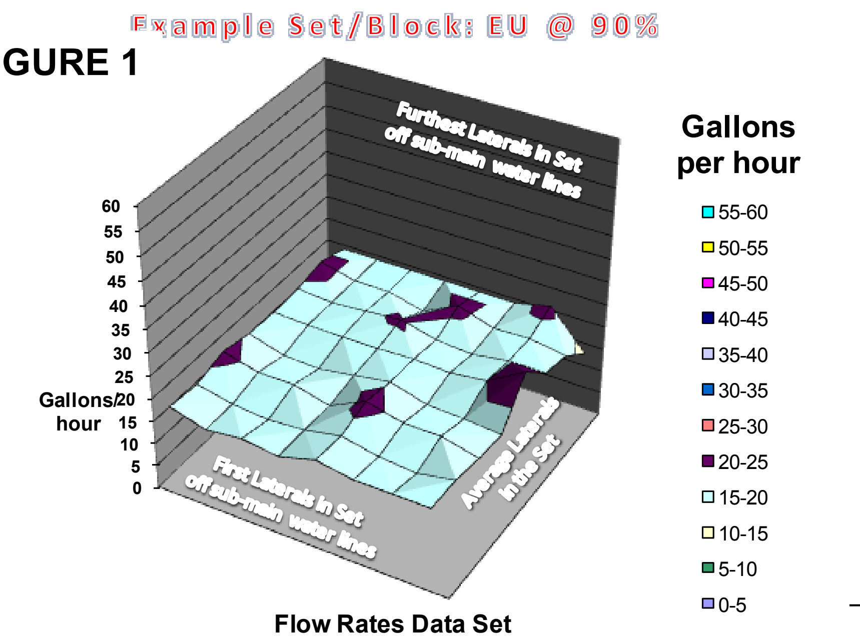
Introduction

What is the Purpose of this Irrigation System Evaluation Report?
The primary purpose of this report is to provide you with an assessment of your irrigation systems' performance based on the data we collected during the day of our initial site visit. In this report, irrigation system performance is defined in terms of *emission uniformity* (EU).

What is Emission Uniformity?
EU is a measure of how evenly water is applied throughout a specified area. An irrigation system that operates at a high level of EU is one that supplies, in a set amount of time, nearly the same volume of water to each crop element (i.e. plant, tree, shrub) within an irrigated area. Conversely, a poorly performing system is one in which crop elements receive markedly different volumes of water over the course of an irrigation event.

The graph depicted in Figure 1 illustrates a finely tuned and highly performing irrigation system with an EU of 90%. This means that the average flow of the lowest flowing emitters in the system supplied 90% of the water supplied by the average of all emitters in the system. To the grower, this means that the irrigation system needs to be run only a small additional amount of time to ensure that the water requirement of every single crop element in the irrigated area is satisfied.

FIGURE 1



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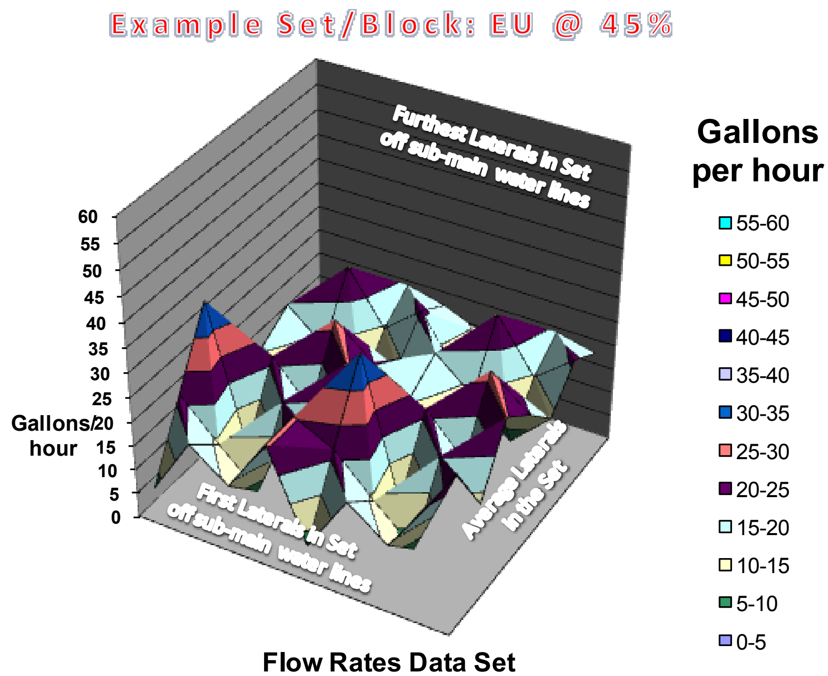
corresponding height of each intersecting line relative to the graph's y-axis indicates the amount of water (in gallons per hour) each sprinkler emitted during the time when the data was collected.

