VI. Know How Much Water Needs to be Pumped

Although the Agricultural Pumping Efficiency Program focuses on pumping for irrigation, the message of this component of the educational program can be applied to any pumping system. That is, know how much water needs to be pumped so that pumping operation is minimized. The obvious question is "How do I know how much water needs to be pumped?"

The focus of this section is on planning an individual irrigation. Each irrigation should have a purpose to put a specific amount of water into a specific volume of soil. Section VI provides methods that you can use to estimate how much water is required for the irrigation, which then leads to an estimate of how long to run the pump. The first part of this section introduces some basic concepts of irrigation science. The second part provides simple procedures for planning individual irrigations. The **Pumping Energy Calculator** that accompanies this book can be used to easily solve the equations in this section.

The Center for Irrigation Technology (managers of APEP) also maintains the WATERIGHT web site ***(www.wateright.org)***. This is a web site dedicated to irrigation water management for homeowners, large turf managers, or irrigated agriculture. Included in this site is the ability to develop seasonal irrigation schedules.

Introduction to Irrigation Science

Definition of Concepts and Terms

This section introduces some concepts and terms that can help you to plan an individual irrigation so that you have a target volume of water to be pumped and a target number of hours to pump. Among these concepts will be:

Application rate (AR) - equivalent depth of water applied to a given area per hour by the system, usually measured in inches/hour.

Daily crop water use (evapotranspiration) - this is the net amount of water extracted from the soil daily by the crop and surface evaporation from the soil.

Distribution uniformity (DU) - a measure of how evenly water is applied across the field during an irrigation.

Effective root zone - the depth of soil in which you are actively managing the crop.

Field capacity - the maximum amount of water the soil will hold.

Frequency - refers to how often you irrigate: high frequency vs. low frequency.

Irrigation efficiency (IE) - a measure of how much water that is pumped and applied to the field is beneficially used.

Net water needed versus gross water applied - net water is what you need to replace in the field. Gross water is how much you have to pump in order to accomplish this goal.

Soil moisture depletions (SMD) - the net amount of water that you need to replace in the root zone of the crop.

Soil probe - this is nothing more than a long piece of 3/8” steel bar, usually tipped by a ball bearing, with a handle (see diagram). The probe is pressed into wetted soil to judge how deep water has penetrated. It can be used during an irrigation to indicate when enough water has soaked into the ground. It can also be used to judge the uniformity of an irrigation. If 2-3 days after an irrigation the probe can be pushed into the soil to a depth of 4 feet at the top of a furrow, and only to 2 feet at the bottom of the same furrow, this is an indication of poor distribution uniformity.

Soil probe

Effective, Efficient Irrigations

Irrigation is both an art and a science. Research has provided many concepts and methods for measuring the various processes involved in irrigation. However, your knowledge of your field and crop, along with your experience in interpreting this science, will remain of utmost importance in achieving effective, efficient irrigations.

- **Effective irrigations produce the desired crop response.**
- **Efficient irrigations make the best use of available water.**

Irrigation efficiency does no good if it is not effective in producing a profitable crop.

Effective, efficient irrigations are a result of knowing ***when*** to irrigate, ***how much*** to irrigate, and ***how*** to irrigate.

- **When -** to irrigate is an agronomic decision based on how you want to manipulate your crop.
- **How much -** to irrigate is the ***soil moisture depletion*** in the effective root zone. This is the amount of water needed to take the soil moisture reservoir back to field capacity or other desired level.
- **How -** to irrigate is not just knowing how to set a siphon, or connect a sprinkler pump. It is also knowing how to apply water evenly to a field while controlling the total amount applied.

Effective, efficient irrigations produce a profitable crop while making the best use of available water supplies and creating a minimal impact on water quality. In doing so they also minimize energy use and save you money.

Distribution Uniformity versus Irrigation Efficiency

There are two measures of irrigation performance - distribution uniformity (DU) and irrigation efficiency (IE).

Distribution uniformity is a measure of how evenly water soaks into the ground across a field during the irrigation. If eight inches of water soaks into the ground in one part of the field and only four inches into another part of the field, that is poor distribution uniformity. Distribution uniformity is expressed as a percentage between 0 and 100%. Although 100% DU *(the same amount of water soaking in throughout the field)* is theoretically possible, it is virtually impossible to attain in actual practice.

