Comparison of Distribution Uniformities of Soil Moisture and Sprinkler Irrigation in Turfgrass

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Final report

Introduction:

This research was a study on the relationship of sprinkler distribution uniformity, DU, as measured with catch can tests and soil moisture distribution in the root zone. Observations by water managers have raised the issue that the use of lower-quarter distribution uniformity, DU_{LQ} for irrigation scheduling results in over watering of landscapes The Irrigation Association (IA) proposes in their recent water management publications, the use of the lower-half distribution uniformity, $DU_{LH,}$ for landscape irrigation scheduling. There is particular interest in the relationship between DU as determined by a catch can test and the distribution of water in the soil.

Irrigation scheduling, specifically the runtime calculation, is based on irrigation efficiency which is determined by irrigation management efficiency and the distribution uniformity, DU. Catch can uniformity data is used to calculate sprinkler low quarter distribution uniformity, DU_{LQ} for irrigation scheduling purposes. The applied irrigation water can move laterally as surface flow when the soil surface layer is saturated, and laterally and vertically due to capillary action in the soil. This redistribution of water in the soil may result in a more uniform distribution of water available for plant use than the DU_{LQ} catch can data would suggest.

Objective:

1. To determine time dependent relationship between catch can distribution uniformity DU_{LQ} and soil moisture DU_{LQ}.

Recent Studies

A study in Colorado (Mecham 2001) compared the DU_{LQ} based on catch cans and a DU_{LQ} for soil moisture at the catch can locations. For example one irrigation zone had a catch can DU_{LQ} of 68% and DU_{LQ} in the soil of 87%. The author suggested use of DU_{LH} , based on the lowest half of the catch can readings, for scheduling. A preliminary California study (Curry 2004) found that the soil DU_{LQ} values were an average of 33% higher than the catch can DU_{LQ}. An additional find was that the soil moisture DU_{LQ} was similar to the catch can DU_{LH} in clay soils with turfgrass. The results appear to be similar in both studies and suggest use of DU_{LH} for turfgrass irrigation scheduling can maintain turf quality and reduce the amount of water applied. Based on these studies and the Irrigation Association recommendation (Landscape Irrigation Scheduling and Water Management 2003) in their draft document for use of DU_{LH}, this study expanded the work done by Curry for Southern California turfgrass over a longer time frame.

Methods and Procedures:

Three turf plots with different soil and turf conditions were setup for this project. At the beginning of the project several procedures to collect catch can data sprinkler distribution and measurements of volumetric soil moisture were explored and evaluated. The procedures selected were: 1) to do a catch can test two times, once before the beginning of the tests and once after all tests were completed for each plot, 2) measure the volumetric soil moisture with time-domain reflectometry (Field Scout TDR 300, Spectrum Technologies, Inc.[1]).

Each plot had 49 points uniformly distributed(equidistant from each other) throughout the plots for catch can locations. For each irrigation event, TDR readings were recorded within one hour before the irrigation, and 1, 2, 6, 24, and 48 hour intervals after the irrigation for a total of 245 TDR readings after each irrigation event. Soil moisture was measured within one foot diameter of each catch can location. Since 6 TDR measurements were taken at each location over a 2 day period, the TDR probe locations were rotated in this one foot diameter area to minimize the effect of the probes on the soil.

Table 1 gives additional information for each plot.

Table 1. Summary of turf plot and data collection information.

Plot Number	**Soil**	**Turf**	**Irrigation System**	**Catch Can DU_{LQ}(Ave of 2 tests)**	**TDR Probe Length**
1	Clay Loam	Fescue, good condition	Half Circle Rotor Sprinklers, 35 ft spacing, Pr = 0.44 in/hr	73%, 5 foot square spacing for catch cans, 49 cans	4.8 inch(12 cm)
2	Sandy Clay Loam	Fescue, new planting, medium conditions	Quarter Circle Rotor Sprinklers, 50 ft Spacing, Pr = 1.4 in/hr	72%,7 foot square spacing for catch cans, 49 cans	3 inch(7.5 cm)
3	Sandy Loam	Fescue, good condition, 4 - 6 inch height	Full Circle Rotor Sprinklers, 50 ft Spacing, Pr = 0.36 in/hr	65%, 7 foot square spacing for catch cans, 49 cans	4.8 inch(12 cm)

The irrigation systems were tuned up before the tests to correct arc orientation, vertical plumb, and head height. Three inch probes on the TDR were used on plot 2 because the soil was compacted with poor infiltration and the 4 inch probes could not be inserted to their full length. There were about 8 locations out of the 49 locations in this plot where the TDR could not be used with the 3 inch probes.

