Liquid Asset Management:

Design, Chemical and Cultural Considerations to Stretch Irrigation Supplies

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Irrigation & Turfgrass Services
Dana Point, CA

Today's Topic: Water Use Efficiency

"I believe that the organizers of this conference have chosen a very timely subject for our discussion - because the 21st century will confront us with an entirely new set of challenges."

Lord Robertson – NATO Secretary General

The Value of Water

$150 to $3,000 AF
$0.34 to $6.90 CCF

$325,851 AF
$748 CCF

$724,114 AF
$1664 CCF

$351,980 AF
$809 CCF

$410,141 AF
$942 CCF

Sports Event, Airport, etc.

$3.00 /16 oz

$7,820,424 AF
$17,977 CCF

Efficiency & Uniformity: Man vs. Equipment

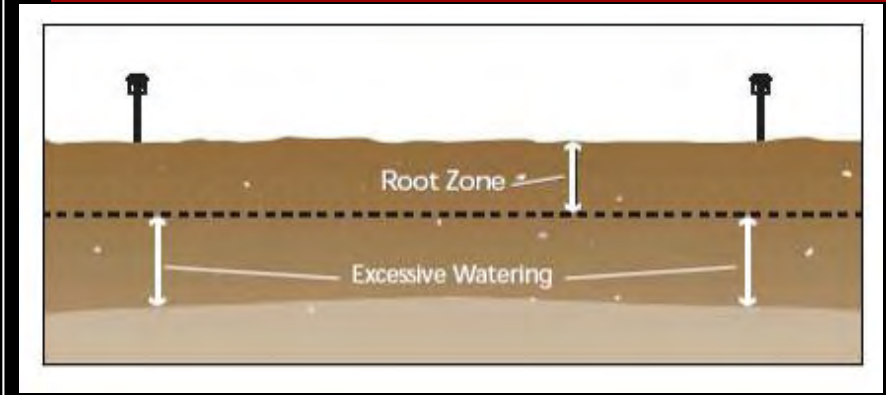
"You can't always get what you want,
But if you try sometimes well you might
find you get what you need"

The Rolling Stones

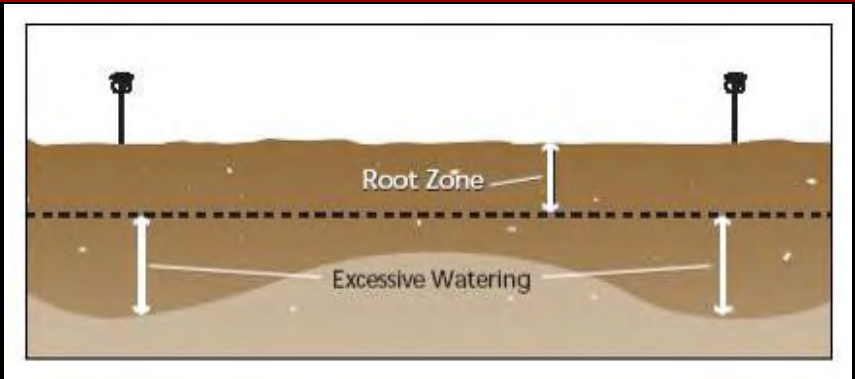
Irrigation Efficiency (IE) Vs Distribution Uniformity (DU)

- IE = The amount, percentage or ratio of water used by the plant compared to the amount of water applied that includes runoff and deep percolation
- DU = A measure of how uniformly water is applied to the area being watered, expressed as a percentage

Why uniformity & efficiency are important for water conservation.



Poor Efficiency & Good Uniformity



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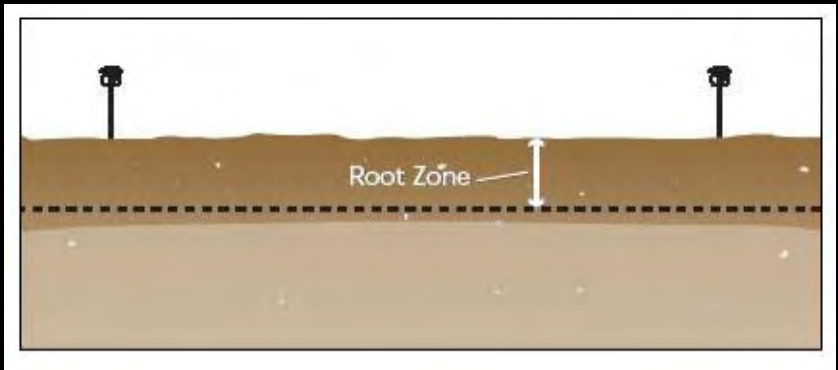