Irrigation efficiency was defined by the American Society of Civil Engineers On-Farm Irrigation Committee in 1978. IE is the ratio of the volume of irrigation water which is beneficially used to the volume of irrigation water applied. Beneficial uses may include crop evapotranspiration, deep percolation needed for leaching for salt control, crop cooling, and as an aid in certain cultural operations. Differences in specific mathematical definitions of IE are due primarily to the physical boundaries of the measurement *(a farm, an irrigation district, an irrigation project, or a watershed)* and whether it is for an individual irrigation or an entire season.

Irrigation efficiency is also expressed as a percentage between 0 and 100%. An IE of 100% is not theoretically attainable due to immediate evaporation losses during irrigations. However, it could easily be close to 95% IE if a crop is under-watered. In this case, assuming no deep percolation, all water applied and not immediately evaporated would be used by the crop.

The term irrigation efficiency should not be confused with the term water use efficiency (WUE). WUE is generally a measure of yield per unit water applied.

Relationships Between DU and IE - There are two important relationships between DU and IE, described with the help of ***Figures VI.1 - VI.4.***

The figures are a profile view of two adjacent sprinklers in a field and the root zone under them. The horizontal, dashed line in the figures depicts the depth of the actual soil water depletion at irrigation. This is the amount of water that the grower would be trying to soak into the soil to satisfy crop water use requirements. The blue shading depicts the actual depth of water infiltrated during the irrigation.

Deep percolation is indicated whenever the actual depth of irrigation *(blue water level)* is below the soil water depletion line *(the horizontal, dashed line)*. Conversely, under-irrigation is indicated whenever the actual depth of irrigation is above the soil water deficit line.

Figures VI.1 and VI.2 demonstrate the first relationship:

> **There must be good distribution uniformity before there can be good irrigation efficiency if the crop is to be sufficiently watered.**

In ***Figure VI.1***, the farmer has irrigated to sufficiently water the entire field. The poor DU, indicated by the uneven blue water level, has resulted in excessive deep percolation. (Much more water infiltrated between the sprinklers than next to the sprinklers.)

IMPORTANT!

Leaching must be uniform across the field over a number of years to prevent areas of excessive salt accumulation.

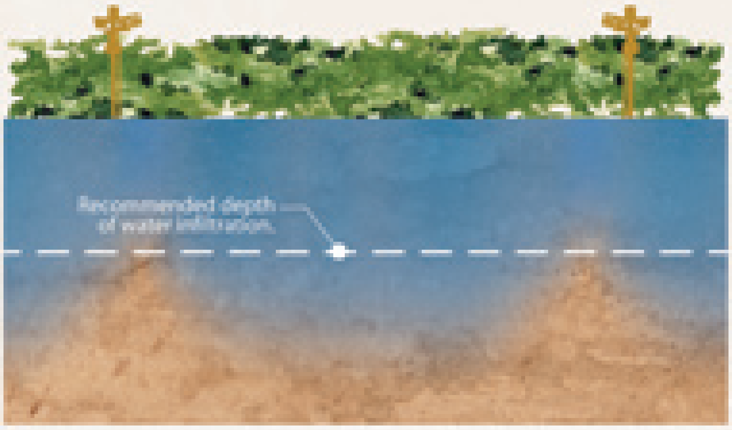

FIGURE VI.1 - *Depiction of irrigation resulting in poor distribution uniformity and excessive deep percolation.*

In ***Figure VI.2***, the farmer has acted to prevent excessive deep percolation by shortening set times. Now part of the field remains under-irrigated. Under-irrigation usually results in high irrigation efficiency because most water applied is stored in the root zone, available for plant use. However, under-irrigation is usually not an effective way of growing since the resulting water stress on the crop in some parts of the field will usually decrease yields. Also, there is a need for some deep percolation for leaching to maintain a salt balance.

