Agriculture Drip Irrigation Scheduling Calculator Users Guide

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Irrigation Industry Association of British Columbia (IIABC)

Editors

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www.irrigationbc.com

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Agricultural Drip Irrigation Scheduling Calculator User's Guide

Information from the B.C. Trickle Irrigation Manual and the Irrigation Management Guide produced by the **Irrigation Industry Association of British Columbia** has been used as a guide in the preparation of this document. The Irrigation Scheduling Calculator was developed solely by the Ministry of Agriculture and Lands and the Irrigation Industry Association of British Columbia with funding from the Canada British Columbia Water Supply Expansion Program.

INTRODUCTION

The Irrigation Scheduling Calculator found at **www.irrigationbc.com** has been developed specifically for use in British Columbia although other regions can use the calculator by entering their own Reference Evapotranspiration (ETo) data. This guide provides background information on the parameters and calculations used for sprinkler systems in the Agricultural Irrigation Scheduling Calculator. While there is on line help available on the calculator often not enough detail is provided to make a good determination on which value to use.

Irrigation systems should be designed and operated to supply the crop water requirement while minimizing runoff and leaching. To ensure peak irrigation system performance the system design should take into account evapotranspiration, crop coefficients, soil type and irrigation system efficiencies. High frequency irrigation leads to increased surface evaporation and usually a higher rate of transpiration by the crop. The Agricultural Irrigation Scheduling Calculator minimizes the frequency of irrigation but maximizes duration of application that is allowed by the soil and crop. It is better to have an irrigation schedule where irrigation occurs less frequently but fully utilizes water stored in the crops' root zone.

The Agricultural Irrigation Scheduling Calculator assumes that the irrigation system has been properly designed to match the location, soil type and crop water requirements and maintained in good operating condition. It is recommended that a Certified Irrigation Designer be used to design an irrigation system.

The calculator takes the following information into account in the development of an irrigation schedule:

- How much water the crop requires.
- How much water can be stored in the soil that is readily available to the plant?
- The amount of effective rainfall that is useable by the plant.
- How much water the irrigation system needs to apply to make up the moisture deficit that has occurred.

This User's Guide provides direction on the calculations that are made by the calculator and how to select the information that populates the entry boxes in the calculator. There are four sections in the calculator that must be completed in order for a schedule to be developed. These are:

- Crop Type
- Soil Cross-section
- Irrigation System Design
- Irrigation Scheduling

To navigate from step to step click the next button on the lower right side of the screen.

To begin using the irrigation calculator, open the website **www.irrigationbc.com** Scroll down to the irrigation calculators. Click on the Agricultural Calculator icon.

Figure 1- Irrigation Calculators

The sign-in page will appear. Follow the instructions on the page if creating a new account. See Figure 2.

Enter your username and password, then click **Login!**

Figure 2 - Login

The opening page will appear. See Figure 3. You will need to select a field you have already entered or create a new one by clicking on **New Field**.

Figure 3 - New Field

Now select the irrigation system you entered earlier. See Figure 4. Then click complete worksheets. You can create another system by clicking on **New System**

Figure 4 - New System
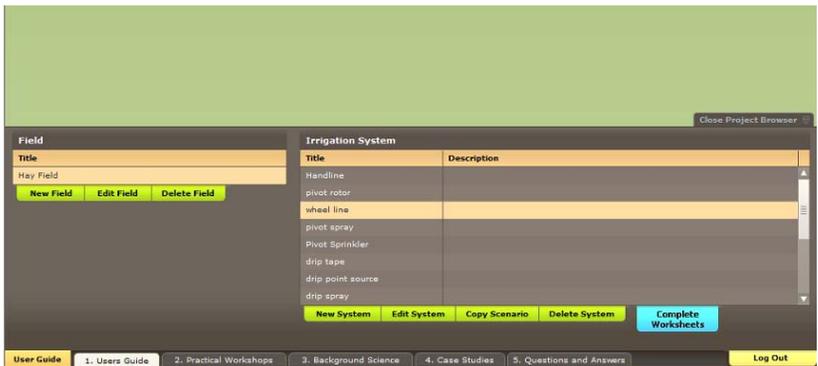
1.1   CROP TYPE

The crop tab allows the type of crop that is to be grown to be selected. The plant and row spacing also needs to be entered. Once this is done a number of default values will be displayed.

Figure 5 - Crop Type Tab

Crop

Select the crop type by clicking the drop down menu.

Plant Spacing

The plant spacing is the distance between each plant in the row. This is important for determining the area that is utilized by each plant. The default measurement is in feet but by clicking the drop down menu metres can be selected. This feature will be found throughout the calculator.

Row Spacing

The row spacing is the distance between each planted row. This distance is also used in calculating the area for each plant.

Effective Rooting Depth of Mature Crops

The crop's effective **rooting depth (RD)** is the soil depth from which the crop extracts most of its water needs. It is determined by digging a soil pit to observe the actual rooting depth or using plant rooting depth information from other sources. A deeper rooting depth creates a larger reservoir of water for the plant to draw upon between irrigation. The calculator provides an estimate of the crop rooting depth automatically. The depth selected by the calculator can be altered if the plant is not mature or if there is a soil depth restriction that limits the crop rooting depth by clicking on the override defaults tab.
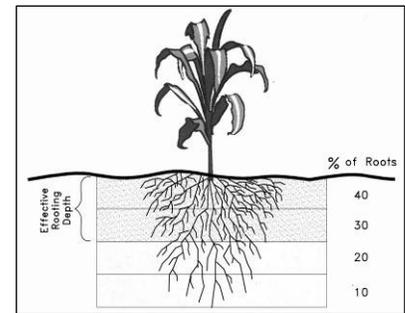
Figure 6 - Rooting Depth

Availability Coefficient

Plants can only extract a portion of the water stored in the soil without being stressed. The **availability coefficient (AC)** is used to determine the portion of water stored in the soil that is readily available to the plant. The availability coefficient is expressed as a percentage and is used to calculate the Maximum Soil Water Deficit (MSWD) in the soil cross – section tab. The MSWD is the maximum amount of water that may be removed from the soil before irrigation is again required. The calculator selects a default AC automatically as shown in Table 1. This value can be changed by clicking on the override defaults tab.

