# Maximizing Irrigation Distribution Uniformity with Catch-Can Performance Data

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**Abstract.** *Continued demand for high quality sports and recreation turf facilities has driven many innovations in the irrigation industry. Increasing irrigation distribution uniformity has been a major goal behind many design and management decisions. Using scheduling coefficients to compensate for poor irrigation uniformity increases water use and extends application times beyond what may be practical or safe. Knowing the actual precipitation rates of every individual zone in an irrigation system can provide the information needed to increase distribution uniformity and reduce over or under watering.*

*An irrigation audit of a 12-zone, block design, NCAA men's baseball field was completed to address non-uniformity issues. All zones were tested separately and individual precipitation rates determined. Two hundred fifty-three catch cups were used in the analysis. Distribution uniformity was determined as operated by the groundskeeper and after inputting the correct precipitation rates of all zones.*

*Distribution uniformity was improved nearly 9% compared to groundkeeper controlled irrigation management practices and was 20% greater than a typical audit outcome using this technique. In addition, actual measured precipitation rates were determined allowing for more precise irrigation scheduling and optimization of overall irrigation system performance.*

**Keywords.** *Optimization, distribution uniformity, precipitation rate, RTM, sports turf.*

## Introduction

Currently audits are done after all known problems with an irrigation system have been addressed. Performing an audit after everything has been fixed makes it impossible to document any changes, positive or negative, as a result of repairs. Also, audits are usually only conducted once and overall performance and irrigation scheduling based on this single event. Current guidelines suggest that, for rotors, each sprinkler stream pass over an individual cup at least five times. This may not be adequate to truly represent the performance of an irrigation system. In personal examination of this observation, I believe that an audit should be conducted over multiple days (~3), and values from individual test runs added together (pooled) to calculate overall performance. In performing an audit three separate times, differences in predominant wind direction (even when very calm), operating pressure, sprinkler rotation speed, and even air humidity tend to normalize. Distribution uniformity always improves when pooled data from multiple audits on an individual sprinkler system are compared to single event testing.

Most audits are not used to determine sprinkler precipitation rates, but water management decisions are decided based on the outcome of an audit. By using the Low-half Distribution Uniformity ($DU_{LH}$) as determined by an audit to calculate a run-time modifier (RTM) and relying on catalog precipitation rates, misapplication of water will result. Even if precipitation rates are based on audit results, these values can represent an average across several individual irrigation circuits. Slight differences in water pressure, sprinkler spacing, nozzle wear, sprinkler orientation and any obstructions to the water stream from the nozzle can influence irrigation delivery rates. These small differences are missed when precipitation rates are represented by using the average catch cup volume across adjacent zones.

To follow the recommended procedure for conducting an audit (IA, Recommended Audit Guidelines), the precipitation of all zones involved, must be known in advance. Since any number of factors can influence actual sprinkler performance, being able to predict the real precipitation rate of an irrigation system may be impossible. Determination of the precipitation rate for complex irrigation systems like those found on baseball fields, makes actuate prediction much more difficult.

A more comprehensive approach to irrigation system testing is warranted and would involve an audit "as is" prior to any repairs. Actual run times would be those that the irrigation manager normally uses during a regular scheduled irrigation event. From this test, the current irrigation system parameters could be determined. Distribution uniformity and actual applied water depth could be calculated from the "as is" audit and documented. The next step would be to make **all** repairs to the system. Check and adjust sprinkler arcs, measure pressure, make sure all sprinklers have the correct nozzles installed, adjust sprinkler orientation to surrounding grade, and remove anything that may obstruct the spray pattern (e.g. tall grass). Once all repairs are complete, test the system one zone at a time and determine individual precipitation rates for each zone. Then, conduct a final audit that reflects the differences in run times between zones to apply the same depth of water (Table 1.). The outcome of this procedure optimizes the sprinkler system, increases the distribution uniformity, and reduces potential water waste.

This technique is possible on all spray head or rotor irrigation systems, from those that have multiple sprinklers on a single circuit to valve-in-head rotor-type sprinklers commonly used on golf courses.  Optimizing the performance of an irrigation system can reduce water use by minimizing the need to “cover up” deficiencies using large run-time modifiers.  Operating an irrigation system that has been optimized makes both economical and ecological sense and should be seen as being more “green” and environmentally responsible.

## Materials and Methods

An irrigation audit of a 12-zone, NCAA men’s baseball field was conducted to address irrigation non-uniformity. Each zone consisted of five to eight individual sprinklers in a block configuration. Each zone had water that was contributed to it from as many as three to four adjacent zones. All zones were operated separately so that individual precipitation rates could be determined. Two hundred fifty-three catch cups were used in the analysis.