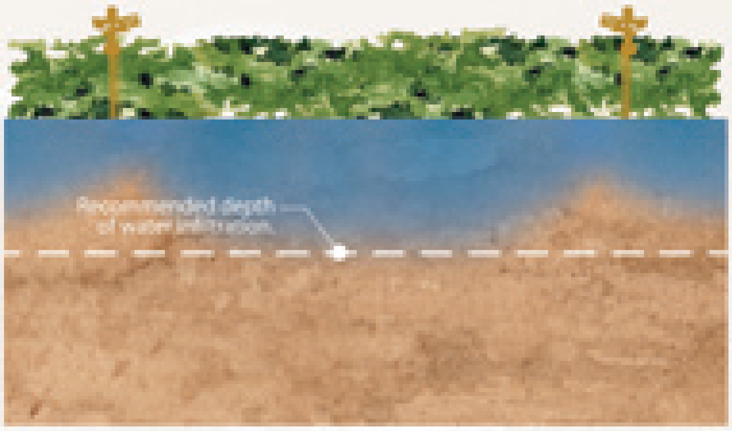

FIGURE VI.2 - *Depiction of irrigation resulting in poor distribution uniformity while under-watering the field.*

Figures VI.3 and VI.4 demonstrate the second relationship:

Good distribution uniformity is no guarantee of good irrigation efficiency.

Figure VI.3 depicts a good irrigation. There was a high DU as indicated by the flatter blue water level. Approximately the right amount of water was applied. There is little deep percolation (enough for salt control) and the entire field is wetted sufficiently. It is assumed that surface runoff was minimal or collected for reuse.

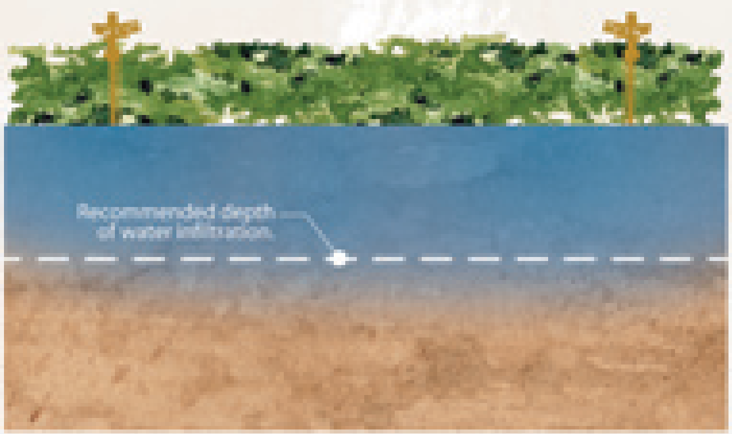

FIGURE VI.3 - *Depiction of an irrigation sufficiently watering the entire field with good uniformity and irrigation efficiency.*

Figure VI.4 depicts an irrigation with the same high DU as ***Figure VI.3***. However, twice as much water as needed was applied, resulting in low irrigation efficiency. A practical example of this situation is the farmer who is using a well-designed and maintained micro-irrigation system. The hardware provides good DU and the potential for high IE. However, if the farmer runs the system twice as long as necessary, that potential is not realized.

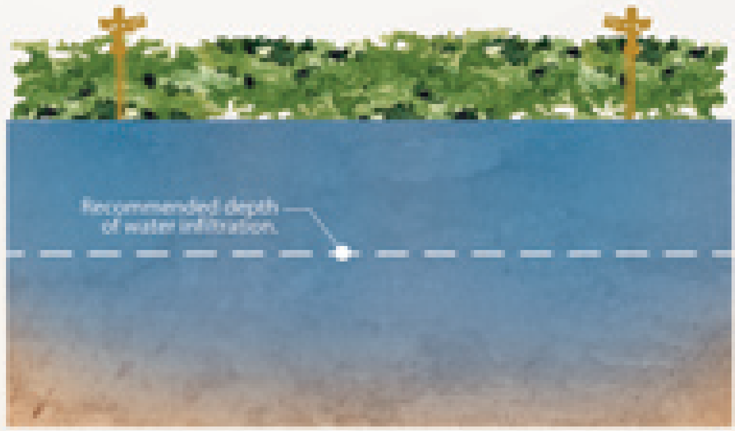

FIGURE VI.4 - *Depiction of irrigation with good uniformity but excessive deep percolation (a good irrigation system that was run twice as long as necessary).*

To summarize: Improved irrigation system hardware or management may result in higher distribution uniformity and improve the potential for higher irrigation efficiency. It then follows that distribution uniformity is the first concern when improving irrigation system performance. However, actually achieving high irrigation efficiency ultimately depends on two factors - knowing how much water is needed and controlling the amount of water applied to match that need.