Notice that the data collected for the high performing system in Figure 1 generates a plane on the graph that appears *almost* flat. If it were possible to design an irrigation system that operated at 100% EU, it would produce a set of data points that would appear *completely* flat. This would mean that on the day data was collected, all sprinklers emitted exactly the same amount of water during a given time period.

On the other hand, irrigation systems operating poorly with regard to EU will produce a graph much different than the one depicted in Figure 1. A graph demonstrating poor EU would show significant peaks and valleys, which indicates that sprinklers are emitting highly variable amounts of water during a given period of time. High areas, peaks on the graph, would illustrate high sprinkler flow rates. Low areas, valleys on the graph, would depict low flow rates. 's an example of an irrigation system demonstrating poor emission uniformity.

FIGURE 2



What are the Drawbacks of Poorly Performing Irrigation Systems?

Irrigation systems exhibiting low levels of emission uniformity are troublesome because when this type of system is run for a set amount of time, some crop elements receive too little water, some too much water, and very few the correct volume of water. As a result, a few things happen: water is lost to deep percolation and/or runoff, this lost water carries with it nitrate fertilizers to underground and surface water supplies, and the overall health of the crop is compromised.

Why are High Levels of Emission Uniformity Important?

EU is considered an important indicator of irrigation system performance because high levels of EU can contribute to more efficient use of water, more efficient use of fertilizers, maximized crop health, and cleaner water supplies. It is in the interest of every grower to achieve high levels of EU since water and fertilizer use efficiency combined with maximized crop health lead to lower production costs and higher fruit yield. And lower production costs combined with higher fruit yield equal increased profit.

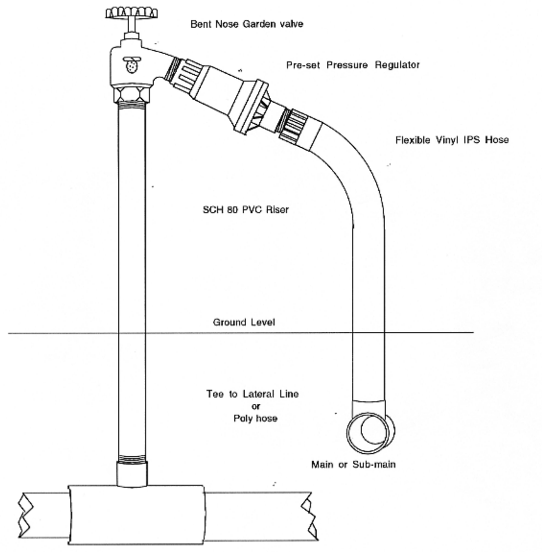
Essential Maintenance Procedures for Maintaining High EU Levels

System Pressures -- Since water pressure has a direct effect on sprinkler flow, variable pressures within an irrigation system are a major cause of poor emission uniformity. Micro-irrigation systems will deliver water most effectively if they are operated at or near 20 psi. Low pressures (those below 20 psi), can lead to under irrigation due to reduced sprinkler flows. Reduced pressures can also cause the area wetted by each sprinkler to become unacceptably small. High pressures (those over 20 psi), can lead to the premature deterioration of system components such as tubing, hoses, sprinklers, etc. Excessive pressures will also cause water leaving the sprinkler to mist. Mist is very susceptible to wind movement and often drifts away. Often this water (which you have paid for), never reaches the tree’s root zone where it will do the most good.

Pressure Regulation -- Effective pressure regulation is an essential part of good irrigation water management. It helps to ensure that all portions of your grove receive equal amounts of water during each irrigation cycle. If irrigation block pressures are poorly regulated, much more irrigation water ends up being applied to the trees at the bottom of the slope. Similarly, if pressures are unregulated, trees at the top of the hill are often under irrigated.

