# Issues in Irrigation: The Uniformity Myth

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**Bottom line: Ideally, irrigation systems should apply just enough water to eliminate dry spots, without creating soggy areas. In reality, this is rarely achievable. There are several reasons why even a new, state-of-the art irrigation system cannot provide the desired results. First, even under perfect conditions, the best uniformity that can be achieved with any irrigation system is about 80%. And if irrigation systems are NOT perfect, then fluctuating pressures, poor design or maintenance of nozzles or of the overall system further reduce performance. For all of these reasons, distribution uniformities on fairways are typically in the 60-70% range – a situation that leads to both very dry and very wet areas throughout the course. If you are lucky enough to have sandy soils and a sufficient water budget, then these problems can be overcome by over-irrigation. But many golf courses deal with heavy, poorly draining soils, which makes overwatering unfeasible. Under these conditions, the only solution is a multi-pronged approach that includes the vigilant use of portable sprinklers, cultivation programs to gradually improve water movement throughout the soil, improved drainage and routine irrigation system auditing and maintenance.**

**Low distribution uniformity (DU) causes dry areas.** On the right side of this photo, note the regular pattern of dry areas falling between irrigation heads. The DU for this fairway was 63%.

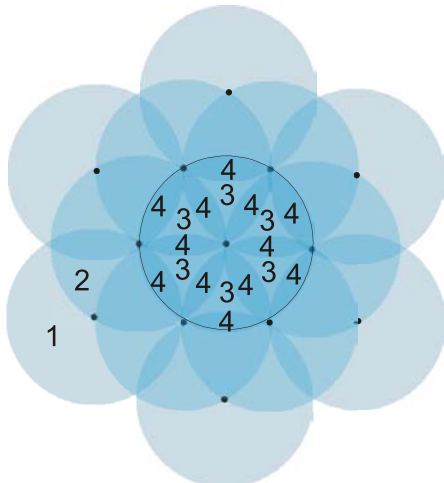
### Re-defining the goal

When discussions turn to irrigation uniformity, how often have you heard it said, "Well, even rain isn't 100% uniform, so how can we expect complete uniformity from our irrigation systems?" This is one of those statements that has been cited so frequently that it has come to have the weight of fact. But in fact, nothing could be more mis-leading, or ultimately more discouraging than comparing irrigation systems to rain. Because while there are a few, relatively minor factors (such as wind and terrain changes) that can reduce it's distribution, rainfall still approaches near perfection in terms of uniformity in most cases. In contrast, irrigation systems are plagued with a broad spectrum of so many different problems that even with the best equipment available, uniformity of 81% is the best that can be achieved, and uniformities of 60-70% are more typical. In other words, even under ideal irrigation conditions, there is no way that the almost 100% uniformity of rainfall can be approached. And by expecting irrigation systems to behave anything like rainfall, we set ourselves an impossible standard to achieve. In this issue of *PACE Insights,* we want to re-define the standards to better reflect the technical reality that our most current technology offers, and in doing so, provide a basis for more realistic goals to shoot for.

### 100% Irrigation uniformity: in your dreams!

Is 100% irrigation uniformity possible? Based on our calculations, 81% uniformity is the best we can hope for, and that's under ideal conditions.

To look into this question, we have illustrated below the irrigation distribution patterns for an ideal system: a perfectly operating rotary nozzle design with full head-to-head spacing. The numbers 1 through 4 refer to the number of heads (represented by black dots) that apply water to a specific area. Thus, the darkest blue areas ("4") are covered by four heads, and receive four times as much water as the lightest colored areas ("1").