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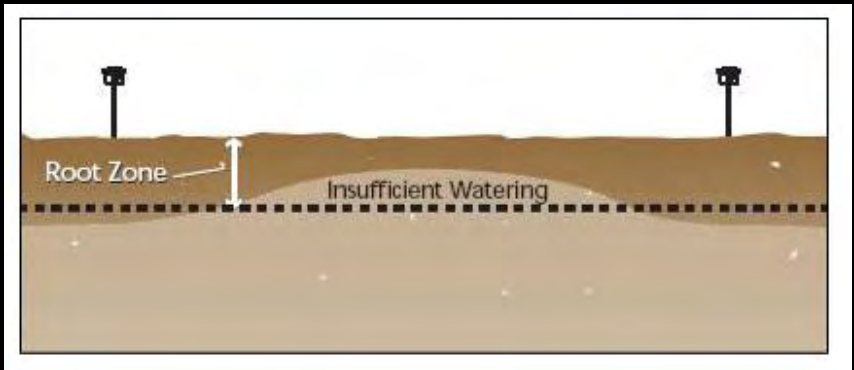


Good Efficiency & Poor Uniformity

Highest concentrations of salts will be at the leading edge of the wetting front

Summary Report of Performance Evaluations on Lawn Sprinkler Systems

- Based upon combined data of 6800 audits
  - A few sprinkler systems performed exceptionally well with DU in the high 70's to mid 80's had theses things in common:
    - Precise (uniform) spacing
    - Correct water (uniform) pressure for the type of head
    - Correct (& uniform sized) nozzles and arcs
    - Heads were set in the ground properly / level
  - Report by Brent Mecham – Northern Colorado Water Conservation District