Know (and Improve) the Distribution Uniformity of the Irrigation System

Remember that the first consideration for effective, efficient irrigations is distribution uniformity. DU can be improved by understanding the different aspects of DU for each system type, then working to improve these parts.

Furrow and border strip systems

You need to be concerned about:

1. **Down-row uniformity -** how evenly water infiltrates at the top and at the bottom of a furrow.
2. **Cross-row uniformity -** how evenly water infiltrates from row to row. Be especially aware of the different infiltration rates in rows compacted by tractor tires.
3. **Soil variability -** although there is usually very little that can be done to alleviate the effects of soil variability, be aware of different soil types within a field. Modify your irrigation management whenever possible to compensate for the different infiltration rates.

Generally, with border systems you would only be concerned with the down-row uniformity and soil variability issues.

Sprinkler systems

There are three main factors in uniformity:

1. **Pressure uniformity -** Check the pressure throughout the irrigation system. It should not vary more than 10-15% at the nozzles throughout the field. Also make sure the system is operating within the correct base pressure range (minimum to maximum.)
2. **Device uniformity -** Device uniformity means that each sprinkler is emitting the same amount of water. Assuming that the pressure uniformity is okay, check for worn or plugged nozzles and systems with more than one size nozzle or sprinkler head.
3. **Overlap uniformity -** Overlap uniformity is important with field sprinkler systems and depends on the correct choice of sprinkler spacing, pressure, and head/nozzle size. In many areas, wind is the major factor affecting overlap uniformities. Using alternate sets is always a good idea with field sprinkler systems. Also make sure that the risers are high enough so that the crop doesn't interfere with the stream. Overlap uniformity is not as important with undertree systems since the widespread rooting system of the orchards will compensate.

Micro-irrigation systems

You need to be concerned with pressure uniformity and device uniformity with micro-irrigation systems. Also with trickle systems make sure the filters are kept clean. Use chemical amendments on a regular basis to prevent algae and slime buildup. Keep the system flushed clean.

There should not be excessive surface runoff with sprinkle/trickle/spitter systems. If there is, either the set times are too long or the system was not designed properly. The soil/water chemistry interactions may also have changed. Check for required amendments.

Mobile Irrigation Laboratories

There may be a Mobile Irrigation Laboratory in your area. They can perform irrigation system evaluations. They will measure the distribution uniformity of your system and offer suggestions for improvement. A list of Labs in California and how to contact them is provided in the "Other Tools" section on page 2.30. Another important resource is your local University of California Cooperative Extension office.

Control the Total Irrigation Water Application

Remember, good hardware is only as good as its management. The most uniform drip irrigation system in the world is only 50% efficient if it is run twice as long as needed. Plan your irrigations and know how much water you are trying to apply. Measure water flows to know how much water has been applied and turn off the irrigation system when enough water has been applied.

Be aware of how much flexibility you have in the frequency, flow rate, and duration of your water supplies. Some irrigation districts deliver water in 24-hour increments. In some situations, investing in an on-farm reservoir may be profitable.

High Frequency versus Low Frequency Irrigation Systems

Frequency refers to *how often you irrigate.* High frequency irrigation systems are utilized every 1 to 3 or 4 days and are typically micro-irrigation systems. The intent is to maintain an optimum soil moisture condition, usually with a high uniformity and efficiency.

On the other hand, low frequency irrigation systems are utilized every 8 to as much as 20-30 days depending on the climate, crop, and soil. These are typically furrow, border strip, or field sprinkler systems.

Another important aspect of high versus low frequency systems is the amount of soil that is wetted. Flood irrigation systems and field sprinkler systems will wet the entire field. High frequency, micro-irrigation systems only wet part of the field.

The frequency of irrigation is important since the method of estimating how much water to apply at each irrigation is different for low versus high frequency systems.

With low frequency irrigation systems usually some method is used to estimate the soil moisture depletion (SMD) in the effective root zone. This is because the SMD is substantial due to the long interval between irrigations. Also, since the entire field is being wetted there is no question as to the extent of the wetted root zone.

