2011 PLANET SCD Irrigation Troubleshooting Reference Guide

The landscape irrigation industry is committed to promoting and implementing water conserving products and practices in support of regional and national conservation programs such as the EPA Water Sense program. Many regional water districts and purveyors are regulating and mandating the use of water in the landscape to reduce waste and over watering. The future of the industry is dependent on the knowledge of irrigation professionals at all levels to understand the principles of irrigation efficiency while designing, installing and maintaining new installations as well troubleshooting existing systems to be more efficient.

The 2011 PLANET Irrigation Troubleshooting event will focus on *troubleshooting for efficiency* to educate participants on basic procedures to identify and resolve irrigation inefficiencies while understanding the proper application of water conservation practices and devices. The Irrigation Association, the governing body of the landscape irrigation industry, defines irrigation efficiency as being achieved when most of the water that is applied to plant material is utilized by the plant material being irrigated. Participants will be expected to understand and recognize the effects that system pressure, head spacing, and nozzle selection have on the water use of a system while demonstrating proficient auditing techniques and calculations.

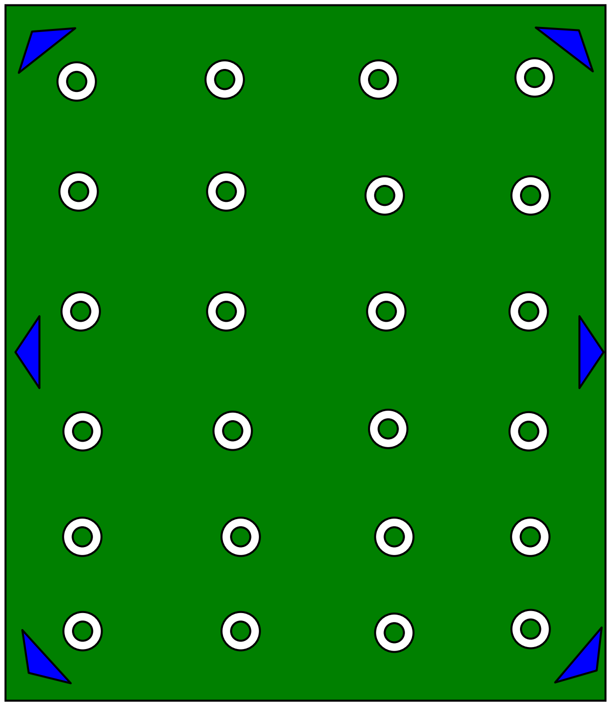
This reference guide will prepare participating students by providing the basic knowledge and skills necessary to effectively evaluate an existing irrigation system and identify the steps necessary to *troubleshoot for efficiency*. Key components include: an audit exercise, plant water requirement, system uniformity, irrigation water requirement, precipitation rate, and run time calculations, and water use estimations.

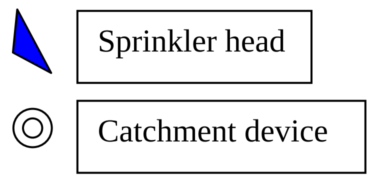
Audit Exercise

Participants will be conducting a field audit utilizing the stations built during the Irrigation System Assembly event. Auditing equipment will be provided including catchments, pressure gauges, and any other equipment, or products that will assist participants in increasing the efficiency of the system. Participants will need to be able to recognize and correct any problems with the system they are auditing and effectively communicate to the judge what needs to be corrected before the audit.

Placement of the catchments must adhere to Irrigation Association Audit Guidelines.The quantity of catchments used must be divisible by four; adjustment of the catchment placement may be required to ensure the proper quantity. Participants must accurately read and record catchment values to be used in the distribution uniformity and precipitation rate calculations.

Illustration:





Plant Water Requirement (PWR)

Participants must be able to correctly calculate the PWR for the irrigated area.

Several factors affect the water requirement of a particular plant or landscape including, but not limited to, evapotranspiration, species, and size of area being irrigated.