The TDR probe developed problems and had to be rebuilt with new firmware in midsummer; only the data with the new TDR are included in this report. Therefore, 3 irrigation events are included in the plot 1 results and 6 irrigation events for plots 2 and 3.

1. Mention of trade names or other proprietary information is made for convenience of the reader and does not imply endorsement by authors.

Results:

Comparison of the distribution uniformities in figure 1 show that the soil moisture distribution had a higher DU_{LQ} than the catch can DU_{LQ} for all three sites. The Mean TDR DU_{LQ} is the mean volumetric moisture content(VMC) of soil based on 49 measurements with the TDR probe for each time interval of 1, 2 , 6, 24, and 48 hours after the irrigation.

The Mean CC DU_{LQ} is the mean of two catch can tests, one test before the series of irrigations at each plot and one immediately after the last data collection at that site.

The soil moisture DU_{LQ} was equal or greater than the mean catch can DU_{LQ} values.

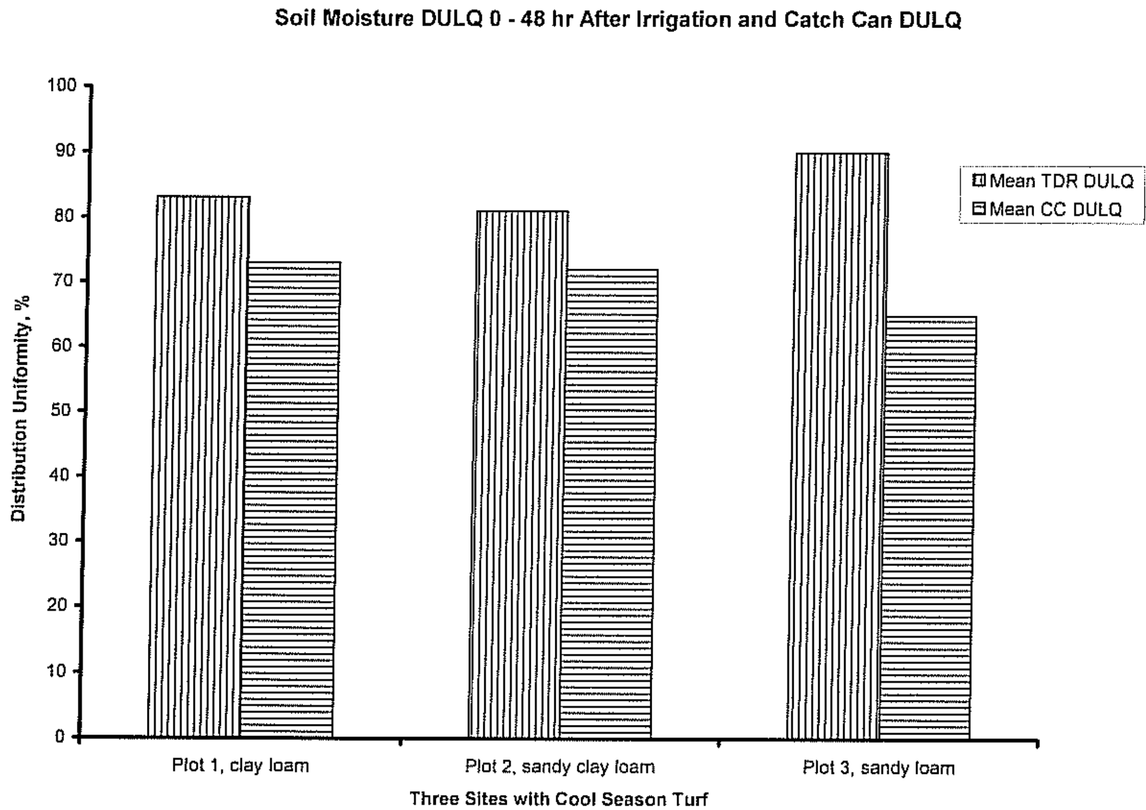

Figure 1. Comparison of distribution uniformity for the soil moisture after irrigation (Mean TDR DU_{LQ}) and sprinkler catch can distribution(Mean CC DULQ).