However, with a high frequency system, it can be hard to judge the SMD when crop water use is on the order of at most .3 to .35 inches per day. A further complication is that not all of the field is being wetted so there is a question as to the extent of the actual root zone. Thus, with high frequency irrigation systems it is advisable to use estimates of the daily crop water use to plan irrigation system run times and some form of soil moisture monitoring system that tracks changes or trends over time.

Planning The Individual Irrigation

Planning a Furrow or Border Strip Irrigation

The following is a suggested way of planning a furrow, border strip, or any type of low frequency irrigation. Four important steps are:

1. Estimate the soil moisture depletion (SMD)(and required leaching if any) - this is the amount of water you want to put into the soil.
2. Pre-plan the irrigation - a simple equation can indicate how long you need to apply water at a given flow rate. This includes considering irrigation efficiency (the combination of distribution uniformity and losses).
3. React to the first irrigation set - it is often difficult to predict exactly what will happen during a furrow irrigation due to changes in climate, soil surface conditions, and soil moisture conditions.
4. React to the irrigation - check the field after the irrigation to see the actual depth and uniformity of water penetration. Compare the total amount of water pumped to your estimate of what was needed. Learn from any mistakes.

The following is a detailed discussion of these steps.

STEP 1: Estimate the SMD in the Effective Root Zone - Using a soil sampler and the moisture chart (***Table VI.1*** on page 2.25) is fast, flexible, and inexpensive. Using something like a neutron probe is expensive, less flexible (constrained to the sampling site), but more accurate (at the site - a question is whether the site is representative of the field). You also may want to compare your estimates to estimates of the total crop evapotranspiration (water use) since the last irrigation.

Dominant Texture →	Fine Sand and Loamy Fine Sand	Sandy Loam and Fine Loamy Sand	Sandy Clay Loam and Clay	Clay, Clay Loam or Silty Clay Loam
Available Water Capacity (in/foot) →	0.6 - 1.2	1.3 - 1.7	1.5 - 2.1	1.6 - 2.4
↓ Available Soil Moisture	Soil Moisture Deficit in inches per foot when the feel and appearance of the soil is as described.			
0% to 25%	Dry, will hold together if not disturbed. Loose sand grains on fingers. 1.2 - 0.7	Dry, forms a very weak ball. Aggregated soil grains break from ball. 1.7 - 1.1	Dry, soil aggregations break away easily, no moisture staining on fingers. 2.1 - 1.4	Dry, soil aggregations separate easily, hard clods crumble under pressure. 2.4 - 1.6
25% to 50%	Slightly moist, forms weak ball with well-defined finger marks. Light coating of loose and aggregated sand grains on fingers. 0.7 - 0.5	Slightly moist, forms a weak ball with defined finger marks, few aggregated soil grains break away. Darkened color, very light water staining. 1.1 - 0.8	Slightly moist, forms a weak ball with rough surfaces, darkened color, and moisture staining on fingers. 1.4 - 0.9	Slightly moist to moist, forms a weak ball. Very few soil aggregations break away, no water stains. Clods flatten under pressure. 1.6 - 1.1
50% to 75%	Moist, forms a weak ball. Loose and aggregated sand grains remain on fingers, darkened water staining. 0.5 - 0.2	Moist, forms a ball with very few aggregated soil grains breaking away. Light water staining, darkened color. 0.8 - 0.4	Moist, forms firm ball with well defined finger marks, irregular soil/water coating on fingers. Darkened color and pliable. 0.9 - 0.5	Moist, forms smooth ball with defined finger marks, little or no granules remain on fingers. Pliable, ribbons between thumb and forefinger. 1.1 - 0.6
75% to 100%	Wet, forms a weak ball, loose and aggregated sand grains form uneven coating on finger. 0.2 - 0.0	Wet, forms ball, free water appears on soil surface when squeezed or shaken. Irregular soil/water coating on fingers. 0.4 - 0.0	Wet, forms soft ball, light to heavy soil/water coating on fingers. Soil may glisten after squeezing or shaking. 0.5 - 0.0	Wet, forms soft ball, soil may glisten following squeezing or shaking. Light to heavy soil/water coating on fingers, easily ribbons. 0.6 - 0.0
Field Capacity (100%)	Wet, forms a weak ball. Free water glistens briefly on surface when shaken. Wet outline on hand after squeezing. 0.0	Wet, forms soft ball, free water appears briefly on soil surface when squeezed or shaken. Irregular soil/water coating on fingers. 0.0	Wet, forms soft soil pat with water glistening on surface after squeezing or shaking. Thick soil coating on fingers. 0.0	Wet, forms very soft soil pat. Thick soil/water coating on fingers. Soil glistens, slick and sticky, will not ribbon. 0.0

