Comparison of Catch Can Distribution Uniformity to Soil Moisture Distribution Uniformity in Turfgrass and the Impacts on Irrigation Scheduling

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Introduction

By using the standardized procedure for performing irrigation audits to measure distribution uniformity and the net precipitation rate, an irrigation schedule can be calculated based on system performance in the field. Current practice is to determine the plant water requirement and then divide it by the lower quarter distribution uniformity to calculate the irrigation water requirement. (IWR = PWR / DU_{LQ}) Once the irrigation water requirement has been determined, the actual precipitation rate is used to calculate the number of minutes the system should run to meet the need (IWR / PR = minutes of run time). Frequently the proposed schedule based upon the audit will have longer run times than what are currently programmed in the controller. This has caused auditors to question the validity of the work they are performing and has been frustrating to explain the proposed schedule to the owner when it would result in additional water being applied to the landscape unnecessarily.

In order to promote conservation of water resources, the proposed procedure that has been developed through the work of the IA's Water Management Committee helps account for the lateral movement of water within the root zone without changing the accepted methodology used to measure sprinkler system performance in the landscape. The proposed procedure focuses on how uniformity changes the minutes of run time that is programmed into the controller versus modifying the plant water requirement to calculate an irrigation water requirement. This alternate method will decrease the amount of water required compared to the current method without severely impacting most established landscapes.

Background

In a paper presented last year in San Antonio titled Distribution Uniformity Results Comparing Catch-Can Test and Soil Moisture Sensor Measurements in Turfgrass Irrigation by Brent Mecham showed that by using data from previous audits of well maintained, properly irrigated turfgrass that the soil moisture DU_{LQ} was 15-20 points higher than the catch-can DU_{LQ}. The paper proposed using the lower-half distribution uniformity (DU_{LH}) to create a run-time multiplier (RTM) from the same data collected to determine the DU_{LQ}. The DU_{LH} is used to divide into the average of all readings (CV_{avg}/ DU_{LH}) and the result is the Run Time Multiplier. The RTM is used to multiply the number of minutes for the perfect system that should be programmed into the controller. The result is fewer minutes of run time compared to using DU_{LQ} to determine IWR.

After the presentation in San Antonio, Rick Allen submitted to members of the Water Management committee a communication titled "Analysis of the Impact of Distribution Uniformity on Gross

Application Depth for Turf Systems" that showed the impact of using DU_{LQ} vs. DU_{LH} vs. $DU_{L3/4}$. Figures 1-3 show how much of each area will receive less than the desired amount (1inch) of water as well how much of the area is over-irrigated. It is assumed that the application depths within the zone were distributed according to a normal distribution which is a good assumption for catch can data. From his analysis the DU_{LH} or $DU_{L3/4}$ provides a profile of gross application depths that seem reasonable for most landscape applications. If a user has a low DU_{LQ}, then he should expect to have some portion of the landscape showing some stress. If the user is unhappy about seeing stress in the turfgrass, then he must make a management decision to over-irrigate most of the landscape to meet the needs of a small portion of the landscape. In other words he is fighting uniformity defects with water. With the many issues regarding the wise use of water resources throughout much of the country, reducing the recommend amount of water to be applied without causing injury would help conserve water resources. In many instances plant health would probably improve.

An aggressive approach to creating irrigation schedules would be to use the lower three-quarters distribution uniformity. For excellent sprinkler systems with high distribution uniformity this would work very combined with excellent water management. A more conservative approach to irrigation scheduling is to use the lower-half distribution uniformity to modify the runtime. In an effort to avoid introducing another DU term when the standard definition for DU is based upon the lowest quarter and to allow using DU_{LQ} to help create the RTM, the equation can be written as:
$RTM = 1 / (.385 + (.00615 \times DU_{LQ}))$ where DU_{LQ} is expressed as a percentage.

As an example if the plant water requirement is 1" and the DU_{LQ} is 65% and the precipitation rate is .75 inches per hour the resulting schedule would be as follows:

Current method:

$IWR = PWR / DU_{LQ} = 1 \text{ in.} / .65 = 1.54 \text{ inches}$

$\text{Run Time} = IWR \times 60 / PR = 1.54 \text{ inches} \times 60 / .75 = 123 \text{ minutes}$

Using the RTM concept the following schedule would be created:

$RTM = 1 / (.385 + (.00615 \times DU_{LQ})) = 1/ (.385 + .00615 \times 65)) = 1.27$

$\text{Run Time} = PWR \times 60 / PR = 1 \text{ inch} \times 60 / .75 = 80 \text{ minutes}$ ideal run time

Adjusted run time is the ideal run time multiplied by the RTM

80 minutes x 1.27 = 102 minutes

Using the RTM method, nearly a 20% of the water would be conserved based upon the amount of time the system would run. A one-time event is not significant, but over the course of a season a substantial amount of water could be saved. In this example a savings of over a quarter inch of water for every inch needed to meet plant water requirement could be achieved.