Rooting Depth (RD) and Availability Coefficient (AC)							
Crop	**RD**		**AC**	**Crop**	**RD**		**AC**
	[ft]	**[m]**			**[ft]**	**[m]**	
Alfalfa	4	1.2	0.55	Hops	4	1.2	0.50
Almonds	4	1.2	0.40	Kiwifruit	3	0.9	0.35
Asparagus	4	1.2	0.45	Lettuce	1 1/2	0.45	0.30
Beans, green	2	0.6	0.45	Loganberries	4	1.2	0.50
Beets	2	0.6	0.50	Onions, green	1 1/2	0.45	0.30
Blackberries	4	1.2	0.50	Pasture species	1 1/2	0.45	0.50
Blueberries	2	0.6	0.50	Peas	2	0.6	0.35
Broccoli	2	0.6	0.45	Peppers, sweet	3	0.9	0.30
Brussel Sprouts	3	0.9	0.45	Potato	2	0.6	0.35
Cabbage	1 1/2	0.45	0.45	Pumpkin	4	1.2	0.35
Cantaloupe	4	1.2	0.45	Radishes	1 1/2	0.45	0.30
Carrots	2	0.6	0.35	Raspberries	4	1.2	0.50
Cauliflower	1 1/2	0.45	0.45	Spinach	2	0.6	0.20
Celery	2	0.6	0.20	Squash	3	0.9	0.50
Cereals	3	0.9	0.50	Strawberries	2	0.6	0.20
Clover (ladino)	1 1/2	0.45	0.50	Sugar Beets	4	1.2	0.55
Clover (red)	3	0.9	0.50	Tomato	2	0.6	0.40
Corn, field	4	1.2	0.50	Tree fruits (12 ft x 18 ft)	4	1.2	0.40
Corn, sweet	3	0.9	0.50	Tree fruits (3 ft x 10 ft)	2	0.6	0.40
Cucumber	1 1/2	0.45	0.50	Tree fruits (6 ft x 12 ft)	3	0.9	0.40
Eggplant	3	0.9	0.45	Turf	1/2	0.15	0.50
Garlic	1 1/2	0.45	0.30	Turnip	1 1/2	0.45	0.50
Grapes	4	1.2	0.40				

Table 1 - Rooting Depth and Availability Coefficient

Crop Coefficient

The crop coefficient takes into account the area of the field that does not need to be irrigated by the drip emitter. Depending on the plant and row spacing a factor is applied to account for this. The calculator provides a default crop coefficient value. Generally crop canopies that cover less of the land base will have lower crop coefficients.

This value can be adjusted by the user but care should be taken that the value used is appropriate.

Climate Coefficients by Month

Each type of crop selected has a different consumptive rate for water. As the crop grows it draws water from the soil depending at what stage of growth it is at. Each crop will have a unique climate coefficient curve. Figure 7 shows a climate coefficient curve for apples.

The calculator provides an average climate coefficient for each month. In reality coefficients in the early part of the season could be quite a bit lower. The user can adjust the climate coefficient manually if required.
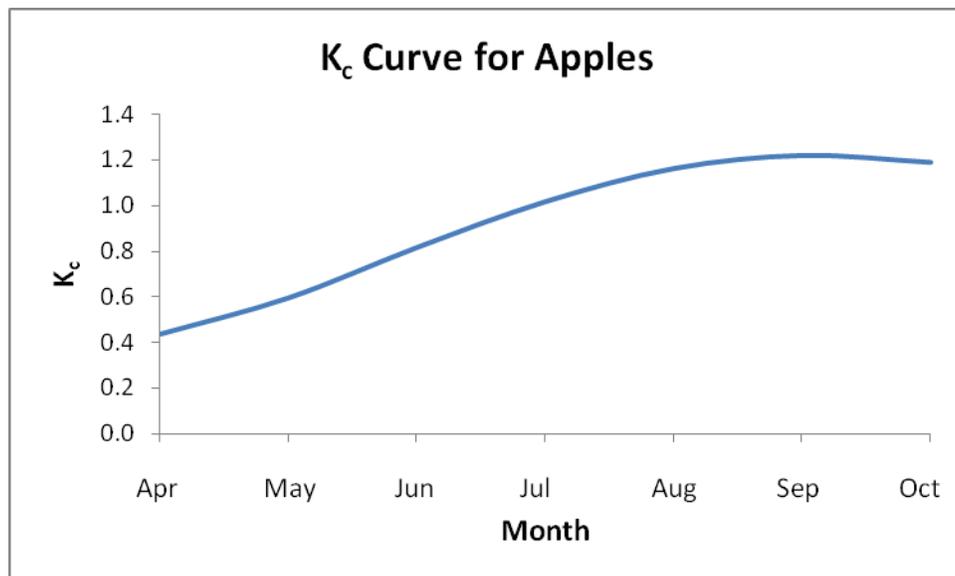
Figure 7 – Climate Coefficient for Apples

1.2   SOIL CROSS SECTION

Knowledge about the soil is important to ensure that water is applied when required by the crop. Also the application rate and irrigation interval are affected by the soil. The basic soil information required and calculated in the calculator is described below. The Soil Texture by Depth tab is where the soil type and depth is entered. The calculator selects the parameters described below.