TABLE VI.1 - Estimating soil moisture depletion from the look and feel of a soil sample *(from USDA, NRCS Booklet "Estimating Soil Moisture by Feel and Appearance").*

STEP 2: Pre-plan the Irrigation - Use ***Equation VI.1*** to estimate how long the pump should run:

VI.1

$$\text{Hours} = \frac{\text{SMD x Acres x 452.2}}{\text{Pump Flow x IrrEff}}$$

Where:

SMD = soil moisture depletion in inches
Acres = area of field in acres
452.2 = a constant
Pump Flow = pump flow rate in gallons per minute
IrrEff = irrigation efficiency as a decimal (0 to 1.0)

It's important to understand that 0 to 1.0 IrrEff is equal to 0% to 100%. For example, .50 is equal to 50% and .75 is equal to 75%.

Example A:

Pump Flow = 1350 gpm
SMD = 4.0 inches
Acres = 147 acres
IrrEff = 75% (.75 as a decimal)

Hours = SMD x Acres x 452.2 / (Pump Flow x IrrEff)
= 4 x 147 x 452.2 / (1350 x .75)
= 263 hours = 10.9 days

This example demonstrates that if you are trying to apply 4 inches of water into the root zone at 75% irrigation efficiency with a pump flow of 1,350 gpm, you need to run the pump for about 11 days.

Use ***Equation VI.2*** to estimate the volume of water to pump:

VI.2

$$\text{Acre Feet} = \text{Hours x Pump Flow / 5432}$$

Where:

Acre-Feet = acre-feet needed for irrigation
Hours = hours of pumping
Pump Flow = pump flow rate in gpm
5432 = a constant

STEP 3: React to the First Irrigation Set - Assuming you estimated the SMD correctly and you know your pump's flow rate, the equation and the answer of 11 days from the previous example is only good if the irrigation efficiency is actually 75%. Use a soil probe to judge how fast water is soaking into the ground. Keep track of how long it is taking for water to reach the end of the furrow. Change the operating parameters (set time, flow per furrow) as needed. Using night irrigators can cost more money but this should be compared to potential water and energy savings.

STEP 4: React to the Irrigation - Use the soil probe 2 or 3 days after the irrigation to judge how far water penetrated at the top and bottom of the furrow. Judge crop response and water penetration to see how close your initial estimate of SMD was to actual. Compare the total amount of water delivered to the field (use a flow meter!) to your estimates of SMD and the pre-planning calculations.

Work Backwards as a Check on Performance - You can use ***Equation VI.1A*** to check on your actual irrigation efficiency, assuming that your estimate of SMD was correct. For example, assume the same situation as in Example A but without knowing the irrigation efficiency, and knowing that it took 15 days to complete the irrigation.

VI.1A

$$IrrEff = \frac{SMD \times Acres \times 452.2}{Pump\ Flow \times Hours}$$

Where:

SMD	=	soil moisture depletion in inches
Acres	=	area of field in acres
452.2	=	a constant
Pump Flow	=	pump flow rate in gallons per minute
IrrEff	=	irrigation efficiency as a decimal (0 to 1.0)

Example B:

Pump Flow	=	1350 gpm
SMD	=	4.0 inches
Acres	=	147 acres
Hours	=	360 (24 hrs/day x 15 days)

IrrEff = SMD x Acres x 452.2 (Pump Flow x Hours)
= 4 x 147 x 452.2 / (1350 x 360)
= .55 = 55%

The question with this example is whether or not 55% is an acceptable irrigation efficiency.

Planning a Sprinkler Irrigation

The same process as outlined in the previous section can be used for sprinkler systems. However, there is an alternative equation to use if you know the application rate of the system.

