Reduced Scheduling Multiplier for High Irrigation Distribution Uniformities

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Abstract. *The Irrigation Association has advanced the use of a SM (scheduling multiplier) to adjust landscape watering schedules based on the* DU_{LQ} *(distribution uniformity - low quarter) obtained from sprinkler audits using surface catchments. However the SM algorithm appears to be overly generous as* DU_{LQ} *increases.*

Present calculation: $SM = 1 / (0.4+0.6*DU_{LQ})$

Proposed calculation: $SM = 1/(0.352 + 0.72 * DU_{LQ})$

The proposed change would have minimal effect on calculation of the SM when DU_{LQ} *is 0.40, but would increasingly lower the calculated SM until SM reaches a minimum value of 1.0 when* DU_{LQ} *is 0.90 or greater.*

Keywords. Distribution uniformity, sprinkler audit, catch can test, scheduling multiplier, irrigation application efficiency.

Background and Methodology

Northern Water has hosted the Irrigation Association's Certified Landscape Irrigation Auditor class in January 2011, 2012, and 2013. A temporary sprinkler system was setup for these classes inside one end of a heated 20-stall vehicle garage. This system has six sprinklers on 15-ft square spacing, arranged to cover a 15-ft by 30-ft area.

The sprinkler system was constructed to allow placement of standard catchment devices on a grid spacing of 3.75-ft, for a total of 32 catchment locations. Up to three catchments can be positioned at each location, with care taken to insure the top of each device is at equal height with the others. Catchment height is established relative to a virtual ground surface at the top of the sprinkler bodies, so as to mimic catchment installation in the field.

During sprinkler tests, operating pressure is maintained at manufacturer specified levels. A flow meter provides gross irrigation application. This paper includes results from sprinkler catchment tests conducted by Northern Water staff (not class participants) to insure consistency of methods, procedures, and technique.

Indoor use of the temporary sprinkler system affords year-to-year standardization of the sprinkler system and catchment locations, along with elimination of wind effects. Every effort has been made to keep changes in sprinkler nozzles as the only variable of significance. Measurements at each station can thus be compared to corresponding measurements made at that same catchment station with a degree of confidence.

Measurements Uncertainty for Catchment Depth

In 2011 a sprinkler audit was performed with three types of catchments at each station. The test was replicated the following day with addition of a fourth type of catchment. Table 1 summarizes the measurements as standardized to volume in milliliters for the collection area of the CalPoly style catchment . The variability of measurements at each station reveals the uncertainty inherent in such measurements.

Table 1. Comparison of Measurements to CalPoly Style Catchment - January 20, 2011.

	CalPoly	Cereal Bowl	Reclamation	Rain Gauge
Number of catchments	32	32	32	32
Ave catch volume (ml)	22.72	22.72	22.72	22.90
Ave LQ catch (ml)	16.63	17.13	17.47	19.43
DU_{LQ}	0.73	0.75	0.77	0.85
Value just greater than highest of low quarter	20	21.87	19.96	21.63
R^2 from linear regression		0.65	0.82	0.36
Standard error from linear regression (ml)		2.63	1.88	3.58

During 2011 and 2012, four sprinkler audits were replicated (or triplicated) the same day, in an effort to determine repeatability of the audits. Measurements were again standardized to volume in milliliters for the collection area of the CalPoly style catchment . These tests are summarized in Table 2 and Table 3. Although the summary results would generally be considered quite close, the variability of individual measurements at each station yet reveals noise or uncertainty in these measurements.

SM calculated from DU_{LQ} indirectly adjusts for some spray, drift, and evaporation losses. DU_{LQ} is derived from net irrigation catchment rather than the gross irrigation applied. Hence some adjustment for application losses is already built-in.

Table 2. Comparison of Measurements from Replicated Audits - January 2011-2012.

	January 21, 2011		January 25, 2012	
	Rain Gauge 1	Rain Gauge 2	CalPoly A1	CalPoly A2
Number of catchments	32	32	32	32
Ave catch volume (ml)	74.95	76.72	22.34	22.91
Ave LQ catch (ml)	40.56	43.60	17.00	17.63
DU_{LQ}	0.54	0.57	0.76	0.77
Value just greater than highest of low quarter	48.67	54.08	20	21
R^2 from linear regression		0.95		0.94
Standard error from linear regression (ml)		6.18		1.09

Table 3. Comparison of Measurements from Replicated Audits - January 26, 2012.