There are three common ways to regulate lateral line pressures. The first is to employ the existing lateral line valves in the grove. Individual lateral line pressures should be regulated to roughly 20 psi by adjusting each lateral line's hose bib. To employ this method, start at the bottom of each sub-main or wherever pressures are the highest. Work up the sub-main (toward the location where pressures are the lowest), adjusting line pressures to roughly 20 psi. Line pressures can be monitored at the closest sprinkler riser to the valve, or at the valve itself with a Schrader adapter. Schrader fittings can be purchased at any auto parts store and are installed by drilling an 11/32" hole and threading it with a 1/8-27 NPT tap. This will allow you to diagnose the operation of the valve and also know exactly what the inlet pressure to the block is. Line pressures should be verified and adjusted (if needed), every second or third irrigation cycle. The primary advantage of this method of pressure regulation is that it does not require any significant capital outlay for new equipment. The main disadvantages of this method are 1. Reoccurring labor in keeping all of the grove's lateral line hose bibs correctly adjusted. 2. Because of the way they are built, hose bibs do not hold their settings very well. They are constructed with rubber components that shrink, swell and deteriorate over time. Hose bibs function better as on/off valves rather than pressure control devices.

The second method of pressure regulation involves the installation of pressure regulators at all lateral line inlets. Pressure regulators automatically compensate for changes in pressure caused by elevation loss/gain and by fluctuations in district water deliveries. The installation of pressure regulators eliminates the labor involved in the repetitive adjustment of lateral line hose bibs.



If you choose to install pressure regulators, be sure to purchase the correct type to fit your needs. Pressure regulators come in different flow rate capacities and output pressures. Purchase only 20 psi regulators that have an adequate flow rate to supply each section that they will control.

> **Hypothetical Example:** A particular lateral line has 20 sprinklers. Testing has shown that the given sprinklers have an average flow rate of 25 gph. The combined output for the above line would be 500 gph (25 gph X 20 sprinklers = 500 gph), <u>OR</u> 8.3 gallons per minute (500 gph / 60 minutes = 8.3 gpm). Thus the proper pressure regulator for this application should have an output of at least 8.3 gpm at 20 psi.

The advantage of pressure regulators, as mentioned above, is that they eliminate the need to keep valves adjusted. They also provide very precise pressure control. The major disadvantage is the expense incurred in purchasing and installing the regulators. To ensure that all of the regulators in the grove are operating correctly, observe the following:

1. **Open all hose bibs completely.** If located before the regulator, a throttled hose bib will reduce the amount of pressure supplied to the regulator. If the amount of pressure supplied is below the regulator's threshold, the regulator will not function correctly. This "double" pressure regulation is not necessary and lowers the system's emission uniformity. If located after the regulator, a throttled hose bib can cause harmonic vibrations that can damage the regulator (see below).
2. **Always install pressure regulators after the hose bib.** The principle behind this is that the regulators should not hold water while the lateral lines are partially or completely turned off. Doing so could cause damage to internal parts of the regulators, causing them to fail.
3. **Verify the operation of all pressure regulators.** Like all things mechanical, pressure regulators can and do fail. The operation of all pressure regulators should be checked once a year. If a lateral line's inlet pressure exceeds 25 psi (measured at the closest sprinkler to the inlet), the regulator should be replaced.
4. **Verify that all lateral lines are equipped with pressure regulators.** It is easy to

miss installing a pressure regulator on a lateral line.

The third method of pressure regulation involves the installation of pressure compensating micro-sprinklers. Unlike conventional micro-sprinklers, pressure-compensating (PC) micro-sprinklers have the ability to deliver a constant flow rate over a range of pressures. Depending on the sprinkler manufacturer, the working pressure range for PC micro-sprinklers is generally 20 to 40 psi. Pressure compensating sprinklers are ideal for long lateral lines or lateral lines where there is a large elevation loss and/or gain between the inlet and the end(s). When properly installed, PC micro-sprinklers are able to produce emission uniformities of over 90% on very steep terrain. However, they are more expensive than conventional micro-sprinklers and will require pressure regulator installation/valve adjustments if lateral line inlet pressures are consistently over 40 psi.

Sprinkler Uniformity -- Irrigation system performance will further increase when all sprinklers in a given block have roughly the same flow rate. Good irrigation practices will provide each like size tree in a block with the same amount of water during each irrigation cycle. When there are a variety of sprinklers with different flow rates present in a field, uniform water application is next to impossible. Negative impacts of mixed sprinklers can include non-uniform growth and poor yields.

The fastest way to lower a micro-irrigation system's emission uniformity is to mix sprinkler models on like size plants. Avoid this practice at all costs. Standardize to a single sprinkler model and then keep enough spares on hand for replacements. Discard all off type sprinklers in such a manner that will prevent them from reappearing in the system at a later time.