Soil Texture and Structure

Soil texture is a term used to describe the size of individual soil particles such as sand, silt, or clay. Soil texture class is a name given to a soil to describe the relative amounts of sand, silt, or clay in that particular soil. The class name may be sandy loam, loamy clay, silty clay loam, etc. See figure below. Soil texture has a major influence on the amount of water that can be stored in the soil against the pull of gravity. It also has a major influence on soil infiltration rate and the permeability of a soil; these terms are described in more detail later in this section.
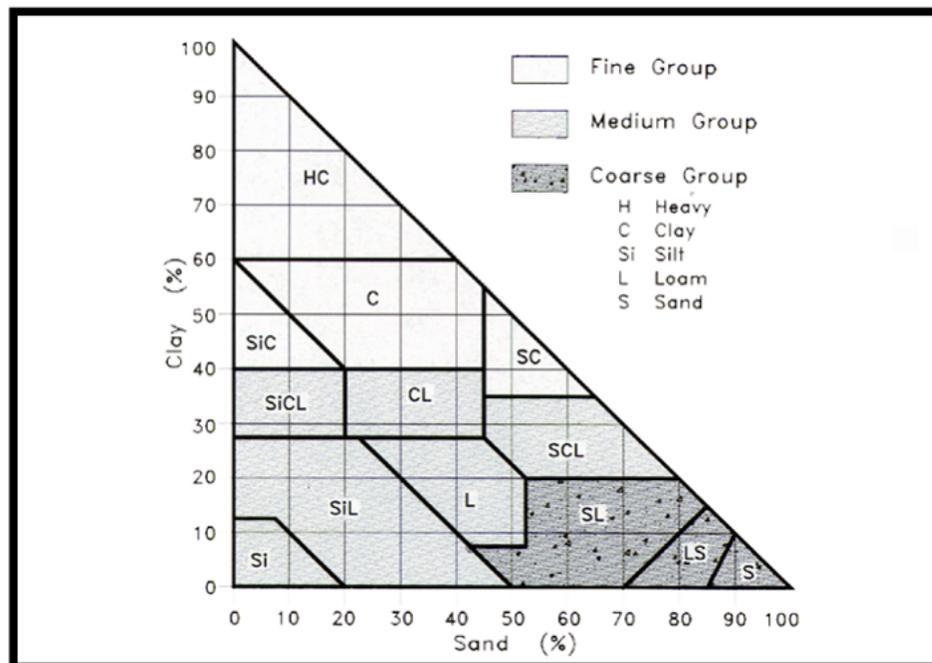
Figure 8 - Soil Textural Triangle

Soil structure is the arrangement of soil particles and soil aggregates into recognizable particles or lumps. Aggregates occur in almost all soils, but their strength, size and shape varies between soil types. Soil structure can be described in many ways such as; granular, blocky, crumb, platy, massive or granular. The structure also influences the amount soil water holding capacity and the infiltration rate. Soil with poor structure at the surface will not allow water to infiltrate easily.
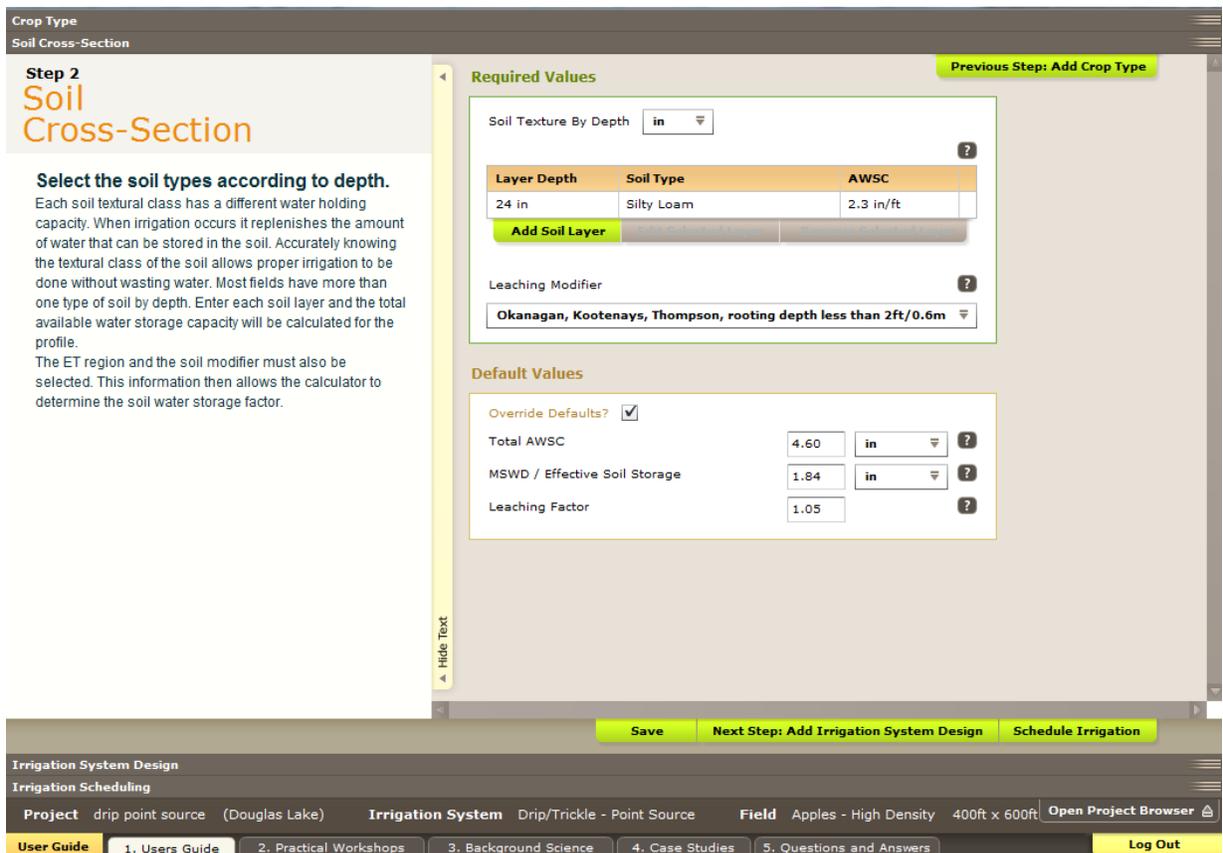
Figure 9 - Soil Cross – Section Tab