The largest difference between the catch can and soil moisture DU_{LQ} was at the plot 3 site for 1, 2 and 6 hours after the irrigation (Figure 2). The catch can DU_{LQ} was lower at this site and the turf quality is good, dense turf, maintained at approximately 4 - 6 inch height. The dense turf may contribute to more dispersion of the applied sprinkler water and higher level of irrigation management at this site may contribute to the high soil moisture DU. Mean soil moisture distribution was higher than catch can distribution uniformity for all sites for each time interval.

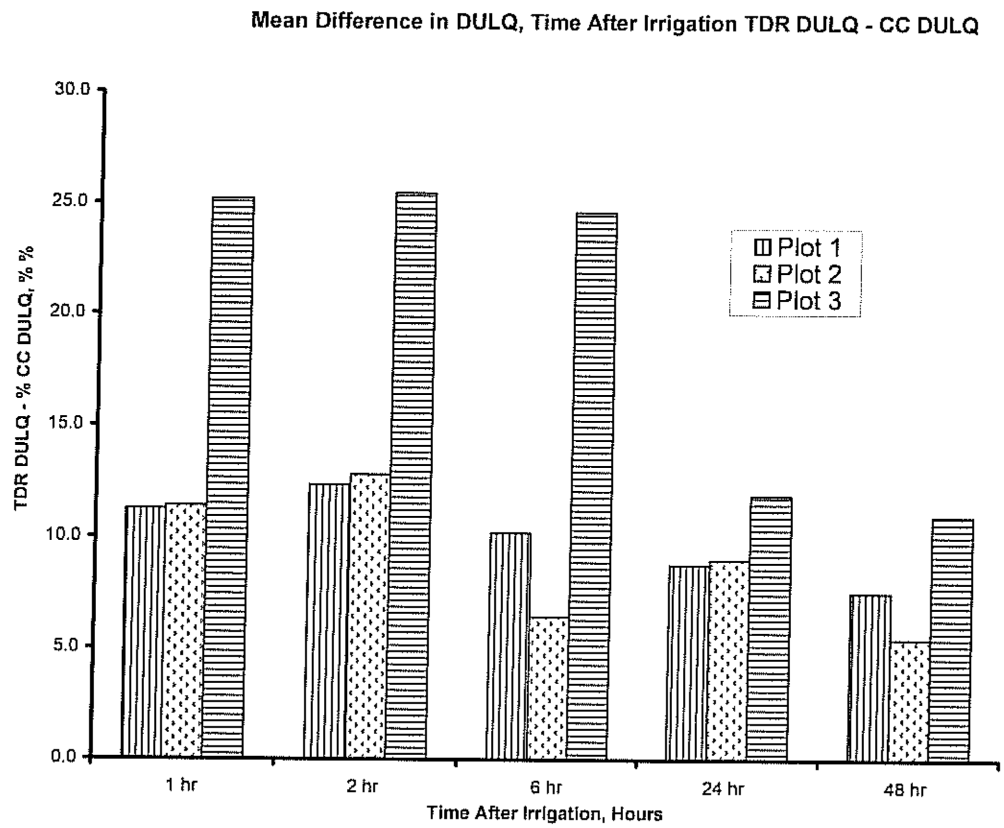

Figure 2. Summary of the differences between the catch can DU_{LQ} and soil moisture DU_{LQ} at the indicated time after irrigation.

When the catch can DU_{LQ} was used for irrigation scheduling purposes in the calculation of the runtime there is about 17% difference in the runtime determined by soil moisture DU_{LQ}. Some recent discussions suggest that use of DU_{LQ} for irrigation scheduling results in excess water being applied. These results along with previous studies may give grounds for using a different metric such as the DU_{LH} based on catch cans.

The equation in the IA publication, Landscape Irrigation Scheduling and Water Management, $DU_{LH} = 38.6 + (0.614 * DU_{LQ})$, can be used to calculate the DU_{LH} based on the DU_{LQ}, or the DU_{LH} can be calculated directly from the catch can data. The catch can DU_{LH} is 82% when calculated using the above equation with a 70% mean CC DU_{LQ} (overall mean for the 3 plots). The DU_{LH} is 80% when calculated directly from the catch data. DU_{LH} of 80% or 82% is a better indicator of the mean soil moisture DU_{LQ} of 85% than the catch can DU_{LQ} of 70% for this study (Table 2). The question of turf quality with irrigation water management based on the DU_{LH} was not addressed in this study.