Wetted Area -- The size of the area wetted by each sprinkler will help dictate how often irrigations must occur. If the wetted area is small, the tree's root system has a reduced area from which to obtain moisture (a small soil water reservoir). Irrigations need to be short and frequent to fill this small soil reservoir. During very warm weather, this reservoir is depleted very quickly. Irrigations will be required very frequently to replenish needed soil moisture and prevent the trees from going into stress. On the other hand, a large wetted area encourages the trees to spread their roots out over a larger area of the grove. Thus, the tree's root system can utilize a greater area from which to obtain moisture. This expanded root zone provides better mechanical stability for the trees and helps make better use of available soil nutrients and soil moisture. Irrigations with a large wetted area are usually longer and less frequent due to a large soil water reservoir.

If implemented, the following recommendations will help to increase the size of the wetted area in your grove:

1. Extend sprinkler risers so that the tops of the sprinklers are between 8 and 12 inches above the grove surface. Taller risers will increase the radius of the sprinkler’s throw, thus increasing the size of the wetted area. Taller risers also make the sprinklers less susceptible to interference problems associated with leaf litter.

2. Adjust and maintain sprinkler risers so they are perpendicular to the grove surface.
3. Walk lateral lines as often as possible. Sprinklers can become clogged, broken or stuck between irrigations due to leaf litter interference, foreign material in the water, plastic deterioration due to heat and age, animal damage, etc.
4. Remove all obstructions that interfere with the wetting pattern of the sprinklers. Typical obstructions include tree branches, pruning debris and weeds.
5. Lateral lines should be flushed at least once every three months during periods of frequent irrigation. This practice helps to clean out accumulated foreign material (sand, silt, clay, insects, plastic parts, etc.), that have slipped into the system and tend to settle toward the ends of lateral lines. If this foreign material is allowed to accumulate, sprinkler plugging can occur. Removing the last sprinkler from each line and allowing clear water to flow from the riser for at least one minute will accomplish lateral line flushing.

Emission Uniformity vs. Irrigation Efficiency

Now that you understand EU, it is important to understand Irrigation Efficiency (IE). EU and IE are sometimes mistakenly used interchangeably when referring to the operation of an irrigation system. While it is important to understand both terms for the sake of growing a healthy crop, it is also important to understand how their meanings differ.

As mentioned before, EU measures the ability of an irrigation system to deliver the same amount of water to each crop element in a given period of time. EU is a function of system design, construction, and maintenance.

IE, on the other hand, has less to do with the functional performance of the irrigation system and more to do with how the system is manipulated by the grower to meet the needs of the crop. More specifically, IE takes into consideration not only the efficiency of the irrigation system but also the grower's ability to supply enough water to the crop at precisely the right time so that the vast majority of the water applied is used by the crop beneficially.

Beneficial water uses include water used by the trees for growth and fruit production, water held in the soil, water used to leach salts and water used for frost control purposes. Beneficial use is calculated by dividing the amount of water beneficially used by the trees by the total amount of water applied minus the change over time of the water stored in a soil. Total water applied includes all beneficial water used plus water lost through pipe leaks, over application resulting in deep percolation, surface runoff, surface evaporation, and wind drift.

IE, then, is not solely a function of system design, construction, and maintenance as is EU, but it is a function of how much water is applied and how often it is applied. Proper irrigation scheduling requires knowledge of irrigation water quality, weather factors affecting water losses, specific crop watering needs, and soil-water relationships. Studying the Irrigation Scheduling Guides in this report and its associated glossary of terms will help you to understand how to irrigate efficiently.

Irrigation Water Quality Issues

While salts are found in virtually all-natural water sources, excessive concentrations can significantly affect irrigation practices. When salts dissolve in water, they separate into electrically charged particles known as *ions*. Ions exist as positively charged *cations* or negatively charged *anions*. Because of the charge, cations bind with soil particles (soil carries a negative charge) and tend to be immobile in the soil profile. Anions, on the other hand, do not bind readily with soil particles and are thus very mobile.

Common cations found in irrigation water include calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^{+}) and potassium (K^{+}). Calcium, magnesium, and potassium are usually considered beneficial cations. Sodium is considered a non-beneficial cation. Excess amounts of sodium can destroy soil structure and severely reduce crop production. Fortunately, most water in San Diego County is high enough in both calcium and magnesium to counteract the ill effects of sodium.