Application Rate (AR) - equivalent depth of water applied to a given area per hour by the system, usually measured in inches/hour. Thus, if an application rate is .2 inches/hour that means that every hour that the system is run is equivalent to a .2 inch rainfall.

Five basic steps (with a little different mathematics) are used to pre-plan a sprinkler or drip irrigation.

1. Estimate the soil moisture depletion in the effective root zone.
2. Know the application rate of the irrigation system.
3. Pre-plan the irrigation.
4. React to the first set.
5. React to the irrigation.

STEP 1: Estimate the SMD in the Effective Root Zone - Estimate the soil moisture depletion in the same manner as for furrows (refer to the discussion on page 2.24).

STEP 2: Know the Application Rate of the Irrigation System - Refer to ***Table VI.2***. Each combination of nozzle size, sprinkler spacing, and system pressure produces a distinct application rate. For example, a 7/64" nozzle running at 55 psi on a 30 x 40 spacing has an application rate of about .2 inches/hour. This means that every hour you run the system is just like a .2 inch rainfall on the field.

If your system combination is not in ***Table VI.2*** or you wish to determine your system's AR exactly, use the following equation.

VI.3 **AppRate = GPMn x 96.3 / Area**

Where: AppRate = the application rate of the system in inches/hour
GPMn = the flow through the sprinkler nozzle in gallons per minute
96.3 = a constant
Area = the system spacing, lateral move times length of each lateral (feet)

For example, if you had a 30-foot sprinkler lateral with a lateral move of 45 feet, and the flow through each nozzle was measured at 2.8 gpm, then:

Example C:

AppRate = GPMn x 96.3 / Area
= 2.8 x 96.3 / (30 x 45)
= .20 inches/hour

Approximate Water Application Rates (inches/hour)

Sprinkler Spacing (ft)	Nozzle Diameter (in)					
	3/32	7/64	1/8	9/64	5/32	11/64
30 x 30	.19	.27	.34	.44	.54	.65
30 x 40	.14	.20	.26	.33	.41	.49
30 x 45	.13	.18	.23	.29	.36	.43
35 x 40	.12	.17	.22	.28	.35	.42
35 x 45	.11	.15	.20	.25	.31	.37
40 x 40	.11	.15	.19	.25	.31	.37
40 x 45	.10	.13	.17	.22	.27	.32

*Assumes standard smooth-bore nozzle in good condition at normal operating pressures.

***TABLE VI.2 -** Approximate water application rates in inches/hour for varying nozzle diameters and sprinkler spacings.*

STEP 3: Pre-Plan the Irrigation - Use the following equation to estimate how long the pump should run:

VI.4 $$\text{Hours} = \frac{\text{Sets x SMD}}{\text{AppRate x IrrEff}}$$

Where:

Hours	=	required hours of pumping
Sets	=	number of lateral moves
SMD	=	soil moisture depletion
AppRate	=	application rate of system in hours
IrrEff	=	irrigation efficiency as a decimal (0 to 1.0)

STEP 4: React to the First Set - There should be no runoff with a sprinkler irrigation system if it is properly designed and operated. Also note excessive wind conditions or poor pressure uniformity that may decrease the estimated irrigation efficiency.

STEP 5: React to the Irrigation - Finally, react to the irrigation as a whole. Use the soil probe 2 or 3 days after the irrigation to judge how far water penetrated in different areas within the sprinkler patterns, and in different parts of the field. Judge crop response and water penetration to see how close your initial estimate of SMD was to actual. Compare the total amount of water delivered to the field (use a flow meter) to your estimates of SMD and the pre-planning calculations.

Planning a Micro-Irrigation

As previously noted, a micro-irrigation system is generally a high frequency irrigation system. Further, they generally do not wet all of the soil. For high frequency irrigations such as with drip, spray, fogger, or mini-sprinkler systems, it is best to base irrigations on daily crop water use in combination with a soil- or plant-moisture monitoring system that tracks changes or trends over time.

One method of planning micro-irrigations involves the following three steps:

1. Develop a seasonal (or possibly only monthly or weekly) first-cut irrigation schedule based on normal crop water use.
2. Maintain a reliable and regular system of monitoring soil and/or plant moisture conditions.
3. React to changes in the trends of these conditions.