Irrigation Design, Rocket Science and the *SPACE* Program

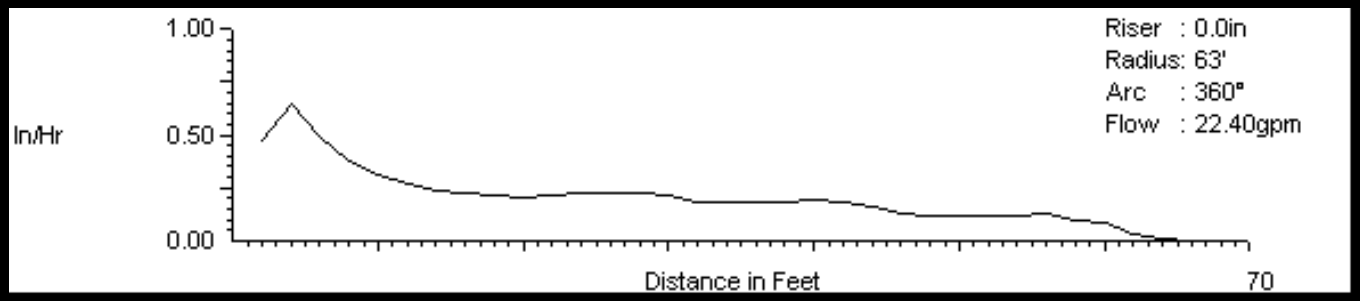
To Infinity & Beyond

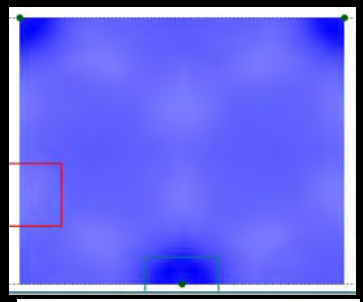
Buzz Lightyear

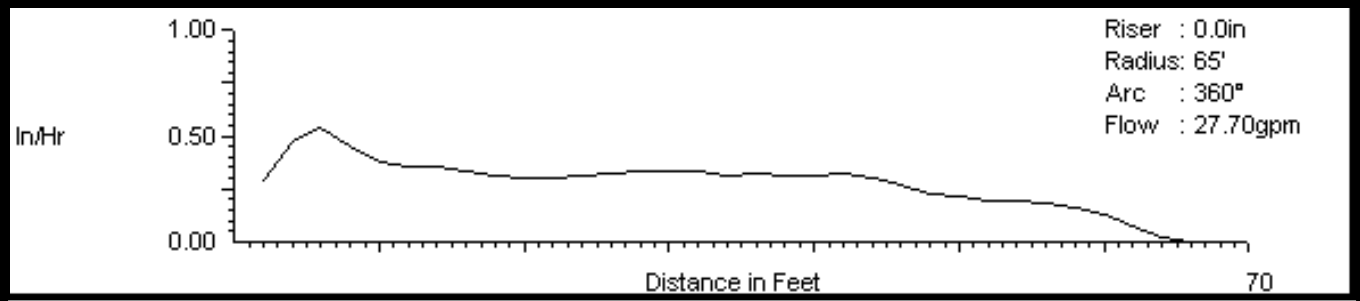
Uniformity Myth, Half Truth

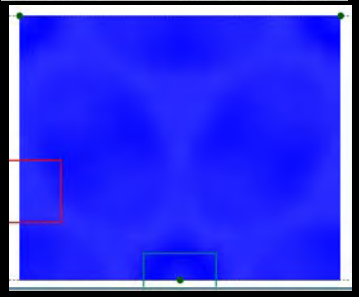
- We are led to believe “head to head coverage provides optimum uniformity”
  - Half truth as results depend also on the application profile shape and sprinkler layout.
- Question: Has anyone here evaluated sprinklers / nozzles with CIT SPACE data from Cal State Fresno?
  - SPACE data cannot assure success, but can guarantee avoiding failure!