Field Results

Because of the extreme drought in Colorado this year and the severe watering restrictions imposed by communities, it has been difficult to find many sites to audit that were not in stressed conditions. The few audits that were conducted used the traditional catch can from Cal-Poly. At each location that a catch can was placed, a soil moisture reading was taken using a portable TDR type soil moisture sensor prior to running the sprinkler system for the test. These audits were done after extended periods of very little rainfall (because we are in a drought) and the zones had been run according to the watering restrictions. Those sites that were irrigated close to ET have results similar to previous paper where the soil moisture DU_{LQ} is 10-15 points higher than the catch-can measured DU_{LQ}. The sites where deficit irrigation was occurring, (which is the majority of sites) the DU_{LQ} for the catch cans and the soil moisture was almost identical.

For the site that was being irrigated at ET the following table shows the results:

	Catch cans	Soil Moisture	RTM
DU_{LQ}	65%	80%	
DU_{LH}	77%	87%	
RTM (from DU_{LH})			1.29
RTM (from equation)			1.27
RTM (Soil Moisture DU_{LQ})			1.25

From this table we can see that the RTM whether it is based on actual field measurements, soil moisture readings or by using the RTM equation the results are very similar.

Another site was audited to measure sprinkler system performance as well as soil moisture uniformity. This site was scheduled to apply .60" of water on the days dictated by watering restrictions. The designated watering days are Mondays and Thursdays.
The audit results are compared to the irrigation schedule that was being used.

	Zone 1 & 2	Zone 3	Zone 4	Zone 5	Zone 6
DULQ(cc)	71	70	70	80	59
DULQ(sms)	74	71	71	80	83
DULH (cc)	85	81	81	84	87
RTM(DU_{LH})	1.18	1.23	1.23	1.19	1.15
RTM(equation)	1.21	1.22	1.22	1.14	1.34
RTM (SMS DU_{LQ})	1.35	1.41	1.41	1.25	1.20
Precip Rate (inches per hour)	1.62	.64	.32	1.06	1.21
Ideal Minutes	22	56	112	34	30
Minutes Using DU_{LQ}	31	80	160	42	50
Minutes Using RTM (eq.)	27	69	138	39	40
Minutes Current Schedule	30	50	99	36	30

Because of the limitations caused by watering restrictions as well as the controller being used for the irrigation system, the current schedule is even less than what would be recommended. This partly explains why there are a few stressed areas in the yard but overall is very acceptable. The current schedule almost meets the PWR for 3” bluegrass for the three weeks prior to the audit.

Table 1. shows DU_{LQ} values to create a “run time multiplier” by dividing the average by the lowest quarter average and comparing it to the results using the equation RTM = 1 / (.385 + (.00615 x DU_{LQ})). One advantage of the RTM equation limits how much extra water will be applied compared to using the DU_{LQ} that has no upper limit. On excellent systems the differences are not great, but as the uniformity deteriorates the differences get much larger. By using the RTM with the measured DU_{LQ} in the equation helps account for the lateral movement of water in the soil. On well-managed sites the soil moisture uniformity is greater than what can be measured using catch cans. Another advantage of using the RTM is the end user can more easily see the impact of poor uniformity on the irrigation schedule that is programmed into the controller. For example if the DU_{LQ} is 70 and to account for the lack of uniformity the chart will quickly show that the RTM will increase the number of minutes to program by 23% to help compensate for the lack of uniformity. This is in contrast to the 43% increase in time that would be calculated using DU_{LQ} to modify the run time.

Conclusion

The Run Time Multiplier method based upon data collected from an irrigation audit will help create irrigation schedules that will adequately irrigate the turfgrass and also result in substantial water savings over the current methodology. It can be shown in statistical analysis as well as in the field that this concept works. The recommendation to continue to “trim back” the schedule is still advised, but the amount of trimming will be greatly reduced and water savings can happen more quickly. This concept has worked well and more closely matches the run times that experienced managers use in maintaining the landscape. This will aid in creating meaningful irrigation schedules that are more realistic especially on systems that have poor uniformity measurements. The RTM combined with irrigation management efficiency will also have an impact upon water budgeting or water allocations which a water purveyor may use.

Evaluating how well a sprinkler system performs by using the DU_{LQ} is still very valid and should continued to be used. Reasonable expectations of how well individual sprinkler zones should perform needs to be emphasized and taught to water purveyors. However, being able to use the DU_{LQ} to calculate the RTM will save water for other applications.