Common anions found in irrigation water include bicarbonate (HCO_3^{-}), carbonate (CO_3^{--}), chloride (Cl^{-}) and sulfate (SO_4^{-}). Of all the anions, chloride gives us the most problems here in San Diego County. It is common in both district water and most well water. High chloride concentrations can cause severe problems in both avocados and citrus. Because it is an anion, chloride moves through the soil profile readily.

When you use saline water to irrigate, salts will accumulate over time in the irrigated root zone (saline water is added to the soil, the water is removed by the plants and evaporation, leaving the majority of the salts behind). Salt accumulation is largely dependent on the salt load of the irrigation water. To counteract this build-up, sufficient amounts of water need to be applied (in the form of irrigation and rain), over and above the normal needs of the crop. This extra water will pass through the root zone and carry salts with it. Applying excess irrigation water to move salts through the soil profile is known as leaching. Several factors determine the amount of leaching necessary. 1. Soil texture. 2. The amount of salt in irrigation water. 3. The tolerance of your crop to salt.

Several approaches can be taken regarding leaching. Leaching can be accomplished by adding extra water during each irrigation cycle. Other methods include leaching monthly, quarterly or annually.

Irrigation Scheduling Guide

The following irrigation scheduling guide was developed using both data collected in the field and data extracted from written publications. Following is an explanation of the factors used to calculate the following Irrigation Schedules:

AWHC (Available Water Holding Capacity) - The amount of moisture a given soil can hold between field capacity and permanent wilting point.

Root Depth - The depth to which it is generally accepted that active roots of the crop in question grow. This factor greatly affects irrigation run time and frequency.

PAW (Plant Available Water) – This calculation is made by multiplying AWHC by the depth of the root zone in inches.

PAW = AWHC (inches per inch) X Root Depth (inches)

MAD (Maximum Allowable Depletion) - The percentage of available soil moisture that can be depleted before irrigating. Depending on crop characteristics, MAD is usually 30 - 50% of the Adjusted AWHC.

AD (Allowable Depletion) – This is calculated by multiplying PAW by MAD.

AD = PAW (inches) X MAD (percentage converted to decimal)

Emission Uniformity – Measurement of the ability of an irrigation system to deliver the same amount of water to each plant.

Shaded Area Factor – This factor is used to adjust slightly the irrigation requirements for crops based on the amount of soil surface shaded by the crop canopy.

Aspect Factor – This factor is used to adjust slightly the irrigation requirements for crops based on their exposure (i.e. southern, northern, etc…)

Application Rate – An average rate of a sprinkler flow in gallons per hour and/or inches per hour.

CIMIS Station – This indicates which CIMIS Station was used for creating the irrigation schedule.

Sprinkler Pattern Area – This factor is expressed in square feet and is very important for determining irrigation run time.

****NOTE** -- These schedules make no provisions for water conservation. They assume normal year water availability conditions. They are also based upon some numerical estimations as well as prior years' weather conditions. For more information on water conservation, irrigation scheduling or any information contained in this report, contact the Mission Resource Conservation District at (760) 728-1332.**

Glossary of Terms

Acre-Foot (Ac/Ft)

The amount of water needed to cover one acre (43,560 square feet), to a depth of one foot. This is equal to 325,829 gallons.

Available Water Holding Capacity (AWHC)

The available water holding capacity of a soil is the difference in the soil moisture level between field capacity and permanent wilting point. Field capacity is the maximum amount of water a well-drained soil can hold against gravity. Permanent wilting point is the soil moisture level at which the plant can no longer meet transpiration requirements; the plant wilts and does not recover when soil moisture is replenished. Available water holding capacity can be expressed as either inches of water per inch of soil, inches of water per foot of soil or total inches of water in the entire root zone.

The available water holding capacities of various San Diego County soils are listed below.

Soil Type	AWHC inches/inch
Sand	0.05 - 0.08
Loamy Sand	0.06 - 0.08
Coarse Sandy Loam	0.09 - 0.12
Sandy Loam	0.10 - 0.13
Fine Sandy Loam	0.13 - 0.15
Sandy Clay Loam	0.14 - 0.18
Clay Loam	0.17 - 0.21
Sandy Clay	0.13 - 0.17
Clay	0.14 - 0.16

Clay

As a soil separate, clay makes up the mineral soil particles that are less than 0.002 millimeters in diameter. As a soil textural class, it is a soil that is 40 percent or more clay, less than 45 percent sand and less than 40 percent silt.