Evapotranspiration. Evapotranspiration is defined as the sum of water lost from the soil surface (evaporation) and water used by plants (transpiration), often referred to as ET. Many factors affect the rate of ET, including plant type, solar radiation, temperature, humidity, wind, and the amount of water available to the plant. Without a calibrated weather station at your disposal it can be difficult to determine ET, therefore Reference ET (ET_o) is commonly used to determine ET for a particular site. ET_o is expressed in terms of a depth of water per unit of time, such as inches per day, week, month, or year. ET_o is available from local Cooperative Extension Services, National Weather Service or numerous websites.

Species. Turf and ornamental plants are the two major classifications of plants found in landscapes. The water requirements of each can vary widely, referred to as the crop coefficient (Kc). Water use by a particular plant is affected by the density of the planting and the microclimate that the plant is growing in. For example, turf planted in full sun on a slope with a west exposure is going to have a different water requirement than turf planted in part shade on the east side of a building. Because of the massive size of the landscape plant palette and the wide ranging micro-climates found on any particular site, it can be difficult to identify exactly what the PWR may be for the plants being irrigated. Again, the internet provides a wealth of information to help determine what the water requirement for a particular plant species. A very comprehensive listing for California can be found within the Water Use Classifications of Landscape Species (WUCOLS) found as a PDF file on many websites. Simply Google WUCOLS to find those web pages. For purposes of the *troubleshooting for efficiency* exercise, the only factor needed is the species factor for cool or warm season turf, .80 or .60 respectively. Simply multiply ETo by the species factor to determine the water requirement.

Area. Knowing the area of the zone or landscape being irrigated is critical to determine the amount of water the area requires based on the ET and plant species. It is also important to understand the amount of water being applied in terms of gallons. One acre inch of water equals 27,154 gallons of water, or .623 gallons of water covering a square foot one inch deep.

Formula: **PWR = ETo x Kc**

Example: 1,500 square feet of cool season turf with an annual ETo of 34"

Plant water requirement **(PWR) =** 34" x .80 = **27.2"**

Water use estimation:

Gallons required = 27.2" x .623 = 16.94 gallons per foot

16.94 x 1,500 = **25,418 gallons annually**

System Uniformity

In addition to the audit exercise, participants must correctly calculate DU_{LQ} for the system.

Uniformity refers to how evenly the sprinkler system applies water to an area being irrigated. It is known technically as Distribution Uniformity (DU) expressed as a decimal. Since no landscape irrigation system achieves perfect, the following table shows the ranges of uniformity that can be found for various types of irrigation systems. The higher end of the ranges would be for sprinkler systems that have regular spacing between the sprinklers and the rows of sprinklers. The lower end of the range would be for sprinklers that re used in curvilinear or amoeba shaped areas.

Lower Quarter Distribution Uniformity is used to evaluate the quality of the sprinkler system or is the "report card" of the sprinklers.

Distribution Uniformity Low Quarter Expected Values

Sprinkler Type	Achievable	Target	Historical*
Rotary sprinklers	0.75–0.85	0.65–0.75	0.55–0.65
Spray sprinklers	0.65–0.75	0.55–0.65	0.45–0.55
* If lower than this, consider system improvements.			