Add Soil Layer

The soil cross section tab in the calculator allows a user to **add soil layer** by using the drop down table or the soil texture triangle. Once a soil type is selected a soil layer **depth** must be added in inches. The total depth of the soil must be greater than the rooting depth that was selected in the previous tab. The first soil depth can be less than the rooting depth if a second rooting depth is added. The total depth of the two or more soil types should be greater than the plant rooting depth.
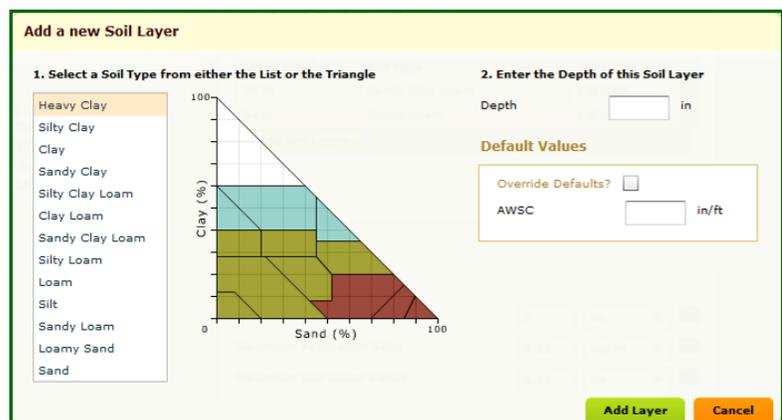
Figure 10 - Soil Triangle Tool

When the soil layer has been added the calculator will select and calculate a number of soil

parameters using the information shown in table below. The soil's **Available Water Storage Capacity** (**AWSC**) is the amount of moisture the soil can store between field capacity and the permanent wilting point. The AWSC is related to the soil texture and the soil structure.

SOIL PROPERTIES					
SOIL TEXTURE CLASS	AWSC (in. water/ in. soil)	AWSC (in. water/ ft. soil)	AWSC (mm water/ m soil)	INFILTRATION RATE	
				(in/hr)	(mm/hr)
Clay	0.20	2.4	200	0.25	6.3
Silt loam	0.21	2.5	208	0.35	8.9
Clay loam	0.20	2.4	200	0.30	7.6
Loam	0.18	2.1	175	0.35	8.9
Fine sandy loam	0.14	1.7	142	0.40	10.1
Sandy loam	0.12	1.5	125	0.45	11.4
Loamy sand	0.10	1.2	100	0.65	16.5
Sand	0.08	1.0	83	0.75	19

Table 2 - Soil Properties

Although all the values are shown as defaults only the Available Water Storage Capacity should be adjusted by the user if better information is available.

Leaching Modifier

Drip irrigation systems have a tendency to deposit salts in the soil as the water is evaporated or used by the plant. To help prevent this, a leaching factor is added to the amount of water to be applied by the drip system to push the salts out of the root zone. This is a greater problem in drier regions. To add the leaching factor click the drop down menu and pick the leaching factor according to your crop and location.

Total Available Water Storage Capacity

The Total AWSC as shown in the calculator is determined from the Available Water Storage Capacity (AWSC) and the plant's active rooting depth (RD). Knowing the soil water storage allows the calculator to determine how much water to apply at one time and how long to wait between irrigations. For example, the amount of water applied at one time on a sandy soil, which has a low soil AWSC, would be less than for a loam soil, which has a higher AWSC. This is assuming the plant's rooting depth is the same for both soils. Applying more water to the soil than can be stored results in a loss of water to deep percolation and leaching of nutrients beyond the root zone.

Maximum Soil Water Deficit / Effective Soil Storage

The **Maximum soil water deficit (MSWD)** is the amount of water that can be stored in the soil that is readily available to the plant. It is the maximum amount of water that should be removed from the soil before irrigation is again required. The MSWD is also the maximum amount of water that can be applied at one time before the risk of deep percolation occurs. It is calculated by multiplying the Total AWSC by the Availability Coefficient.