The central circle in the diagram above has the best possible coverage. The areas marked with "4" represent 69% of the area in the central circle, and the areas labeled "3" represent 31% of the area in the central circle. For every inch of water delivered to the "4" areas, there will be 0.75 inches delivered to the "3" areas. The **distribution uniformity** (see definitions below) of the central circle can now be calculated.

$$\text{Distribution Uniformity} = 100 \times \left( \frac{0.75}{(0.69 \times 1.0) + (0.31 \times 0.756)} \right) = 81.3\%$$

## Other factors contributing to reduced uniformity

While circular patterns, such as those illustrated above, give us the most even distribution of water, a distribution uniformity of 81% is a far cry from perfection. Yet that is as good as it gets, at least with the technology currently available to us. Unfortunately, in real life situations there are several additional factors that further decrease uniformity from our “ideal” starting point of 81%. These include:

Design: The practice of irrigating roughs and fairways together frequently results in wet areas of the rough or dry areas in the fairways, due to the fact that shady roughs do not need as much water as sunnier, lower mown fairways. If this is the problem, rough and fairway irrigation heads should be isolated so that the different irrigation requirements can be applied as needed. For superintendents who leach their greens, a similar situation arises when the high volumes of water applied to the green results in unacceptably wet surrounds. The installation of heads with part circles can help solve this problem.

System maintenance: Fluctuating pressure, mis-aligned heads, and sunken or broken sprinkler heads can be detected through an irrigation audit (see below). Routine system maintenance is critical for avoiding irrigation related problems.

Poor sprinkler nozzle design: Some sprinklers do not adequately meet their specifications for coverage. If this is the case, sprinklers should be replaced with improved models. The best way to detect this problem is with an irrigation audit (see below).

Factors increasing run-off: Sloped areas, hydrophobic areas and/or poorly draining soils will cause water to be diverted from its target area (which produces dry spots) and towards a non-targeted area (resulting in wet spots). These problem areas are best dealt with using short, multiple irrigations that allow small amounts of water to soak in before saturation occurs. Hydrophobic areas can be improved through cultivation and through application of wetting agents. In the long run, deep aerification and/or sand top dressing is the best way to improve water movement, but this is a slow process that may take several years to yield obvious results.

**The relationship between soil type and water drainage.** As the table below illustrates, heavy soils with large fractions of clay and silt will drain very slowly (less than 0.2 inches per hour), while sandy soils drain more rapidly. Since typical sprinkler precipitation rates are greater than 0.2 in/hr for even a single head, heavy soils are incapable of absorbing water at the rate it is delivered, which leads to wet soils and run off. The best solution to this problem is the use of multiple short irrigation soak cycles in problem areas.

| Soil type* | Drainage | in/hr (percolation rate) |
|---|---|---|
| Clay | Very slow | Less than 0.05 |
| Silt | Slow | 0.05-0.2 |
| Very fine sand | Somewhat slow | 0.2-0.8 |
| Fine sand | Moderate | 0.8-2.5 |
| Medium sand | somewhat rapid | 2.5-5 |
| Coarse sand | Rapid | 5-10 |
| Very coarse sand | Very rapid | 10 or more |

* data from Pira, 1997.

## ETs – they can’t replace your judgement

Another factor contributing to irrigation problems is over-reliance on evapotranspiration (ET) for irrigation scheduling. ET, or the amount of water lost via plant transpiration and soil evaporation, is determined by solar radiation, wind speed, humidity and temperature. The higher the ET, the more water is required to keep the plant healthy. Many weather stations are equipped to calculate ETs on-site, but these values are also available through either the local extension service, or through state supported weather stations.

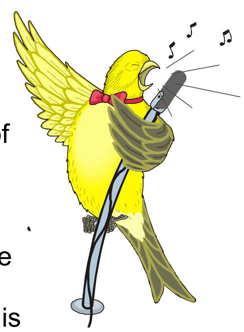
Most modern irrigation systems use ETs to schedule irrigation so that they conform to changes in the weather. And while this is a good starting point for determination of your irrigation needs, complete reliance on ETs can lead to problems. This is because the use of ETs for irrigation scheduling is based on the built-in assumption that the golf course receives uniform irrigation in all locations. And as we have illustrated above, 100% uniformity is never the case. Another way of saying this is that ETs don’t take into account the need to overwater as a means of compensating for dry spots due to non-uniform irrigation. For this reason, irrigation based on ETs alone will almost always result in dry areas in at least 19% of the course.

What is the solution to this problem? It’s doing what most of you are already doing. That is, using ET-based irrigation schedules as a starting point, and then using your powers of observation and judgement to adjust as needed.