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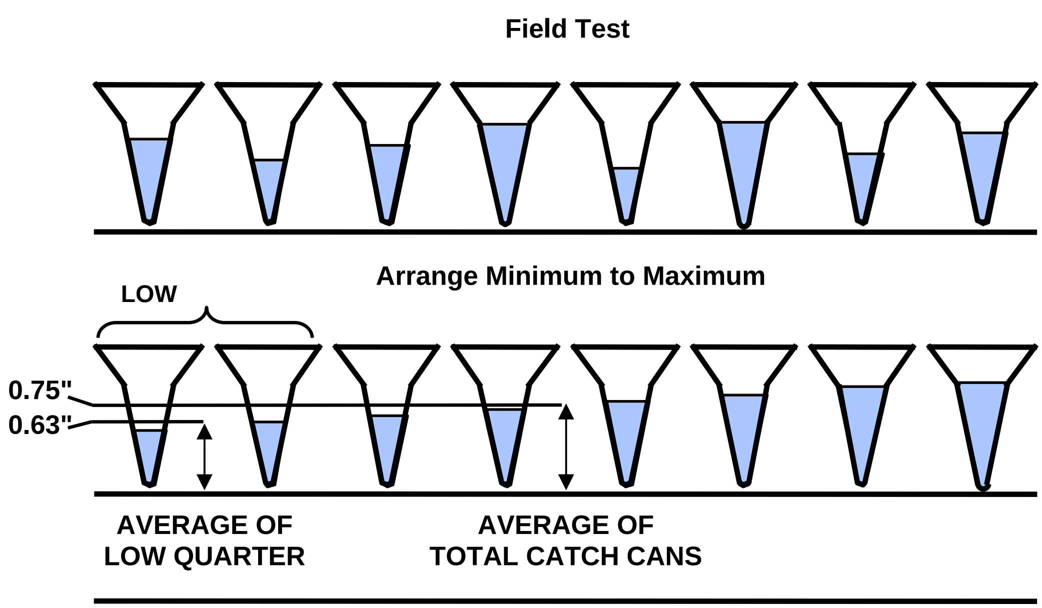
To calculate DU_{LQ}, utilize the catchment values obtained during the audit exercise. Add the sum of all water collected in the catchments and calculate the average volume by dividing the total sum by the number of catchments. Next, find the average volume of water caught by the driest 25% of the catchments by identifying one quarter of the catchments with the least amount of water collected. Add the sum of those catchments and divide by the number of catchments identified as the driest quarter. Finally, divide the average of the driest quarter by the total average which provides a decimal value as shown in the example below.



Formula:

$$DU_{LQ} = \frac{\text{Average of lowest quarter}}{\text{Average of all catchments}}$$

Example: 24 catchments were placed within a stand alone spray head zone. The system ran for 5 minutes. Catchments were placed at the head and half way between each head. The following catchment volumes were recorded in milliliters in the chart below:

12 mil	17 mil	35 mil	29 mil	5 mil	19 mil
9 mil	24 mil	42 mil	30 mil	9 mil	22 mil
15 mil	50 mil	21 mil	11 mil	23 mil	24 mil
18 mil	34 mil	16 mil	36 mil	12 mil	13 mil

Add the sum of all values:

12 + 17 + 35 + 29 + 5…..+ 13 = 526 mil

Average the sum:

526 mil / 24 catchments = 21.91 mil

Identify 25% of the driest catchments, or the lowest quarter (6 catchments).

Add the sum of the low quarter values:

5 + 9 + 9 + 11 + 12 + 13 = 59 mil

Average the sum of the low quarter:

59 mil / 6 catchments = 9.83 mil

Calculate DUlq by dividing the average of the low quarter by the overall average and multiply by 100 to get a percentage value:

$$\mathbf{DU_{LQ} = \frac{Average\ of\ lowest\ quarter}{Average\ of\ all\ catchments}}$$

$\mathbf{DU_{LQ}}$ = 9.83 mil / 21.91 mil
= .4488

= 0.**45**

Scheduling Multiplier

Because sprinkler systems are not perfect at applying water evenly across the area, the Scheduling Multiplier [SM] is used to help estimate the additional amount of water required to achieve an acceptable appearance. This is usually focused on the turf areas in the landscape where the lack of uniformity can manifest itself as dry spots or stressed areas within the irrigation zone. The typical practice to apply more water is to increase the run time on the controller. The SM provides guidance on how much extra time could be needed. It helps determine the upper scheduling boundary by increasing the number of minutes that sprinklers would operate to deliver an adequate amount of water. There are many other factors that influence how much extra water should be applied, including the required appearance, use of the turfgrass area, and horticultural maintenance practices. The SM also partially recognizes that there is lateral movement of water in the soil. The scheduling multiplier is based upon the following equation:

$$SM = \frac{1}{0.4 + (0.6 \times DU_{LQ})}$$

where

SM	=	scheduling multiplier {decimal}
DU_{LQ}	=	lower quarter distribution uniformity {decimal}
0.4 and 0.6	=	constants

If the DU_{LQ} is below 0.40, then time and effort should be spent identifying what needs to be done to assure the system is operating optimally. This may include recommendations for improving maintenance or to seek the services of a certified designer and/or contractor to identify the factors that are causing such poor performance. When the uniformity is low, it is hard to justify the amount of additional water needed to minimize stressed areas and achieve an acceptable appearance. When additional minutes of run time become excessive, runoff potential increases, and it becomes more difficult to do proper maintenance if the sprinkler system is operating beyond its desired or designated water window.