To encourage deep root growth for plants, a sprinkler irrigation system should be operated as infrequently as possible, irrigating just long enough to fill the soil water storage to full capacity. The maximum amount that can be applied will be equal to the MSWD, providing that the soil moisture level had dropped this amount prior to irrigation.
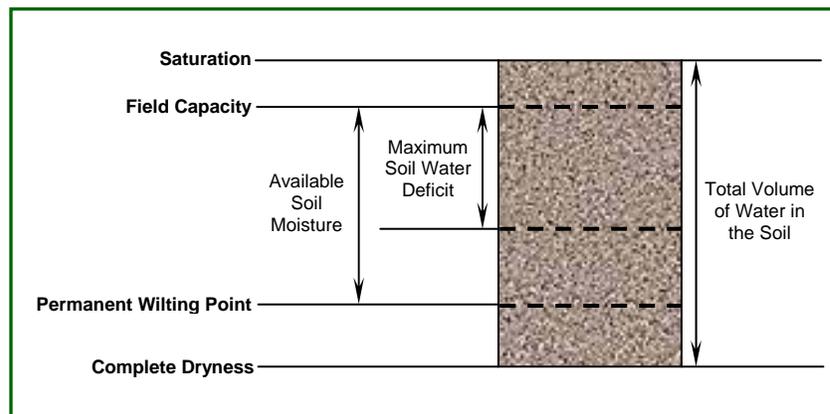

Figure 11 - Soil Water Moisture Terminology

Leaching Factor

The leaching factor is determined from the leaching modifier selected above. If the leaching factor is greater than one it will add additional water to the irrigation requirement to help flush the salts out of the crop root zone.

1.3 IRRIGATION SYSTEM DESIGN

The Irrigation System Design tab allows for the entry of irrigation design and operation parameters. The basic information that must be entered is the emitters per plant, emitter flow rate, irrigation interval and system run time.
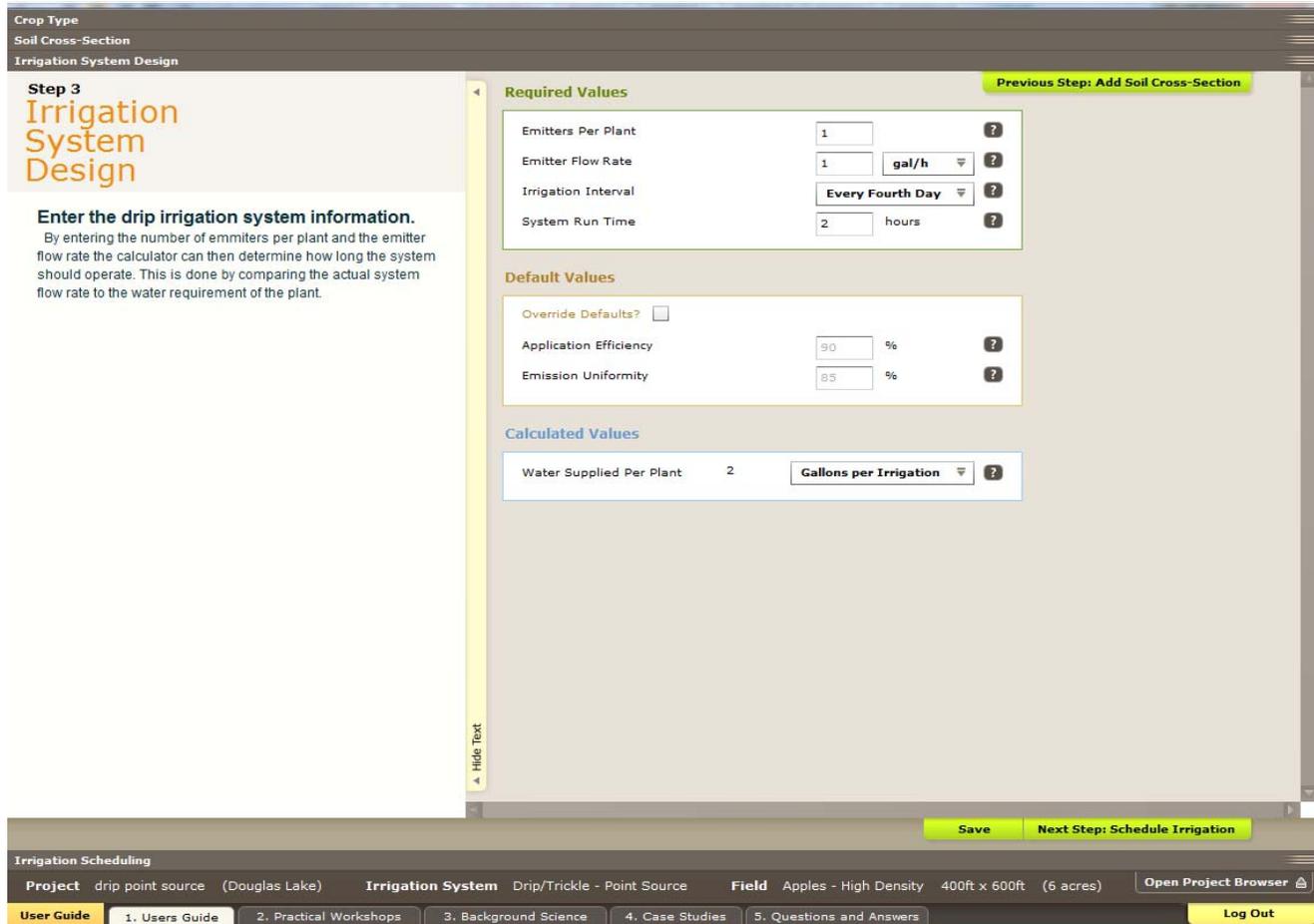
Figure 12 - Irrigation System Design

It is very important that accurate data is entered in to the calculator. The entered data will be used to calculate the amount of water that enters the soil. The calculator also offers the option of using metric numbers. By clicking the drop down menu where available meters or feet can be selected.