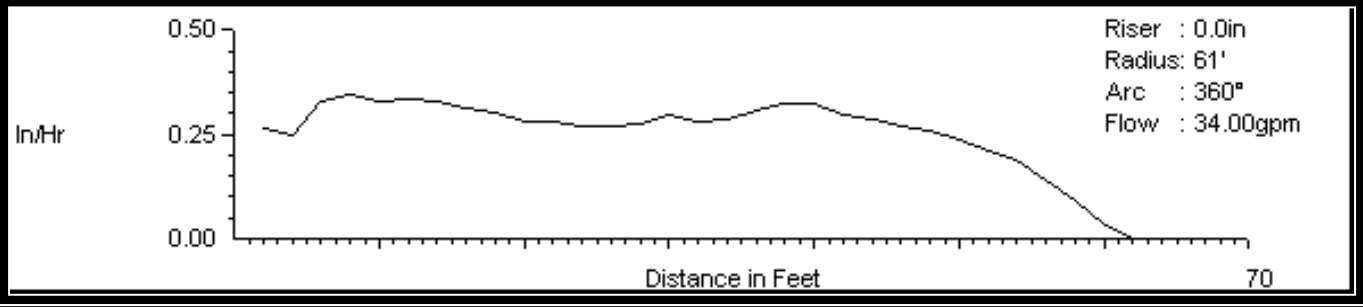
Profiling Sprinkler Performance

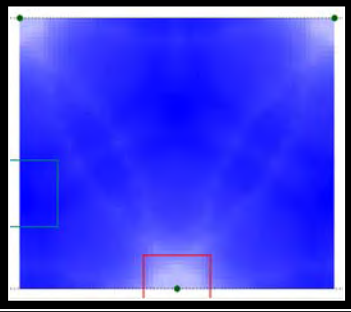






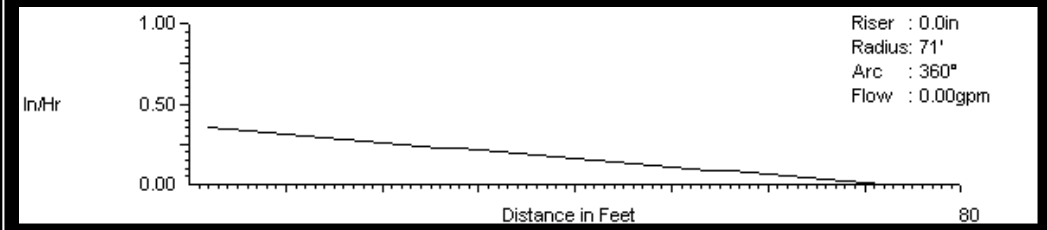


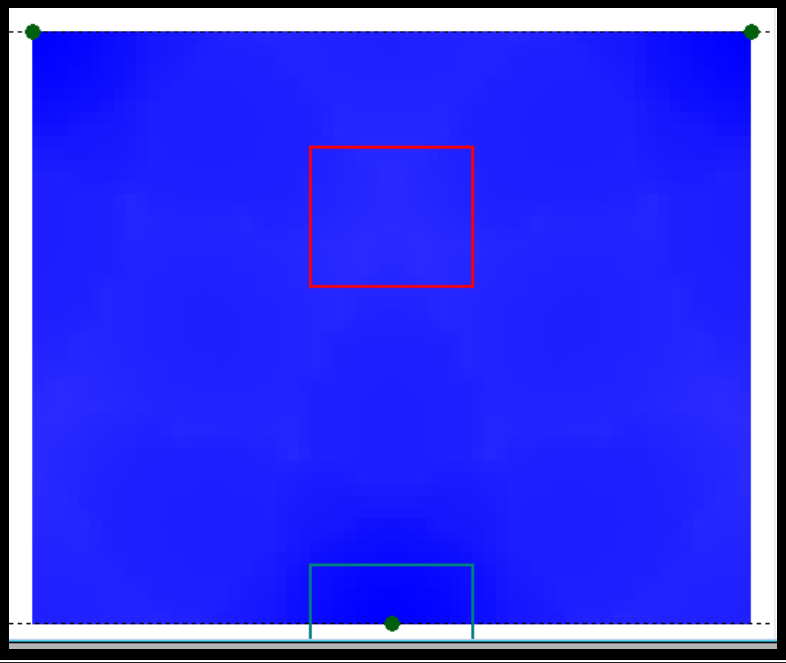


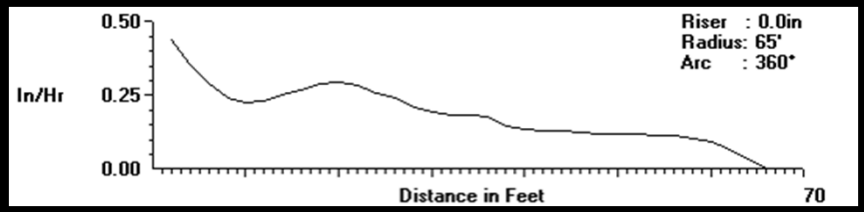


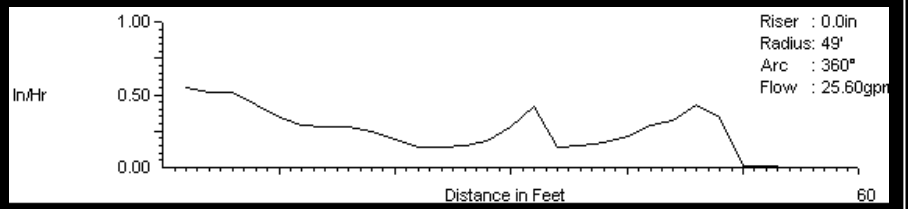
The Theoretical Ideal

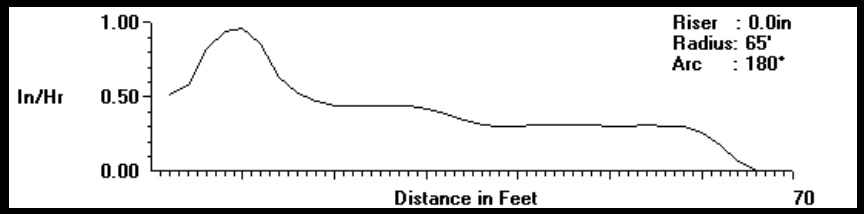