Table 2 is a quick reference for the SM that corresponds to the measured DU_{LQ} for a particular sprinkler zone or area. The SM is a quick way to determine how much extra water could be applied. For example, a DU_{LQ} of 0.60 has an SM of 1.32, which indicates that about one-third more water would be applied.

Table 2

Conversion table from DU_{LQ} to scheduling multiplier

DU_{LQ}	SM	DU_{LQ}	SM	DU_{LQ}	SM
1.00	1.00	0.78	1.15	0.58	1.34
0.98	1.01	0.76	1.17	0.56	1.36
0.96	1.02	0.74	1.18	0.54	1.38
0.94	1.04	0.72	1.20	0.52	1.40
0.92	1.05	0.70	1.22	0.50	1.43
0.90	1.06	0.68	1.24	0.48	1.45
0.88	1.08	0.66	1.26	0.46	1.48
0.86	1.09	0.64	1.28	0.44	1.51
0.84	1.11	0.62	1.30	0.42	1.53
0.82	1.12	0.60	1.32	0.40	1.56
0.80	1.14	Fix the sprinkler problems if below 0.40			

Example: 1,500 square feet of cool season turf with an annual ET_o of 34”

Plant water requirement (PWR) = 34” x .80 = 27.2”
Gallons required = 27.2” x .623 = 16.94 gallons per foot

16.94 x 1,500 = 25,418 gallons annually

DU_{LQ} = 0.45

Water use estimation for best appearance:

Ideal number of gallons required = 25,148 gallons

Scheduling Multiplier = 1.49

= 37,471 gallons annually

Example: What if the DU_{LQ} was 0.70 instead of 0.45? What would be the potential water savings achieved with a better performing sprinklers?

Ideal number of gallons required = 25,148 gallons

Scheduling Multiplier = 1.22

= 30,681 gallons annually

Gallons required with performance = 37,471 gallons
Gallons required with improved performance = 30,681 gallons

Potential Water Savings 6,790 gallons (22%)

Precipitation Rate (PR)

Participants must be able to calculate the Net PR for the zone audited.

Precipitation rate is the rate at which irrigation water is applied per unit of time. PR is usually measured in inches per hour. There are two measurements of PR. Gross precipitation rate is based upon the total flow of the station and does not account for the losses of water that occur between the nozzle and the landscape. Losses of water may be from wind drift, overspray, or evaporation. Net precipitation rate is a measure of the water that actually reaches the landscape. Precipitation rate calculations are used to properly schedule the controller to operate enough time to apply the IWR.

Formula: **PRnet =**

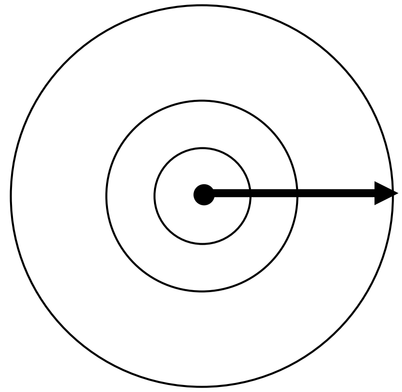
$$PRnet = \frac{CVavg \times 3.66}{TR \times CDA}$$

CVavg = Average catch volume
3.66 = Constant that converts millileters and minutes
TR = Testing run time
CDA = Catch device throat area

**The formula to determine the throat area of a round catchment device is:* πr^2

***The CDA for catchment devices used in the audit is* 16.5

$\pi = 3.14$
r = radius of device – measurement from the center of the device to the outer edge



Example: Using DUlq calculation values from previous example.

$$\textbf{PRnet} = \frac{21.91 \text{ mill} \times 3.66}{5 \times 16.5}$$

$$= \frac{80.19}{82.5}$$

$$= \textbf{.97" / hour}$$

As you can see, the PRnet is significantly lower than the precipitation rate published by most manufacturers for a spray nozzle. This will impact the time the controller needs to operate the zone in order to apply the IWR.