Table 1. **Run Time Table based on Catch DU_{LQ}**

Catch Can DU_{LQ}	Run Time Multiplier RTM	Using DU_{LQ} to modify times
100	1.00	1.00
98	1.01	1.02
96	1.03	1.04
94	1.04	1.06
92	1.05	1.09
90	1.07	1.11
88	1.08	1.14
86	1.09	1.16
84	1.11	1.19
82	1.12	1.22
80	1.14	1.25
78	1.16	1.28
76	1.17	1.32
74	1.19	1.35
72	1.21	1.39
70	1.23	1.43
68	1.25	1.47
66	1.26	1.52
64	1.28	1.56
62	1.30	1.61
60	1.33	1.67
58	1.35	1.72
56	1.37	1.79
54	1.39	1.85
52	1.42	1.92
50	1.44	2.00
48	1.47	2.08
46	1.50	2.17
44	1.53	2.27
42	1.58	2.38
40	1.58	2.50
39	1.60	2.56
36	1.65	2.78
33	1.70	3.03
30	1.76	3.33
27	1.81	3.70
24	1.88	4.17
21	1.94	4.76
18	2.02	5.56
15	2.10	6.67
12	2.18	8.33
9	2.27	11.11
6	2.37	16.67
3	2.48	33.33

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Figure 1.

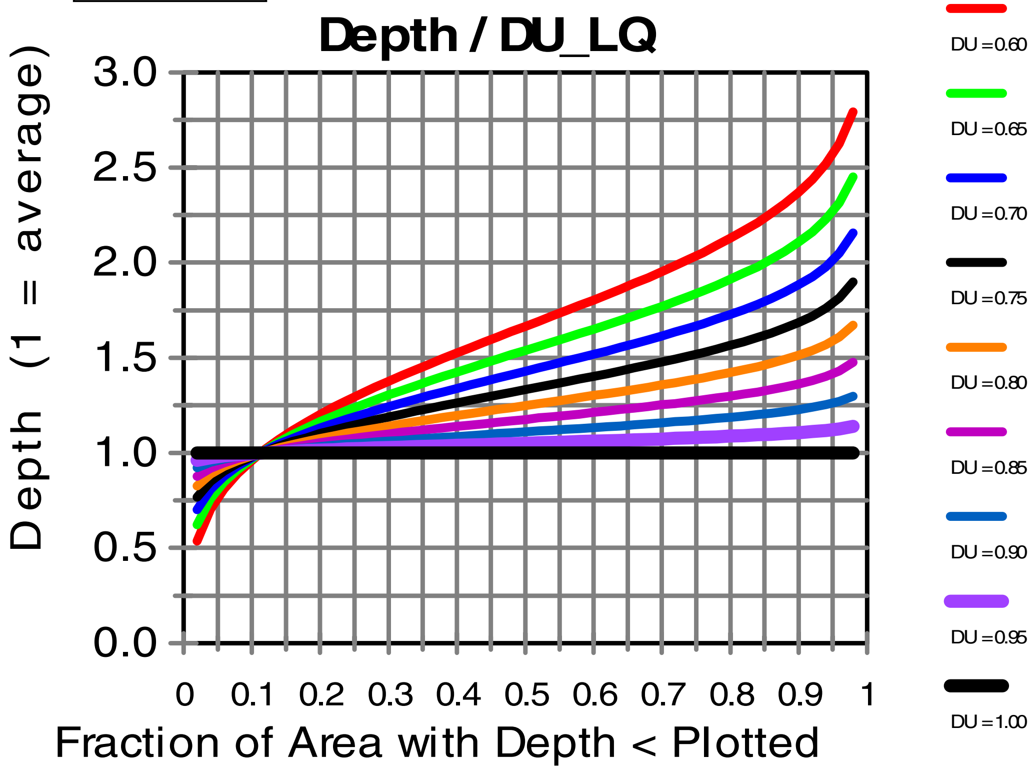


Figure 2.