Catch Can spacing was approximately 15’, which allowed for 3 catch cups between the individual sprinklers and 1 cup next to each sprinkler (IA, Recommended Audit Guidelines). Cups were laid out in a grid pattern. Gear driven rotor-type sprinklers were spaced at approximately 55-60’ with full-circle sprinklers occupying the center of the infield and part-circle heads along all perimeters.

Prior to zone-by-zone analysis of the entire field, an audit of a large central area in the outfield was conducted **(see figure 1.)**. In this audit 60 catch cups were used and spaced in a square grid pattern at 15 feet. Runtimes for all zones were controlled by the groundskeeper with a desired application of 0.25 inches. The irrigation in the center area of the outfield was audited on three separate nights and data pooled for calculation of distribution uniformity (DU) and total volume applied (aka. precipitation). This audit allowed for the determination of observed conditions under current management practices.

## Results and Discussion

The DU (low quarter) as operated by the groundskeeper was approximately 65%; low half distribution uniformity ($DU_{LH}$) was 76%. The average applied water depth was 0.21”per night, 19% lower than intended. After the initial audit, both the number and size of the overly wet and dry areas were noted and reconfirmed initial concerns regarding uniformity.

The zone-by-zone audit was then conducted, one morning to measure and mark all locations for the catch cups and a second morning to operate each of the 12 zones and record catch volumes. After calculation of the individual zone precipitation rates and reprogramming the irrigation controller, the “center” area which was tested prior to runtime adjustment was re-tested. Low quarter DU was now 74% an increase of 9%, and $DU_{LH}$ increased by 4%**.** Distribution uniformity for the entire field was also determined and averaged 71% ($DU_{LH}$ = 80%).

Evaluating how an audit is typically done and using this technique are possible by ‘virtually’ comparing the expected catch volumes from each procedure. In a usual audit, all zones would be operated a set time based on either the catalog precipitation rates or by summing the expected total gallons per minute over a given area. With the proposed technique, recorded catch volumes would reflect zone-by-zone runtime adjustment based on measured precipitation rates. Fair comparison between these two procedures can only be made in the “center” square area which was initially tested. This area was irrigated by full-circle sprinklers and the water applied by 5 separate zones (Figure 1.). Had all 5 zones been run for 21 minutes with the intent to apply 0.25 inches (based on a catalog precipitation rate of 0.72) so that there would be about 25 ml or more in each catch-can (Table 1.), the $DU_{LQ}$ would have been approximately 54% and the average hourly precipitation rate would be approximately 0.43 inches (Table 2.). Compare these results with a $DU_{LQ}$ of 74% and an average hourly precipitation rate of 0.59” (5 ‘center’ zones) after optimizing the runtimes. By using a ‘set’ runtime for all full-circle sprinkler zones an underestimation of the potential distribution uniformity and precipitation rate would result. A runtime modifier (RTM) calculated using the $DU_{LH}$ value determined by using a ‘set’ runtime would result in 21% more water being applied compared to a RTM determined after using the zone-by-zone optimization technique (table 2.). Additional over-application (approximately 37%) of water would also be made using the lower precipitation rate supplied by the ‘set’ runtime procedure compared with the zone-by-zone optimization technique.

Additional benefits to this type of an audit are the determination of actual precipitation rates. Catalog precipitation rates for the sprinklers tested ranged from 0.67-0.77, depending on square or triangular spacing (both of these sprinkler arrangements are used on this site) with an average of 0.72. Tested IPH values for the ‘center’ area averaged 0.59”. Catalog inch-per-hour (IPH) values have a difference of 13-30% or average approximately 22% greater than actual measured precipitation rates. Using catalog precipitation rates to schedule irrigation would result in a general under application or deficit irrigation.

Another advantage to zone-by-zone testing is being able to make changes in a single sprinkler and not having to re-test the entire field. For example, a nozzle change to one or more sprinklers may increase overall DU. Testing the possible improvement would involve operating only the affected zone(s), making sure to maintain the same cup grid as was used in the initial audit. Once the new data has been collected, replace the old data for the same zone in the original matrix and recalculate the precipitation rates and DU.

**Conclusion**

Improvements in overall irrigation distribution uniformity are possible using the zone-by-zone determination of sprinkler precipitation rates prior to an audit. Overall DU compared to that applied by the groundskeeper at this baseball field was improved using this technique. This is a highly maintained facility with a relatively small amount of turfgrass and irrigation is frequently monitored and adjusted. All sprinklers on this site were at an ideal orientation to the surrounding grade and had nothing obstructing the spray patterns. Greater improvements in DU have been observed using this technique on other landscaped turf areas (data not shown). Additional improvements in DU at the baseball field are possible and would involve the relocation of select sprinklers, changing some nozzles and making sure there was adequate water pressure on all zones.