Table 2. Summary of mean volumetric soil DU_{LQ} (TDR), mean catch can DU_{LQ} (CC) and calculated runtime multipliers.

	Mean TDR DU_{LQ} Soil	Runtime Multiplier Soil	Mean CC DU_{LQ} Sprinkler	Runtime Multiplier Sprinkler
Plot 1, clay loam	83	1.20	73	1.40
Plot 2, sandy clay loam	81	1.23	72	1.39
Plot 3, sandy loam	90	1.11	65	1.54
Mean of three sites	85	1.18	70	1.43

The catch can DU_{LQ} for both catch can tests at the plot 2 location were very similar and the hourly wind speed recorded at a nearby CIMIS weather station were nearly the same for both test dates (Table 3). Distribution uniformities for the two catch can tests at the CIMIS site(Plot 3) were 74 with 2.8 MPH and 55 at 4.2 MPH wind. This site is an open area and the wind appears to affect the CC DU_{LQ} substantially. There was a 2.9 MPH difference in wind speeds at the Plot 1 area that resulted in a small difference in CC DU_{LQ}. However, this plot is surrounded with some trees and buildings which may have limited the effects of wind on catch can DU_{LQ} at this site.

Table 3. Wind speed during the catch can tests.

Date	Hour	Wind Speed (MPH)	Catch Can DU_{LQ}, %	Location
4/18/2005	1100	5.6	69	Plot 1
10/21/2005	1000	2.7	77	
			Ave = 73	
9/14/2005	1000	3.0	71	Plot 2
11/23/2005	800	2.9	72	
			Ave = 72	
9/13/2005	1000	2.8	74	Plot 3
11/23/2005	900	4.2	55	
			Ave = 65	

Summary and Conclusions:

Three plots with cool season turf and rotor sprinklers were monitored to compare catch can DU_{LQ} and soil moisture DU_{LQ}. Soil moisture was measured with a TDR with 4 inch probes on two plots and 3 inch probes on one plot at 1, 2, 6, 24, and 48 hours after the irrigation. The series of measurements were analyzed for 6 irrigation events for plots 2 and 3, and 3 irrigation events for plot 1.

1. The mean soil moisture DU_{LQ} was 85% and when combining data from the three plots for time after irrigation from 1 to 48 hours. The mean catch can DU_{LQ} was 70%.
2. The DU_{LH} was 82% when calculated from the equation in IA publications and 80% calculated directly from the catch can data. The soil moisture DU_{LQ} was 85%. This data may suggest that the catch can DU_{LH} may better represent the soil moisture distribution in the 3 – 4 inch root zone.

3. Irrigation scheduling based on the soil moisture DU_{LH} would apply about 17% less water than using the catch can DU_{LQ}.
4. The largest differences between soil moisture and catch DU's were at Plot 3 at the 1, 2, and 6 hour measurements. This weather station site has very dense turf maintained at a 4 – 6 inches height which may contribute to a more uniform distribution of the irrigation water in the soil.

References:

1. Curry, C. 2004. Comparison of Catch Can and Soil Moisture Distributions. Unpublished Project. Cal Poly University Pomona.
2. Mechan, B. 2001. Distribution Uniformity Results Comparing Catch-Can Tests and Soil Moisture Sensor Measurements in Turfgrass Irrigation. Irrigation Association 2003 Conference Proceedings.
3. Ossa, J. (committee chairman). 2005. Landscape Irrigation Scheduling and Water Management Irrigation Association http://www.irrigation.org/gov/pdf/IA_LISWM_MARCH_2005.pdf. Accessed March 28, 2006

Appendix

Page:

1. Plot 1 Golf Rough Data (three dates only)
2. Plot 1 Golf Rough Data (all dates)
3. Plot 2 Tractor Shop Data
4. Plot 3 CIMIS Weather Station Data
5. Sample data for TDR soil moisture measurements
6. Sample data for sprinkler catch can tests

Revised Data												
Golf Rough												
7 Points remov.	Soil TDR LQDU						Catch Can					
Date	Pre	1 Hour	2 Hour	6 Hour	24 Hour	48 Hour	CC LQDU					
6/6/2005							69					
6/20/2005							77					
7/27/2005	82	84	82	81	84	78						
9/8/2005	83	86	88	86	81	81						
9/14/2006	79	83	86	82	80	83						
Ave by time	81	84	85	83	82	81	73					