If the product being used is **Drip/Trickle Linear Tape,** the calculator will require slightly different irrigation system parameters to be entered. Instead of Emitters per plant and emitter flow rate the linear tape flow rate needs to be entered.

Emitters per Plant

If you are using the drip point source or spray emitters then enter the number of **emitters per plant.** The emitters per plant are used to determine the amount of water applied to the plant.

Emitter Flow Rate

If you are using the drip point source or spray then enter the **emitter flow rate.** It is the flow rate per hour of the emission device. It is often stamped on the side of the emitter in gallons per hour or litres per hour.

Linear Tape Flow Rate

If using the **Drip/Trickle Linear Tape** calculator the l**inear tape flow rate** needs to be entered. This flow rate is supplied by the manufacturer and is listed per a specific length of tubing.

Irrigation Interval

The **irrigation interval** is the time between irrigations. Four choices are offered when the drop down menu is selected. Since drip systems are operated very frequently it is not often that more than a four day interval is selected. The calculator can evaluate one irrigation by selecting an appropriate start and end date that allows for only irrigation to take place.

System Run Time

The **system run time** is the length of time the zone will operate during the irrigation interval selected. Note that the calculator can only evaluate one zone at a time unless the zones are identical.

Application Efficiency

Not all the water that leaves the emitter enters the soil profile and is available to the plant. Evaporation, wind and runoff account for a proportion of this water. When taken into account they determine the **Application Efficiency (AE)** of the irrigation system. The default application efficiency for the irrigation system type will be automatically entered. This number can be altered but should only be done by a knowledgeable irrigation designer.

Emission Uniformity

The intent is design and install an irrigation system that delivers the same amount of water over the entire zone. In reality variance in emitter production that changes the orifice size and therefore the flow rate, changes in pressure due to elevation and friction and water temperature variation along the lateral line will effect the irrigation system emission uniformity. The design of a drip system should take all of these into account with an emission uniformity targeted by the designer. The minimum emission uniformity (EU) should not be less than 80% with a preferred EU of 90 – 95%.

Water supplied per plant

The **water supplied per plant** is calculated from the emitter flow rate, runtime and the number of emitters per plant. This number is the gross water applied per plant.

1.4 IRRIGATION SCHEDULING

When the crop, soil and irrigation system information has been entered into the calculator, an irrigation schedule can now be determined. The calculator will retrieve Evapotranspiration data from a weather station of your choice. The calculator operates in real time so the climate date generated by the calculator will be the current date with an estimated forecast of the next five days. Climate data for the calculator is obtained from **www.Farmwest.com**

Evapotranspiration (ET) is the term used to describe plant water use and is a measurement of the total amount of water evaporated from the soil and plant surfaces plus the amount of water transpired by the plant. Factors such as temperature, wind, solar radiation and latitude all determine the ET rate. ET can be obtained from various sources. The data is collected daily but can be summarized for any time period.

Note: If accessing the calculator in the morning the climate data for the current date may not have been posted to the Farmwest web site yet. Climate data gets posted in the early afternoon of each day. For best results the calculator should be used in the evening to determine a schedule for the next few days.

Figure 13 - Irrigation System Scheduling Tab Inputs

Closest Weather Station

Figure 14 - Closest Weather Station

The **Closest Weather Station** will default to the station selected when the field was entered in the calculator. This can be changed if the station data is missing or another station better represents the climatic conditions at the field. If you have your own data that is not connected through Farmwest.com then **Custom Values** can be entered. This is explained in greater detail at the end of the user's guide.

Schedule Start Day
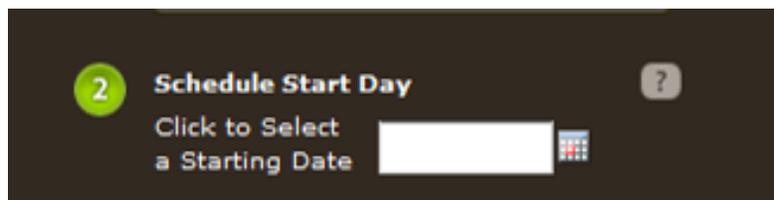
Figure 15 - Schedule Start Day

The **schedule start day** refers to the starting date for this irrigation cycle not the beginning of the season. When the irrigation system was designed and installed it should have had an irrigation schedule supplied. This supplied schedule would have been based on a Peak ET rate for the hottest time of the year. This calculator determines an irrigation schedule for times of the year when ET conditions are not at peak conditions. For best results the calculator should be used after the field has been irrigated and prior to the next irrigation. For drip systems the irrigation interval may remain the same but the operating time for each zone may be reduced during non peak conditions.

Explore Historical Weather Data
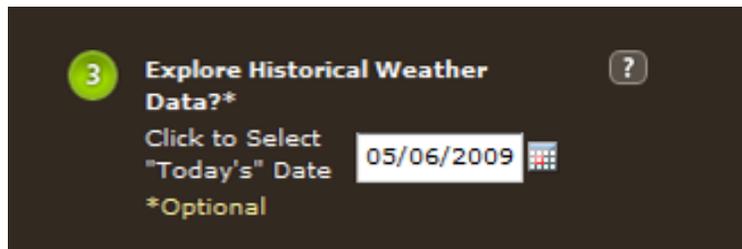
Figure 16 - Explore Historical Weather Data

The **Explore Historical Weather Data** calendar allows the user to look at past climatic records and compare to the irrigation practice that was done. When explore historical data is selected the field irrigation started on date needs to be earlier.