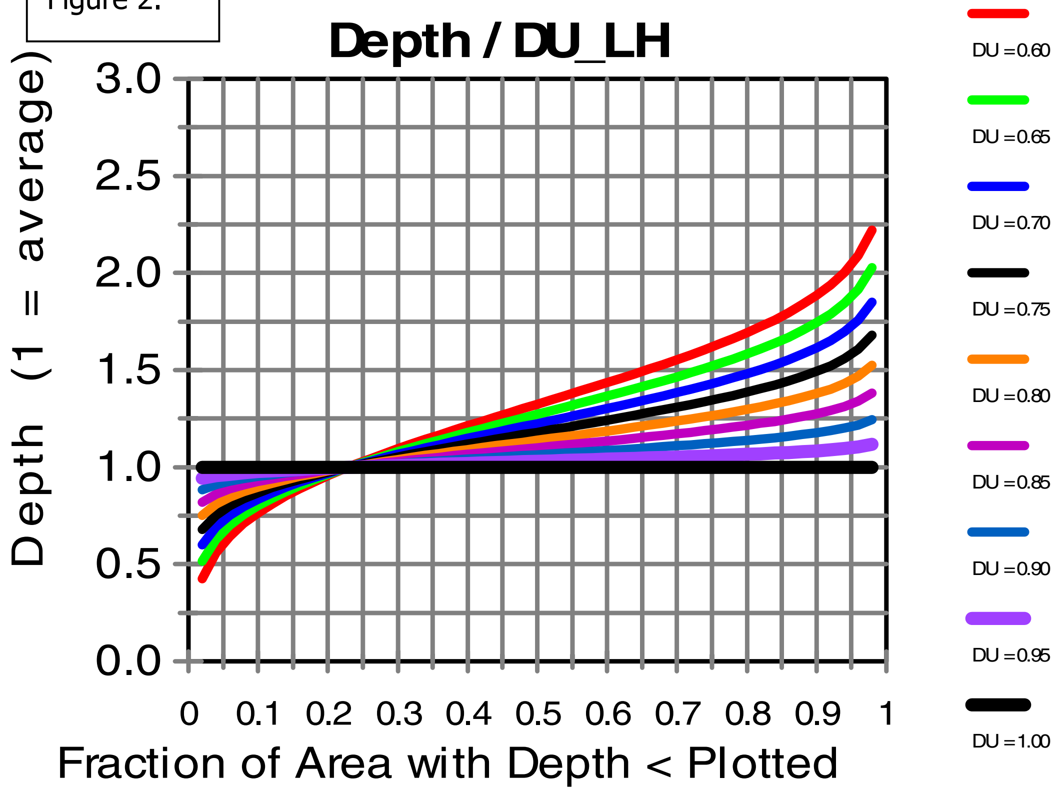
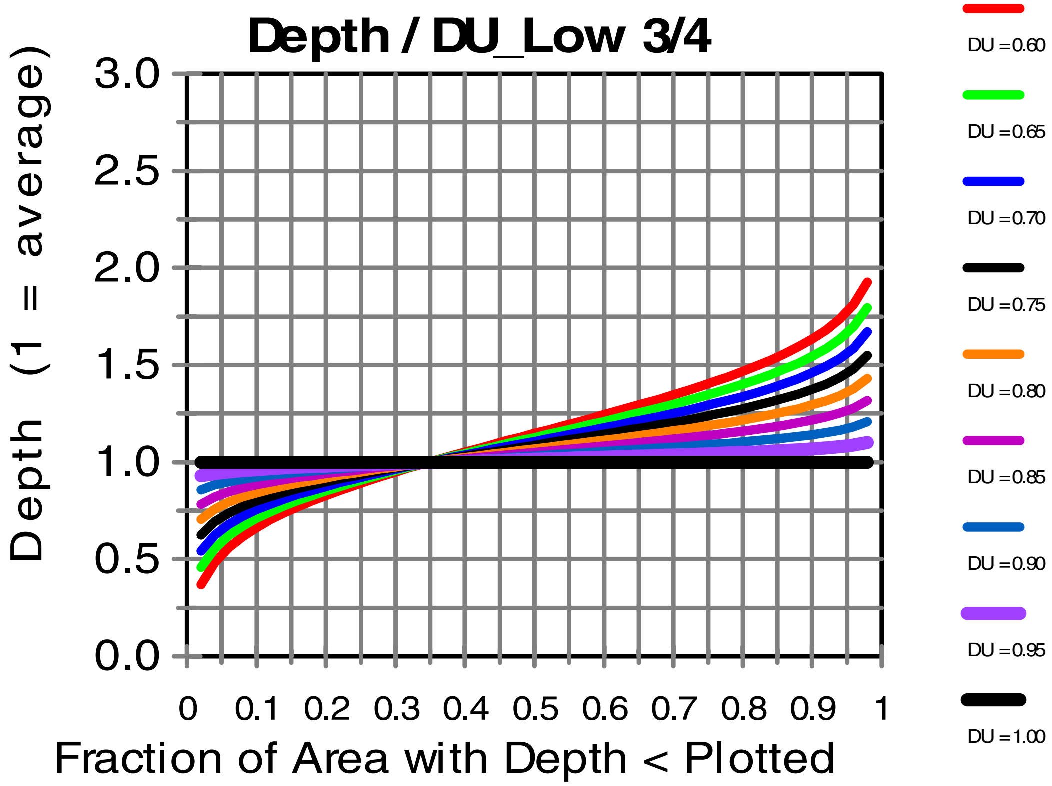


Figure 3.



Depth / DU_Low 3/4
Depth (1 = average)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Fraction of Area with Depth < Plotted
DU =0.60
DU =0.65
DU =0.70
DU =0.75
DU =0.80
DU =0.85
DU =0.90
DU =0.95
DU =1.00