STEP 1: Develop a First-Cut Schedule of Operating Hours - To develop the first-cut schedule of operating hours use this equation:

VI.5 $$\text{Hours} = \frac{\text{Sets x ETc x Area}}{\text{GPH x IrrEff x 1.605}}$$

Where:

Hours	=	required hours of pumping
Sets	=	number of irrigation sets (blocks) in the drip system
ETc	=	crop water use between irrigation (inches)
Area	=	planted area per tree or vine (sq. ft.)
GPH	=	gallons per hour per tree or vine
IrrEff	=	overall irrigation efficiency (0 to 1.0)
1.605	=	a constant

STEP 2: Maintain a Reliable, Regular System of Monitoring Soil and/or Plant Moisture Conditions - Micro-irrigation systems are sometimes referred to as subtle systems (meaning that by the time problems appear visually, much damage may have already been done). It is imperative that some type of soil and/or plant moisture monitoring be done. Commonly used methods include granular-matrix blocks, gypsum blocks, pressure chambers, TDR or FDR electronic sensors, and tensiometers.

STEP 3: Graph the Measurements and Note Any Trends - For example, if you see that the trend in soil moisture is up or down, instead of relatively steady (and at the moisture content you want) then possibly your estimate of crop water use is wrong, or there is a problem with the irrigation system.

Row Crop Drip Systems - Because of the terminology used to describe drip tape systems you would use the following ***Equation VI.6*** instead of ***Equation VI.5***.

VI.6

$$\text{Hours} = \frac{\text{Sets} \times \text{ETc} \times \text{Spacing}}{\text{GPM100} \times \text{IrrEff} \times 11.55}$$

Where:

Hours	=	required hours of pumping
Sets	=	number of irrigation sets
ETc	=	net crop water use between irrigations (inches)
GPM100	=	gallons per minute per 100' of tape
IrrEff	=	overall irrigation efficiency (0 to 1.0)
11.55	=	a constant

Other Tools

The Pumping Energy Calculator

The Pumping Energy Calculator (***Figure VI.5***) is available from the Program and accompanies this book. This simple-to-use device can calculate the gross depth of water required, dollars per hour or dollars per acre-foot pumping costs, and the number of required pumping hours per irrigation for the major types of irrigation systems. Contact one of the Program offices to obtain one. This calculator will help solve ***Equations VI.1-VI.6*** presented in this book.

***FIGURE VI.5 -** The Pumping Energy Calculator.*

WATERIGHT for Seasonal Irrigation Scheduling

The Pumping Energy Calculator can be used to estimate the number of pumping hours required for individual irrigations. An important piece of required information is the gross depth of water to apply. It is always best to use one of many available methods for checking soil moisture depletions to directly measure this at the time of irrigation. However, seasonal irrigation scheduling can help you anticipate irrigations and provide a check on the estimates for net water required.

The **WATERIGHT** web site ***(www.wateright.org)*** will help you to develop a normal, seasonal irrigation schedule for either low frequency or high frequency systems. This site is dedicated to improved water management. There is a link to the **WATERIGHT** site from the Agricultural Pumping Efficiency Program's web site, ***www.pumpefficiency.org***.

WATERIGHT also contains information on how you might be able to improve your irrigation system's performance.

Mobile Labs

Mobile Irrigation Laboratories evaluate irrigation system performance. They measure such things as water application rates and system distribution uniformity. If necessary, they give recommendations for system improvement. Mobile labs can be an important part of managing water resources.

Mobile Labs:

- Santa Barbara County - (805) 928-9269, ext.5
- Riverside County
  – East County/High Desert - (760) 347-7658
  – West County - (909) 683-7691 www.rcrcd.com
  – South East County - (909) 654-7733
- North San Diego County - (760) 728-1332
  www.tfb.com/~missnrcd/
- Fresno/Tulare County - (559) 237-5567 www.krcd.org
- Kern County - (661) 861-4129 www.pswrcd.ca.nacdnet.org
- Santa Clara Valley Water District - (408) 265-2607
- Tehama County RCD - (530) 527-3013, ext. 119
- Lava Beds-Butte Valley RCD - (530) 667-3473
- Yolo/Colusa County - (530) 662-2037, ext 5
  www.yolorcd.org

Additional Mobile Lab information can be found at:
www.pumpefficiency.org/mobilelabs