Effective Rooting Depth

This is the maximum depth in inches, where the majority of a crop plant's roots reside. Shallow soils or restrictive soil layers can prevent crops from reaching their full effective rooting depth. The following is a chart of effective rooting depths of crops commonly grown in San Diego County:

Crop	Effective Rooting Depth
Avocado	24 Inches
Citrus	36 Inches
Deciduous	36 Inches
Flowers	6 - 24 Inches
Vegetables	6 - 24 Inches

Emission Uniformity (EU)

This is a measure of the ability of an irrigation system to deliver the same amount of water to each plant. EU is primarily a function of system design, construction, operation, and maintenance. There are several ways to calculate EU. The method used in this report is as follows:

$$EU = \left(\frac{Ave.OfTheLow1/4EmitterFlows}{AveEmitterFlow} \times \frac{Ave.OfTheLow1/4\,\mathrm{Pr}essure}{Ave\,\mathrm{Pr}essure} \right) x100$$

A high EU indicates that water is being evenly applied throughout a given area. A high EU is essential when fertilizer or chemicals are being injected into the water to assure that all plants receive the same amount. A poor EU makes management difficult because there can be gross over irrigation and gross under irrigation occurring simultaneously in different parts of the field.

Evapotranspiration (ET)

This is the amount of water that is transpired by vegetation plus that evaporated from the soil.

Maximum Allowable Deficiency (MAD)

This is the percentage of available soil moisture that can be depleted before irrigating. MAD is usually 30 - 50% of the Adjusted AWHC. The idea is to allow the crop to use 30 - 50% of the available soil moisture and then replace it. This wetting and drying cycle is essential for crop health.

Mesh

Mesh or mesh number refers to the number of openings in a filter screen per linear inch. This means, the larger the number, the smaller the opening in the screen. The following table contains common screens and their opening sizes:

Screen Size	Opening Size		
Mesh	**Inches**	**Millimeters**	**Microns**
20	0.02800.711	711	
40	0.01650.420	420	
80	0.00710.180	180	
100	0.00600.152	152	
120	0.00490.125	125	
150	0.00410.105	105	
180	0.00350.089	89	
200	0.00300.074	74	
270	0.00210.053	53	
325	0.00170.044	44	

Water should be filtered down to between one fifth (0.20) and one-tenth (0.10) of the smallest orifice dimension. **Example:** A micro-sprinkler has a nominal orifice size of 0.039". The amount of filtration for this sprinkler should be between 0.0078" (0.20 X 0.039") and 0.0039" (0.10 X 0.039"). Using the above chart, it can be seen that a screen with a mesh of between 80 and 180 would be required.

Nominal Flow Rate

This is the flow rate that has been predetermined at the factory where the sprinkler was manufactured. Sprinkler flows (generally at several different pressures) are determined under carefully controlled laboratory conditions. While the nominal flow rate of a sprinkler and other factory specifications can be used as a guide, they cannot be assumed to be absolutely correct. Measurements taken under field conditions (the way you usually irrigate) are essential to know the actual emission rate and other characteristics of a sprinkler.

Parent Material

This consists of Disintegrated and partly weathered rock from which soil has formed.

Sand

As a soil separate, sand consists of the individual rock or mineral fragments ranging from 0.05 to 2.0 millimeters in diameter. Most sand grains consist of quartz, but they may be of any mineral composition. Sand is the textural class name of any soil that is 85 percent or more sand and not more than 12 percent clay.

Silt

As s soil separate, silt consists of individual soil particles that range in diameter from the upper limit of clay (0.002 millimeters) to the lower limit of very fine sand (0.05 millimeters). Soil of the silt textural class is 80 percent or more silt and less than 12 percent clay.

Soil Texture

This is the relative proportion of sand, silt and clay particles in a mass of soil. The basic textural classes (in order of increasing amounts of fine particles) are as follows: *Sand, loamy sand, sandy loam, loam, silt loam, silt, sandy clay loam, clay loam, silty clay loam, sandy clay, silty clay, and clay.* The sand, loamy sand and sandy loam classes may be further divided by specifying *"coarse," "fine"* or *"very fine."*

Wetted Area

That portion of the planted area that is fully wetted during an irrigation. This means the area is wet down into the soil profile, not just on the surface. Most micro-sprinklers wet roughly 20 to 50 percent of the soil area in a mature crop planting. The size and shape of the wetted area can be adjusted according to plant growth.