Effective Precipitation & Daily ET
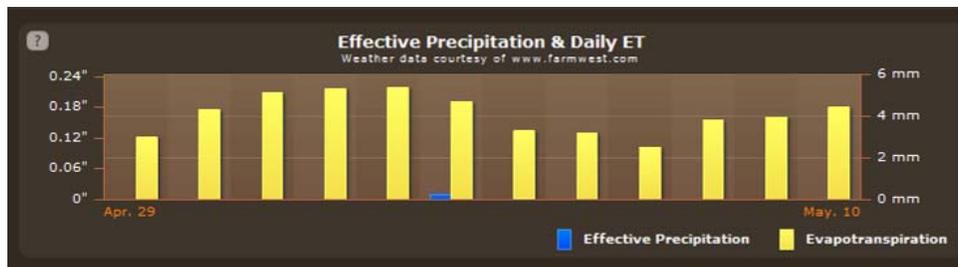
Figure 17 - Effective Precipitation & Daily ET

The Effective Precipitation & Daily ET box has the downloaded data from Farmwest.com. By putting the computer mouse on top of a graph bar for the ET or Effective Precipitation the amount for that date will be shown.
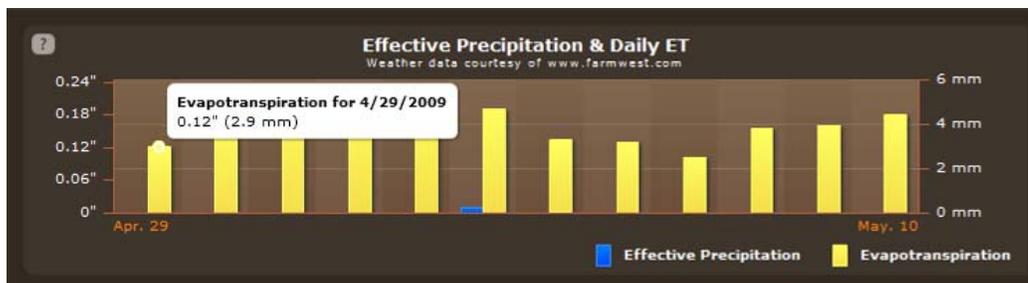
Figure 18 - Evapotranspiration by Date

Effective precipitation is the amount of rainfall that occurs above 5 mm. It is then multiplied by 75 percent to cover application efficiency losses. If the rainfall event is less than 5 mm then no rainfall amount is entered since very little or none of the rainfall will enter the soil reservoir.

Water Remaining in the Soil by Set and Date Irrigated

Figure 19 - Irrigation Applied & Daily Water Requirements

The irrigation applied is indicated by the orange bar in the graph. This number is determined from the water supplied per plant, irrigation efficiency, leaching factor and the emission uniformity. The daily water requirement is determined from the supplied evapotranspiration, area per plant, crop coefficient, and the climate coefficient.
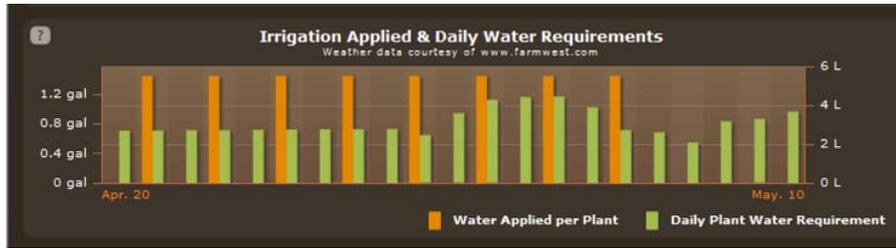
A quick review of this information will allow the user to determine if the system is operating to match crop and climatic conditions. In the case above the irrigation system is applying more water than what is deemed necessary by the calculator. The calculator will provide an estimated run time for the irrigation system as shown below.

Estimated Runtimes

Figure 20 - Estimated Runtimes

The estimation box returns an estimated run time for the drip system and will also calculate this value for the forecasted evapotranspiration data. This value should be compared to the actual runtime that was put into the calculator. It is suggested that the user average the daily estimated runtimes for a number of days. The averaged value should be used to alter the actual runtime that is in the timer until the calculator is run again.

Entering Custom Evapotranspiration Data

The **Custom Values** option is at the bottom of the weather station drop down menu. When this is selected the Enter Custom ET Values button appears. By clicking this button the process for entering custom ET begins.

Figure 21 - Custom Values

The **Enter Custom Evapotranspiration Data** pane appears first. The Start date and then the end date are requested. After they are entered the daily ET and Effective Precipitation data can be entered. Each box requires data for the schedule to be determined. The Fill ET and Fill Precip box will populate all the boxes with the same data then edits can be done. After entering the data click the Use Entered Data button.
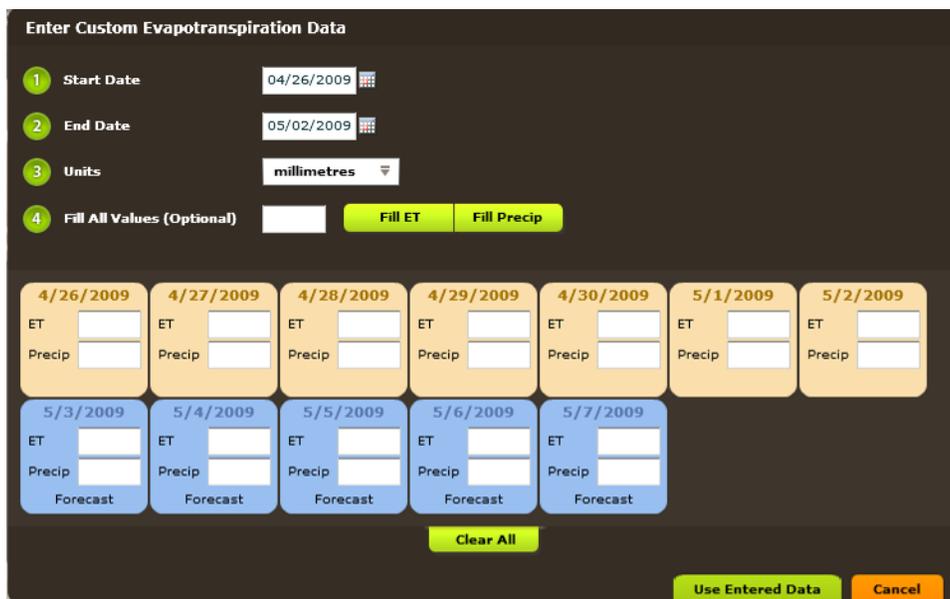