Removed seven points adjacent to fairway							Difference in DU between CC and TDR VMC by Time					
Date	1 hr - Pre	2 hr - Pre	6 hr - Pre	24 hr - Pre	48 hr - Pre		1 hr - CC	2 hr - CC	6 hr - CC	24 hr - CC	48 hr - CC	
6/6/2005												
6/20/2005												
7/27/2005	1.58	-0.50	-0.80	2.04	-4.61		10.82	8.75	8.44	11.29	4.64	
9/8/2005	2.56	5.07	3.20	-1.98	-2.21		12.53	15.04	13.17	7.99	7.76	
9/14/2006	4.30	7.11	2.89	1.01	4.08		10.39	13.19	8.98	7.10	10.17	
Ave by Time	2.81	3.89	1.76	0.36	-0.91		11.25	12.33	10.20	8.79	7.52	

	Revised*:use dates 7/27 - 9/8 only for golf rough					
	Ave TDR Diff, Time - CC DU					
	1 hr	2 hr	6 hr	24 hr	48 hr	
Plot 1	11.2	12.3	10.2	8.8	7.5	Golf rough
Plot 2	11.4	12.8	6.4	9.0	5.4	Tractor Shop
Plot 3	25.2	25.5	24.6	11.9	11.0	CIMIS

* The two June dates for golf rough were deleted because they used the older TDR. The new TDR was used for all the data in this table

Golf Rough

Catch Can				
Date	DULQ	Pr.	Time	Runtime
4/18/2005	69	0.44	11:30 AM	15
10/21/2005	77	0.44	10:00 AM	15

All points	Soil TDR DULQ, %						Catch Can	
Date	Pre	1 Hour	2 Hour	6 Hour	24 Hour	48 Hour	CC DULQ	DULH
6/6/2005	0	63	71	63	62	66	69	80
6/20/2005	56	64	65	60	56	44	77	85
7/27/2005	81	83	82	80	82	76	0	0
9/8/2005	82	84	88	86	82	81	0	0
9/14/2006	78	84	85	82	79	82	0	0
Ave by time	74	76	78	74	72	70	73	83

Removed seven points adjacent to fairway, Soil TDR DULQ, %							
Date	Pre	1 Hour	2 Hour	6 Hour	24 Hour	48 Hour	CC DULQ
6/6/2005		65	71	64	62	71	69
6/20/2005	60	69	70	63	62	48	77
7/27/2005	82	84	82	81	84	78	
9/8/2005	83	86	88	86	81	81	
9/14/2006	79	83	86	82	80	83	
Ave by time	76	77	79	75	74	72	73

Removed seven points adjacent to fairway

	Soil TDR DULQ and TDR VMC							Average	
Date	Pre	1 Hour	2 Hour	6 Hour	24 Hour	48 Hour		TDR VMC	TDR DULQ
6/6/2005		65	71	64	62	71	TDR DULQ		
		80	91	89	84		TDR VMC		
6/20/2005	60	69	70	63	62	48	TDR DULQ		
	30	70	67	64	51	41	TDR VMC		
7/27/2005	82	84	82	81	84	78	TDR DULQ	57	82
	47	62	66	62	54	50	TDR VMC		
9/8/2005	83	86	88	86	81	81	TDR DULQ	73	84
	69	76	74	80	69	71	TDR VMC		
9/14/2006	79	83	86	82	80	83	TDR DULQ	69	82
	61	77	77	69	62	67	TDR VMC		

Tractor Shop

Soil Texture: Sandy Clay Loam

Catch Can

Date	DULQ	Pr.	Time	Runtime
9/14/2005	71	1.42	10:00 AM	10
11/23/2005	72	1.4	9:00 AM	10

All points	Soil TDR DULQ						Catch Can	
Date	Pre	1 Hour	2 Hour	6 Hour	24 Hour	48 Hour	CC DULQ	CC DULH
9/15/2005	73	81	83	78	73	71	71	81
9/22/2005	69	81	78	79	76	67	72	81
9/30/2005	73	87	86	73	79	75	0	
10/27/2005	75	81	90	85	87	83	0	
11/10/2005	74	88	90	85	90	86	0	
11/22/2005	69	79	79	69	78	79	0	
Ave by Time	72	83	84	78	81	77	72	81