## Well drained soils: the missing ingredient

The information above has hopefully convinced you that even the best irrigation system that money can buy is still plagued with non-uniform delivery of water, and will therefore still produce dry spots throughout the golf course. The best way to deal with dry spots that are caused by lack of uniformity is to overwater to the point that the dry spots receive enough water. But few golf courses are lucky enough to have the drainage and soil composition that makes it possible to overwater without causing overly wet turf in some areas. Instead, in most cases, heavy soils and/or poor drainage systems make overwatering a non-option. This is the dilemma that many superintendents face, and there are no magic solutions. Use of sprinklers in dry spots is the best short term solution available, but it is time and labor consuming, and can interfere with play. Keep golfers informed and educated about the reasons that sprinklers are used. For longer term solutions, the installation of additional and improved drainage systems, in concert with a regular deep aerification program to loosen heavy soils, are your best bets.

## Canary in a coal mine: a quick uniformity test



Like the caged canary that coal miners carried with them as early detection systems for poisonous gasses, dry spots can serve as an early warning of serious irrigation problems that need to be addressed. The starting point for improving your irrigation system is to identify the driest areas of the golf course, determine whether the problem is caused by irrigation, and take the appropriate remedial actions. The "Two Can Scheduling Coefficient Test" described below, which is a quick version of the scheduling coefficient procedure described on page 4, can get you started in this process.

1. Locate a dry area on a fairway or rough, and a nearby good turf quality area that is not too wet, and has good, firm soil. Both areas should be irrigated by the same set of heads.
2. Place a catch can (in its metal stand) in each area (to order catch cans and stands, contact The Toolkit Company, listed in the "Resources" section below) and run the heads at least 10 minutes, or until a minimum of 25 ml has been collected in each catch can. Make sure that the heads you are testing are the heads that operate together in a normal irrigation cycle.
3. Record the volume of water present in each catch can. If there is more water in the catch can on the healthy turf (a 25% or greater difference is usually significant), then lack of irrigation uniformity is probably the culprit. In the photograph to the right, there was roughly a 400% difference in volumes between the two areas.
4. Calculate the increase in irrigation time ideally needed to improve turf quality in the dry area:

$$\text{2 can scheduling coefficient} = \frac{\left(\frac{\text{ml(poor)} + \text{Ml(good)}}{2}\right)}{\text{ml(poor)}}$$

For example, if the catch can in the dry area has 25 ml of water, and the catch can in the healthy area has 35 ml, then:

$$\text{2 can scheduling coefficient} = \frac{\left(\frac{25+35)}{2}\right)}{25} = 1.20$$

In other words, if your current run time for the stations covering the test area is 10 minutes, then it should be increased to 12 minutes (1.2 X 10 minutes), or one additional turn on the heads, whichever is less.

5. Once you have increased the irrigation run time, examine the same two areas two days later. Is the area of good turf now too wet? If so, run times should be decreased slightly. In many cases, a hand placed sprinkler will be needed to increase the volume of water applied to dry areas. Some tinkering will probably be necessary to adjust the system to your liking, but this rough test will give you a good starting point to launch from.

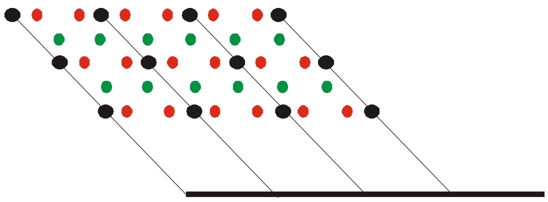
**Use of catch cans to diagnose irrigation problems**. After running the system for 10 minutes, the poor quality turf on the left received only 17 ml of water while the good quality turf on the right received 68 ml. Both areas were irrigated by the same set of irrigation heads.

In some cases, this test may be sufficient to deal with your key irrigation problems, but in many cases a full irrigation audit by a certified specialist is in order.

## Arranging an irrigation audit

A standard irrigation audit can formally document a wide variety of irrigation system problems, and can provide the basis for a program to address any problems. Although you can conduct an audit yourself, the report provided by a certified irrigation auditor may give you more leverage to justify system improvement costs. A list of certified irrigation auditors is available from the Irrigation Association (phone: 703-573-3551. http://www.irrigation.org/).