After the auditor has performed the field tests and calculated the precipitation rate and distribution uniformity, the simple schedule can be created.

Calculating a Simple Schedule

The simple schedule is created using a six step process that established an upper and a lower boundary of minutes to deliver a target amount of water based on the precipitation rate of the sprinklers within the zone being scheduled. The irrigation auditor can then recommend a run time that falls between the upper and lower boundaries that is best suited for the specific irrigation zone. The six steps are outlined on the Simple Schedule worksheet (see fig. 6-1).

Begin by selecting a target amount of water to apply. The target amount of water can be a standardized amount based on local landscape customs such as a ½ or 1 inch per watering day or 1½ inches of water per week or using the plant water requirement for any period of time.

Use the precipitation rate for the sprinklers of the irrigation zone being scheduled. It is recommended to use the net precipitation rate that is calculated from a catch device test of an audit. In cases where this is not feasible or practical, a precipitation rate based on the sprinkler's theoretical performance is used.

Because most controllers are programmed by using minutes, the following equaiton is used to convert inches of water to be applied divided by the precipitation rate of the sprinklers into minutes of run time [RT] that can be programmed into the controller. The inches of water can be a predetermined amount, a target amount or the amount of water used by the plants since the last irrigation. This concept will be discussed in chapter 7.

$$RT = \frac{D}{PR} \times 60 = \text{minutes}$$

where

RT = run time {min}
D = depth or desired amount of water to apply {in.}
PR = precipitation rate (gross or net) {in./h}

Run Time to Apply Water

Using the net precipitation rate from the catch can test the ideal (lower boundary) run time would be calculated as follows:

$$RT_{lower} = \frac{0.50\ \text{in.}}{1.42\ \text{in./h}} \times 60$$

$$RT_{lower} = 21\ \text{min}$$

A total of 21 minutes of run time is needed to supply the target or desired amount of water needed for the lawn area. However, since the uniformity is not perfect, an additional amount of water must be applied to account for the dry areas and to have acceptable appearance.

To calculate the upper scheduling boundary, the ideal run time is determined by using a scheduling multiplier. Referring to the table below, the scheduling multiplier for this area that has a DU_{LQ} of 0.54 is 1.38. The upper scheduling boundary is then determined by multiplying the ideal run time or lower boundary by the SM,

DU_{LQ}	SM	DU_{LQ}	SM	DU_{LQ}	SM
1.00	1.00	0.78	1.15	0.58	1.34
0.98	1.01	0.76	1.17	0.56	1.36

0.96	1.02	0.74	1.18	0.54	1.38
0.94	1.04	0.72	1.20	0.52	1.40
0.92	1.05	0.70	1.22	0.50	1.43
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0.86	1.09	0.64	1.28	0.44	1.51
0.84	1.11	0.62	1.30	0.42	1.53
0.82	1.12	0.60	1.32	0.40	1.56
0.80	1.14	Fix the sprinkler problems if below 0.40			

$$RT_{upper} = RT_{lower} \times SM$$

$$RT_{upper} = 21\,\text{min} \times 1.38$$

$$RT_{upper} = 29\ \text{min}$$

Once the scheduling boundaries are identified, then the auditor would recommend a scheduled run time between 21 and 29 minutes. If the area is of high importance then the upper scheduling boundary would most likely be needed, but if the area was in a low-maintenance situation the lower run time would be appropriate. For the purposes of the competition, the upper boundary of run time will be used. The only other consideration would be to decide if two or three cycle starts would be appropriate to apply the water without causing runoff.

That is easily determined if runoff potential was observed during the performance of the audit, or it can be based on the soil infiltration rate if it is known or measured. Ultimately, the schedule will be adjusted up or down to achieve the desired turfgrass or plant vigor. Ideally, the number of minutes of run time will be within the lower and upper scheduling boundaries when correct inputs have been used.