All points	Soil TDR DULQ and TDR VMC							Average	
Date	Pre	1 Hour	2 Hour	6 Hour	24 Hour	48 Hour		TDR VMC	TDR DULQ
9/15/2005	73	81	83	78	73	71	TDR DULQ	64	76
	57	74	74	67	60	55	TDR VMC		
9/22/2005	69	81	78	79	76	67	TDR DULQ	60	75
	50	68	66	67	55	51	TDR VMC		
9/30/2005	73	87	86	73	79	75	TDR DULQ	49	79
	41	65	64	35	45	43	TDR VMC		
10/27/2005	75	81	90	85	87	83	TDR DULQ	48	83
	43	53	51	50	48	45	TDR VMC		
11/10/2005	74	88	90	85	90	86	TDR DULQ	49	86
	37	54	57	48	48	51	TDR VMC		
11/22/2005	69	79	79	69	78	79	TDR DULQ	44	76
	28	53	54	44	46	41	TDR VMC		

CIMIS Weather Station									
Soil Texture: Sandy Loam and Sandy Clay Loam									
Catch Can									
Date	DULQ	Pr.	Time	Runtime					
9/13/2005	74	0.36	9:52 AM	20					
11/23/2005	55	0.36	9:38	20					
All points	Soil TDR DULQ, %						Catch Can		
Date	Pre	1 Hour	2 Hour	6 Hour	24 Hour	48 Hour	CC DULQ	CC DULH	
9/19/2005	90	93	92	91	0	0	74	83	
9/22/2005	93	93	93	95	93	92	55	67	
9/30/2005	87	85	85	84	85	83	0		
10/27/2005	92	93	93	94	95	92	0		
11/10/2005	91	89	92	85	97	97	0		
11/21/2005	88	86	85	86	89	88	0		
Average by ti	90	90	90	89	92	91	65	75	
	Soil TDR DULQ and TDR VMC							Average for date	
Date	Pre	1 Hour	2 Hour	6 Hour	24 Hour	48 Hour		TDR VMC	TDR DULQ
9/19/2005	90	93	92	91	0	0	TDR DULQ	52	91
	44	55	55	52			TDR VMC		
9/22/2005	93	93	93	95	93	92	TDR DULQ	53	93
	52	55	52	56	49	53	TDR VMC		
9/30/2005	87	85	85	84	85	83	TDR DULQ	42	85
	42	46	45	41	40	36	TDR VMC		
10/27/2005	92	93	93	94	95	92	TDR DULQ	48	93
	46	49	55	50	47	43	TDR VMC		
11/10/2005	91	89	92	85	97	97	TDR DULQ	47	91
	39	48	53	45	43	50	TDR VMC		
11/21/2005	88	86	85	86	89	88	TDR DULQ	41	87
	36	44	42	41	44	41	TDR VMC		

Soil Data Sheet
Location: CIMIS
Date Irrigated 9/22/2005
Run Time In Minutes=60
Units - Centibars (cb)
Raw Data

	Date Collected Time Collected 9/22/2005 8:15 AM	Date Collected Time Collected 9/22/2005 10:23AM	Date Collected Time Collected 9/22/2005 11:30 PM	Date Collected Time Collected 9/22/2005 3:25 PM	Date Collected Time Collected 9/23/2005 11:30 AM	Date Collected Time Collected 9/24/2005 11:30 AM
Time/Date after Irrigation	Pre-Irrigation	1 Hour	2 Hours	6 Hours	24 Hours	48 Hours
Point	Soil Moisture	Soil Moisture	Soil Moisture	Soil Moisture	Soil Moisture	Soil Moisture
1	52	52	52	55	48	50
2	57	60	51	62	58	58
3	54	55	50	57	47	50
4	48	53	52	55	46	46
5	49	50	50	55	47	50
6	53	53	55	58	49	48
7	56	57	59	57	51	58
8	48	58	50	54	47	51
9	49	51	49	57	46	48
10	47	51	49	51	45	48
11	53	53	48	54	46	49
12	49	51	49	57	48	47
13	55	54	56	53	48	54
14	53	56	51	55	54	57
15	52	56	59	57	55	55
16	53	56	50	59	50	55
17	51	55	52	54	45	50
18	51	52	51	54	46	54
19	55	52	51	55	49	55
20	54	56	56	56	47	54
21	54	58	55	57	52	52
22	54	62	50	56	56	53
23	54	59	53	58	50	57
24	52	55	53	54	46	57
25	48	52	53	52	45	51
26	50	55	56	54	53	53
27	51	56	55	55	48	48
28	52	56	55	55	44	56
29	48	54	42	53	53	53
30	54	53	53	51	50	50
31	49	47	51	53	44	49
32	48	53	54	56	41	49
33	52	51	50	58	46	51
34	53	54	53	56	49	52
35	57	58	53	59	52	59
36	59	59	57	62	49	57
37	54	57	55	57	49	54
38	53	52	50	56	46	50
39	51	50	48	51	47	51
40	49	53	50	54	47	50
41	54	52	50	54	46	50
42	54	54	52	53	46	50
43	54	60	55	60	49	60
44	47	55	57	56	49	56
45	54	53	55	54	52	55
46	53	56	52	54	48	53
47	53	56	47	55	53	58
48	56	55	54	58	52	61
49	57	63	58	64	52	55
	52.3	54.7	52.4	55.7	48.7	52.8
L Q DU	0.93	0.93	0.93	0.95	0.93	0.92