This technique can be another tool available to the irrigation manager along with; 1) making sure the sprinkler system has adequate water pressure, 2) there is proper spacing between individual heads, 3) matched nozzles are used within any given zone, and 4) making sure there is nothing obstructing the spray pattern. This technique requires no physical changes to the sprinkler system other than adjustment of runtimes as dictated by the measured precipitation rates. In addition, improvements to an existing sprinkler system can be measured if an ‘as is’ audit is performed prior to making any changes to the system. In this way it makes it possible to document positive changes to an irrigation system and optimize performance. The other benefit to using the zone-by-zone audit is in only having to re-test smaller areas within a lawn area if changes are made to a single sprinkler. Data from a re-test area can be substituted with data from a previous test and new precipitation rates and increased DU often result.

Figure 1. Catch cup placement and large central area location at The University of Arizona Men's Baseball field.

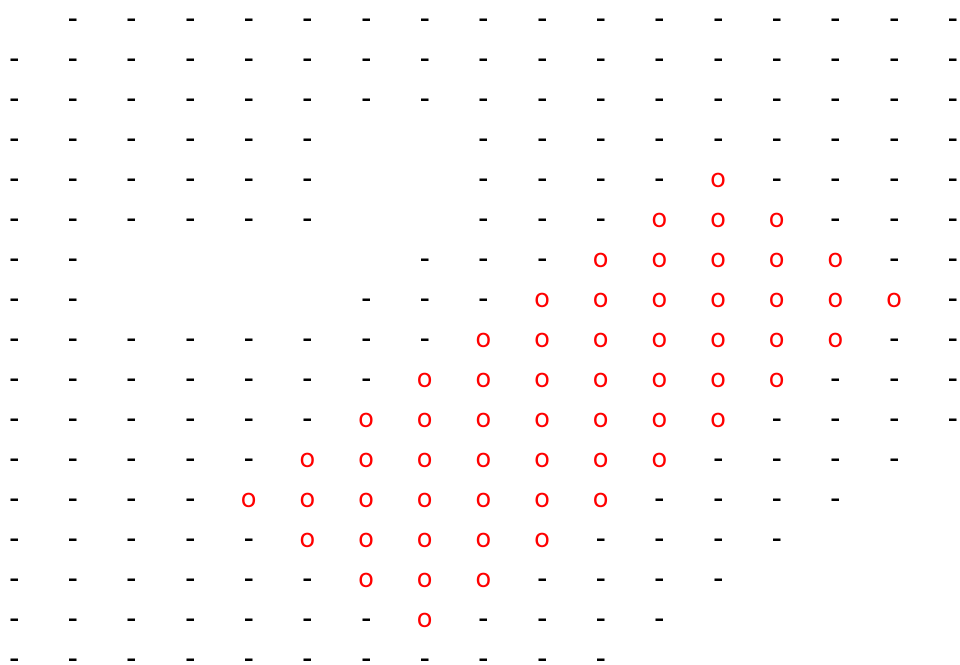

Table 1. Precipitation rates of all irrigation circuits as determined by zone-by-zone testing.

| station # | IPH | min./0.25" | in./21 min. |
|---|---|---|---|
| 1 | **0.71** | 21 | 0.25 |
| 2 | **0.81** | 19 | 0.28 |
| 3 | **0.57** | 26 | 0.20 |
| 4* | **0.71** | 21 | 0.25 |
| 5 | **0.59** | 25 | 0.21 |
| 6* | **0.65** | 23 | 0.23 |
| 7* | **0.56** | 27 | 0.20 |
| 8* | **0.46** | 33 | 0.16 |
| 9* | **0.59** | 25 | 0.21 |
| 10 | **0.66** | 23 | 0.23 |
| 11 | **0.71** | 21 | 0.25 |
| 12 | **0.58** | 26 | 0.20 |

*Stations that contribute to 'Center' square.

Table 2. Distribution uniformity and precipitation rates for Men's baseball field at the University of Arizona.

| | Large 'central' area | | |
|---|---|---|---|
| | Pre | Post | 'Virtual' |
| Low quarter DU | 65.2% | 73.6% | 53.7% |
| Low half DU | 76.0% | 80.4% | 66.2% |
| Inches applied (desired/actual) | 0.25/0.21 | 0.25/0.24 | -/0.11 |
| IPH (avg.) | - | 0.59" | 0.43" |
| RTM | 1.31 | 1.24 | 1.51 |
| | Entire field | | |
| Low quarter DU | - | 71.4% | - |
| Low half DU | - | 80.0% | - |
| Inches applied (desired/actual) | - | 0.25/0.25 | - |
| IPH (avg.) | - | 0.63" | - |
| RTM | - | 1.25 | - |

References

Irrigation Association. 2007. Recommended Audit Guidelines.