Figure 22 - Enter Custom Evapotranspiration Data

View and Print Irrigation Report

At the bottom right hand corner of the irrigation scheduling tab is an icon for printing a report on the irrigation system. Click the <mark>View and Print Irrigation Report</mark> to do this.

Agricultural Irrigation
SCHEDULING CALCULATOR

Report for

Point source drip system in Medium Density Apples

Apples - Medium Density. Field Size: 800 x 500 ft. Irrigation Method: Drip/Trickle - Point Source. Climate Station: Osoyoos

Crop	Apples - Medium Density

Soil Properties		
Soil Type	Soil Depth	Soil AWSC
Sandy Loam	18 in	1.5 in/ft
Silty Loam	30 in	2.3 in/ft
Plant Rooting Depth	3 ft	
Availability Coefficient	0.4	
Crop Coefficient	0.9	
Leaching Factor	1.05	
Max Soil Water Deficit	2.28 in	

Drip/Trickle - Point Source System Design	
Emitters per Plant	2
Flow Rate per Emitter	0.5 gal/hr
Irrigation Interval	Every Day
Application Efficiency	90
Emission Uniformity	90
Water Supply Per Plant	7 gallons per irrigation

Monthly Climate Modifier	
May	0.7
June	1
July	1.1
August	1.1
September	0.9
Off Season	0.5

Simulation Results for the selected period of **Tue May 12 2009** to **Thu May 21 2009**
Irrigate on May 22 for **4 hours, 10 minutes**
Irrigate on May 23 for **4 hours, 1 minutes**
Irrigate on May 24 for **4 hours, 44 minutes**
Irrigate on May 25 for **4 hours, 53 minutes**

Print this Report

File #145-146

Figure 23 – View and Print Irrigation Report

1.5   EQUATIONS

The following formulas are used in the calculator to generate a schedule.

EQUATION 1 - TOTAL AVAILABLE WATER STORAGE CAPACITY

$$\text{Total AWSC} = (AWSC_1 \times RD_1) + (AWSC_2 \times RD_2) + ...$$

*Where***:**

Total AWSC   = Total available water storage capacity, in or mm
$ASWC_{1,2,...}$ = Available water storage capacity of that soil layer
$RD_{1,2,...}$= Rooting depth of that soil layer

EQUATION 2 - MAXIMUM SOIL WATER DEFICIT

$$\text{MSWD} = \text{Total AWSC} \times \text{AC}$$

*Where***:**

MSWD   = Maximum soil water deficit, inch or mm
Total AWSC   = Total available water storage capacity, in or mm
AC   = Availability coefficient of the soil, %

EQUATION 3 - WATER SUPPLIED PER PLANT

$$\text{GWA} \qquad = E \times Q \times T$$

*Where***:**

GWA   = Gross water applied per plant, gallons or litre
E   = Emitters per plant
Q   = Emitter flow rate, gph or lph
T   = System run time, hr

EQUATION 4 - IRRIGATION APPLIED

NWA = GWA x AE x Eu / L

Where:

NWA   = Net water applied, gallons or litre
GWA   = Gross water applied, in or mm
AE   = Application efficiency, decimal
Eu   = Emission Uniformity, decimal
L   = Leaching factor, decimal

EQUATION 5 - CROP EVAPOTRANSPIRATION

The crop **water use (ET_C)** can be calculated for a specific plant by using a reference evapotranspiration rate (ET_O), and applying a **crop coefficient (K_C)** to convert the reported ETo to ET_C.

ET_C = K_C x ET_O

Where:

ET_C = Evapotranspiration Crop, inch or mm
K_C = Crop coefficient
ET_O = Reference evapotranspiration for a grass reference crop, mm

EQUATION 6 - DAILY WATER REQUIREMENT

G/P/D = 0.623 x ETc x S x A x K

Where:

G/P/D   = Gallons per plant per day, gallons or litre
0.632   = Constant
ETc   = Crop Evapotranspiration, in/day
S   = Effective soil water storage factor
A   = area
K   = Crop coefficient factor

EQUATION 7 - WATER REMAINING IN SOIL BY SET AND DATE IRRIGATED

The remaining water each day is determined by removing the daily ET and adding the effective precipitation.

$$\text{MSWD}_R = \text{Previous day MSWD}_R - \text{daily (ET}_c + \text{PPTe)}$$

Where:

MSWD_R	= Remaining available water for plant growth, in or mm
Previous day MSWD	= Previous days maximum soil water deficit, in or mm
ET_C	= daily Evapotranspiration, in or mm
PPTe	= daily effective precipitation, in or mm
PPTe	= (PPT – 5) x 0.75