Sorted Data

Pre-Irrigation	1 Hour	2 Hours	6 Hours	24 Hours	48 Hours
Soil Moisture	Soil Moisture	Soil Moisture	Soil Moisture	Soil Moisture	Soil Moisture
59	63	59	64	58	61
57	62	59	62	56	60
57	60	58	62	55	59
57	60	57	60	54	58
56	59	57	59	53	58
56	59	56	59	53	58
55	58	56	58	53	57
55	58	56	58	52	57
54	58	55	58	52	57
54	57	55	58	52	57
54	57	55	57	52	56
54	56	55	57	52	56
54	56	55	57	51	55
54	56	55	57	50	55
54	56	55	57	50	55
54	56	54	57	50	55
54	56	54	57	49	55
54	56	53	56	49	54
54	56	53	56	49	54
53	55	53	56	49	54
53	55	53	56	49	54
53	55	53	56	49	53
53	55	53	56	49	53
53	55	52	55	48	53
53	55	52	55	48	53
53	54	52	55	48	52
53	54	52	55	48	52
52	54	52	55	48	51
52	54	51	55	47	51
52	53	51	55	47	51
52	53	51	55	47	51
52	53	51	54	47	50
51	53	51	54	47	50
51	53	50	54	47	50
51	53	50	54	46	50
51	53	50	54	46	50
50	52	50	54	46	50
49	52	50	54	46	50
49	52	50	54	46	50
49	52	50	54	46	50
49	52	50	54	46	49
49	52	50	53	46	49
48	51	49	53	46	49
48	51	49	53	45	48
48	51	49	53	45	48
48	51	48	52	45	48
48	50	48	51	44	48
47	50	47	51	44	47
47	47	42	51	41	46
48.4	51.0	48.6	52.8	45.1	48.6

CATCH CAN DATA SHEET FOR CALCULATING DU AND PR

Location: CIMIS

Cal Poly CATCHMENT DIAMETER (IN) =
CATCHMENT AREA (In2) = 3.14d2/4= 15.90
RUNTIME (MIN) = 20 20

Date: 9/13/2006
Time of Irrigation:
Catch Can Run Time: 20
Irrigation total run time
Weather
Data Collectors Name Vis

Data Entered By
Date Data Entered

CATCH CAN MEASUREMENT (ml)

Raw Field Data CAN #	Sprinkler Volume, ml	*Sorted Field Data From High to Low* Sprinkler Volume, ml
1	22	56
2	32	42
3	25	40
4	30	40
5	30	38
6	20	37
7	40	37
8	35	37
9	30	37
10	35	35
11	30	35
12	25	35
13	35	35
14	56	35
15	40	35
16	37	35
17	24	35
18	25	35
19	37	33
20	38	33
21	35	33
22	35	33
23	35	32
24	33	32
25	23	30
26	28	30
27	30	30
28	37	30
29	30	30
30	35	30
31	25	30
32	30	30
33	33	30
34	35	28
35	32	28
36	35	28
37	37	26
38	28	25
39	33	25
40	28	25
41	30	25
42	20	25
43	42	24
44	25	24
45	24	23
46	26	22
47	30	20
48	33	20
49	18	18
AVE =	31.24	LQ Ave = 23

LQ DU =	0.74
RTM =	1.34

PR = (AVE X 3.66)/(RUNTIME X CATCHMENT AREA)

PR (in/hr) = 0.36

Water meter reading	
start	cubic feet
end	cubic feet
total	cubic feet
gpm =	0.00