	January 26, 2012		January 26, 2012		
	CalPoly B1	CalPoly B2	CalPoly C1	CalPoly C2	CalPoly C3
Number of catchments	32	32	32	32	32
Ave catch volume (ml)	43.09	42.38	31.56	32.38	31.84
Ave LQ catch (ml)	21.50	22.75	22.38	22.88	22.25
DU_{LQ}	0.50	0.54	0.71	0.71	0.70
Value just greater than highest of low quarter	30	33	27	28	27
R^2 from linear regression		0.95		0.94	0.93
Standard error from linear regression (ml)		3.86		2.05	2.18

In order to reduce the apparent noise in measurements at each catchment station, a multiple linear regression was accomplished for 17 catchment audits. The regressions provided calculated measurements at each station based on x-y spatial position. It was then possible to expand the 32 actual catchment stations to 800 virtual stations. Through the regression, measurement noise was reduced in the calculated values for catchment depth and high/low trends across areas were more readily identified. The

DU_{LQ} computed from these calculated measurement depths trended significantly higher with increasing DU_{LQ} than the original calculated DU_{LQ}.

The form of the multiple linear regression equation was:

$$\text{Catch (ml)} = C0 + C1*x + C2*y + C3*x*y + C4*x^2*y + C5*x*y^2 + C6*x^2 + C7*y^2$$

Results

Table 4 summarizes the results from the multiple linear regressions. Not all DU_{LQ} increased. In three cases, spatial trending of lower depth measurements captured by the multiple linear regression resulted in lower calculated DU_{LQ}.

Table 4. Comparison of DU_{LQ} and SM for 32 Actual vs. 800 Calculated Catchment Measurements.

	DU_{LQ} from 32 catchments	DU_{LQ} from 800 calculated catchments	DU_{LQ} change	SM for DU_{LQ} from 32 catchments	SM for DU_{LQ} from 80 calculated catchments
1	0.73	0.77	0.04	1.19	1.16
2	0.85	0.90	0.05	1.10	1.06
3	0.78	0.94	0.16	1.15	1.04
4	0.54	0.58	0.04	1.38	1.33
5	0.57	0.62	0.05	1.35	1.30
6	0.59	0.61	0.03	1.33	1.30
7	0.82	0.89	0.07	1.12	1.07
8	0.76	0.91	0.14	1.17	1.06
9	0.77	0.90	0.13	1.16	1.07
10	0.50	0.34	-0.16	1.43	1.65
11	0.54	0.49	-0.05	1.38	1.44
12	0.71	0.85	0.14	1.21	1.10
13	0.71	0.87	0.16	1.21	1.09
14	0.70	0.82	0.12	1.22	1.12
15	0.78	0.81	0.03	1.15	1.13
16	0.66	0.71	0.05	1.26	1.21
17	0.52	0.49	-0.03	1.40	1.44
Ave	0.68	0.74	0.06	1.25	1.21

Horizontal Movement of Soil Moisture

Assuming homogenous soils, uniform initial moisture content, and no hysteretic moisture content-pressure head relation, Elmaloglou, S., and Diamantopoulos, E., 2006 developed methodology for predicting the surface and vertical components of the wetting front under a point source emitter. They utilized the relations developed by van Genuchten, M.Th., 1980. Their results calculated a wetted radius of nearly 13.5 inches for a sandy loam soil and just over 16 inches for a silt loam, using class average values for two of the 12 USDA soil classes. This further corroborates the much relied upon phenomena of horizontal movement of water after it infiltrates the soil.

Consequently it is commonly assumed that soil moisture DU_{LQ} is higher than the DU_{LQ} calculated from surface catchments. However, DU_{LQ} may actually decrease in the presence of significant soil cracking, surface sealing, or similar conditions.

Irrigation Management to Improve Soil Moisture Distribution Uniformity

Elmaloglou, S., and Diamantopoulos, E., 2010 concluded for the same irrigation depth, same dripper spacing, and same soil that the vertical component of the wetted zone is deeper for a smaller/slower discharge rate than for a higher/faster one. Hence wetted radius would decrease and risk of deep percolation loss increase.

Application rates for sprinkler irrigation typically exceed steady state soil infiltration rates. The management practice of cycle and soak would help to maintain a higher/faster net application rate under sprinklers without causing surface runoff losses. This effectively increases horizontal soil moisture movement and increases soil moisture DU_{LQ}.

A second management practice to increase horizontal movement of soil moisture and thus increase soil moisture DU_{LQ} is to irrigate deeply and infrequently. Light, shallow irrigations simply do not provide the same opportunity for homogenizing soil moisture in the root zone.

Conclusions

The inherent variability of sprinkler catchment measurements creates random noise that artificially lowers higher DU_{LQ} and results in larger SM than necessary. Horizontal movement of soil water from wetter zones to dryer zones will further improve the soil moisture DU_{LQ} in the active root zone, particularly when surface catchment DU_{LQ} is higher. Additionally, several common irrigation management factors can further improve soil moisture DU_{LQ} over surface catchment DU_{LQ}.

Present calculation: $SM = 1 / (0.4+0.6*DU_{LQ})$

Proposed calculation: $SM = 1/(0.352 + 0.72 * DU_{LQ})$

The proposed change would not affect calculation of SM when DU_{LQ} is 0.40, and use of SM is not recommended for DU_{LQ} lower than 0.4. The new calculation of SM will have SM descend to 1.0 when DU_{LQ} is 0.90 or greater.

References

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