The diagram below illustrates a catch can layout frequently used to audit golf course fairways where heads (black dots) are arranged in a triangular pattern. One set of catch cans (red dots) is placed 5 feet from each head, and a second set of catch cans (green dots) is placed in the centers of the triangles formed by the heads.



After the system is run for 10 minutes, the water in each catch can is measured. These numbers are then used to calculate uniformity measurements, such as those described below.

## Definitions

The data from catch can tests can be manipulated to provide a variety of different uniformity values. Each of the values described below have their advantages and disadvantages, and the best approach is probably to have all three values calculated, so that you can compare them to one another.

Distribution Uniformity (DU): This is a frequently used uniformity measurement for golf courses, because it emphasizes dry areas in its calculations. In the calculation, the lowest 25% (sometimes called the "lowest quarter") of the catch can values is averaged, and then divided by the average catch can value for the entire test area. For example, a DU of 75% means that the lowest quarter of the catch can volumes were 25% lower than the average catch can volumes for the whole test. The higher the DU, the more evenly water is being applied. On fairways, the goal is to exceed DUs of 70%.

$$\text{Distribution Uniformity (DU)} = 100 \times \left( \frac{\text{Average in/hr for lowest quarter of the observations}}{\text{Average in/hr for the entire set of observations}} \right)$$

Coefficient of Uniformity (CU): Another frequently used measurement of irrigation uniformity, the CU is also derived from catch can test data. However, unlike the DU calculation, the CU treats wet and dry areas with the same emphasis. For this reason, turf managers, who are generally most concerned with dry spots, may rely more on other uniformity estimates. Once again, the higher the CU, the more evenly water is being applied to turf. There are three equations involved in this calculation, where: CU = Coefficient of uniformity; D = the average absolute deviation from the mean; M = mean application volume; $\sum$ = the sum of all values; Xi = individual application volumes; and n = number of individual application volumes. The vertical lines on either side of Xi-M indicate that the absolute value (value regardless of sign) should be used.

1) $$CU = 100\,(1 - D/M)$$

2) $$D = (1/n) \sum \left| Xi - M \right|$$

3) $$M = (1/n) \sum Xi$$

Scheduling coefficient (SC): In contrast to the two measurements above, the SC was developed specifically with turfgrass in mind, and can be put to immediate use to adjust irrigation run times. The SC estimates the amount of extra time needed to give the driest areas enough water. It is a more detailed version of the 2 can uniformity test we have outlined above.

To calculate the SC, only two numbers are involved: 1) the average of all the catch can volumes for the test irrigation zone, and 2) the volume of water in the catch can from the driest area (this will be from the catch can with the lowest volume of water).

$$SC = \frac{\text{average water volume}}{\text{volume of water from driest area}}$$

If the irrigation system is perfectly uniform, an SC value of 1.0 will be obtained. The number will become larger as uniformity decreases. For example, an SC of 1.5 indicates that irrigation run times should be increased by a factor of 1.5 in order to provide enough water to the driest area. If your previous run time was 8 minutes, then the new run time should be adjusted to (1.5 X 8 = 12) 12 minutes. Of course, this new and increased run time will result in overwatering of many other areas, and may need to be ratcheted down to avoid the worst of the overwatering. Your final run times will be a compromise that balances the disadvantages of soggy areas against the risks of dry areas.

## Resources

Irrigation auditing equipment (including catch cans and stands): The Toolkit Company, PO Box 10822, Bakersfield, CA 93389. Phone: 661-587-9854.

Education and Training and Equipment Testing: Center for Irrigation Technology, Fresno, CA. 209-278-2066. http://cati.csufresno.edu/cit/

Education and Training: Irrigation Training and Research Center, Cal Poly San Luis Obispo: 805-756-2434. http://www.itrc.org/

Background Information: The Irrigation Association. http://www.irrigation.org/

Background text: Pira, E. 1997. A Guide to golf course irrigation system design and drainage. Ann Arbor Press. Chelsea, MI.