Observation

The simple schedule is great to determine the number of minutes of run time necessary to apply a specific or target amount of water; however, it does not figure the frequency of irrigation. If the project is located in an area with watering restrictions, the designated days may be Tuesdays and Fridays, or it may be based on even/odd watering days. This is referred to as scheduling based upon designated days. With designated days, the frequency is fixed, with three and four days between irrigations. Irrigation may take place every other day or even every third day. However, since the weather is always changing, the amount of water to apply also changes. These changes in weather cause plants to use water at different rates; therefore, the minutes of run time should be adjusted for each irrigation day.

Station #				
	Item Description	**Source**		**Units**
A	Amount of water to apply	PWR	27.2	inches
B	Precipitation rate	Audit	0.97	inches per hour
C	Distribution uniformity [DU_{LQ}]	audit or estimate	0.45	decimal
D	Scheduling multiplier [SM]	table	1.49	
	Scheduling Parameters			
E	Ideal run time (lower boundary)	(A / B) x 60	1,682	minutes
F	Upper run time boundary	E × D	2,507	minutes
G	**Recommended run time**	management	2.507	**minutes**

Water use estimation: using previous calculations.

1,500 square feet irrigated by nine 15’ spray nozzles, with a flow of 14.52 GPM.

Actual annual water use = 14.52 GPM x 2,507 min

= **36,402 gallons annually**

Factors that contribute to water waste (and poor distribution uniformity)

Pressure. In irrigation there are two kinds of pressure, static and dynamic. Static pressure is the pressure of non flowing water at the point of connection. Dynamic pressure is the pressure at a sprinkler head when the system is on. Static pressure determines pipe sizing and size of sprinkler zones, dynamic pressure determines head performance. Both pressures are commonly misunderstood and can have a significant impact on the efficiency of a sprinkler system.

Different types of sprinklers are designed to operate at different dynamic pressures. Typically, spray head nozzles are designed to perform best at 30 psi, while rotor nozzles are designed to perform best at 45-65 psi. It is important to pay close attention to the nozzle pressure specification because certain dynamic pressures are required to obtain the desired coverage and radius of throw. Under pressurized nozzles typically produce dry rings around the heads, leading to over watering in an effort to compensate for poor coverage. Over pressurized nozzles produce misting and small water droplets that are lost to wind and evaporation. Over pressurized nozzles also flow 20-40% more water than properly pressurized nozzles, resulting in excessive, unnecessary water use.

Head spacing. Head spacing refers to the distance between heads, ultimately dictating nozzle size. Typically spray heads are used when spacing is in the 5 – 15 foot range; rotors are used for radii of 20 feet or more. All sprinkler types perform best when head to head coverage is achieved. Obviously, using 12' nozzles on heads that are spaced 15' apart is going to result in coverage issues. Again, it is critical to refer to the manufacturer's specification to determine the correct nozzle size for the desired radius for the pressure available.

Nozzle selection. Nozzles for different sprinklers apply water at different rates. Spray nozzles typically apply water at 1.5" – 2.0" / hour; rotor nozzles are usually in the range of .4" - .6" / hour. The rate at which the nozzle applies the water is also a determining factor when scheduling the controller. A nozzle with a lower application rate, theoretically, will have to run longer in order to apply the desired amount of water.

Nozzle size can also significantly affect the hydraulics of a sprinkler system. Nozzles are not only rated for a radius of throw, they are also rated for flow, referred to as gallons per minute (GPM) and or gallons per hour (GPH) for drip or micro spray nozzles. A common mistake when visually evaluating rotor heads that are under pressurized, and not achieving head to head coverage, is to use a larger size nozzle that is rated for more distance. Under pressurization is more of a GPM issue than an actual pressure issue, i.e., too much water is flowing through the sprinklers than the supply can provide, by increasing the nozzle size the GPM is increased, exacerbating the problem. Decreasing the flow of a zone by using nozzles with lower GPM is the best way to resolve pressure issues if a booster pump is not an option.