Triangular Spacing & Wedge Profile

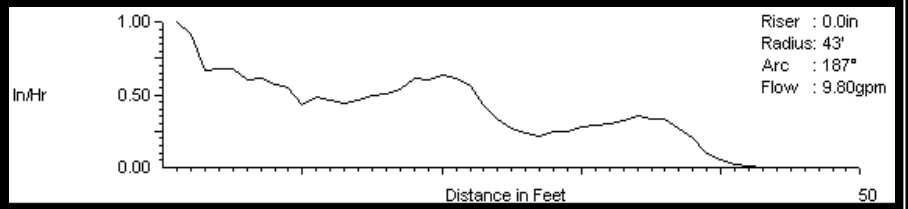


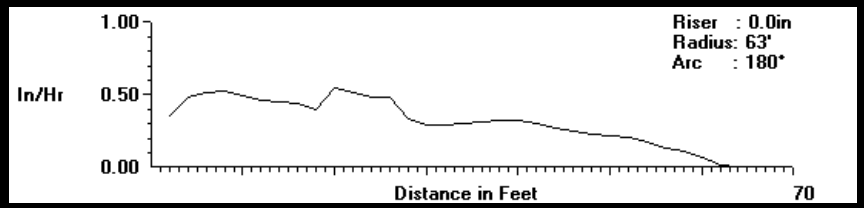


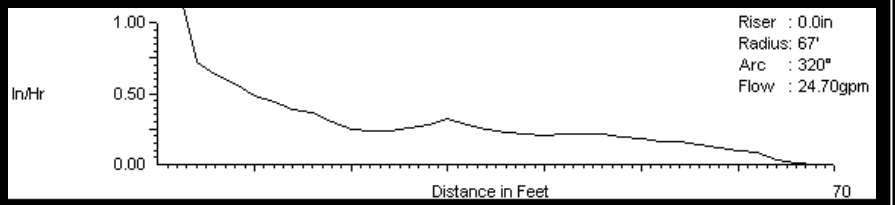


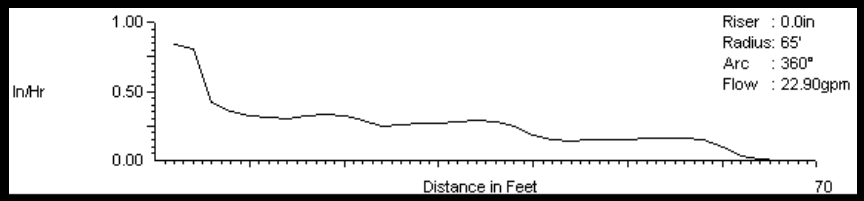


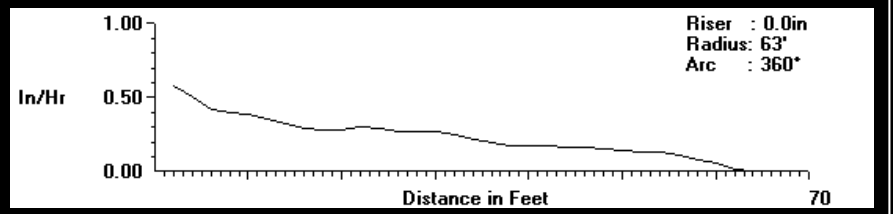


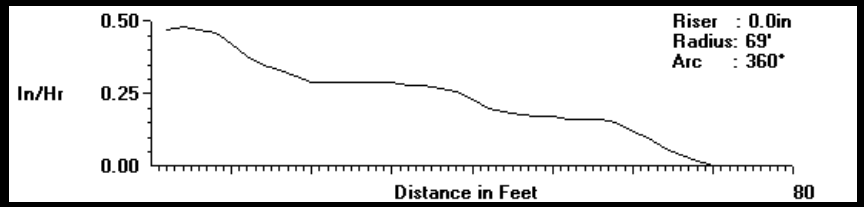


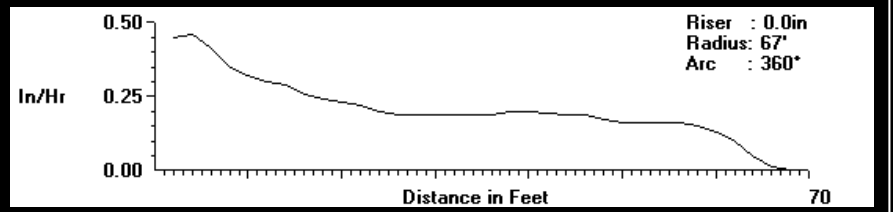






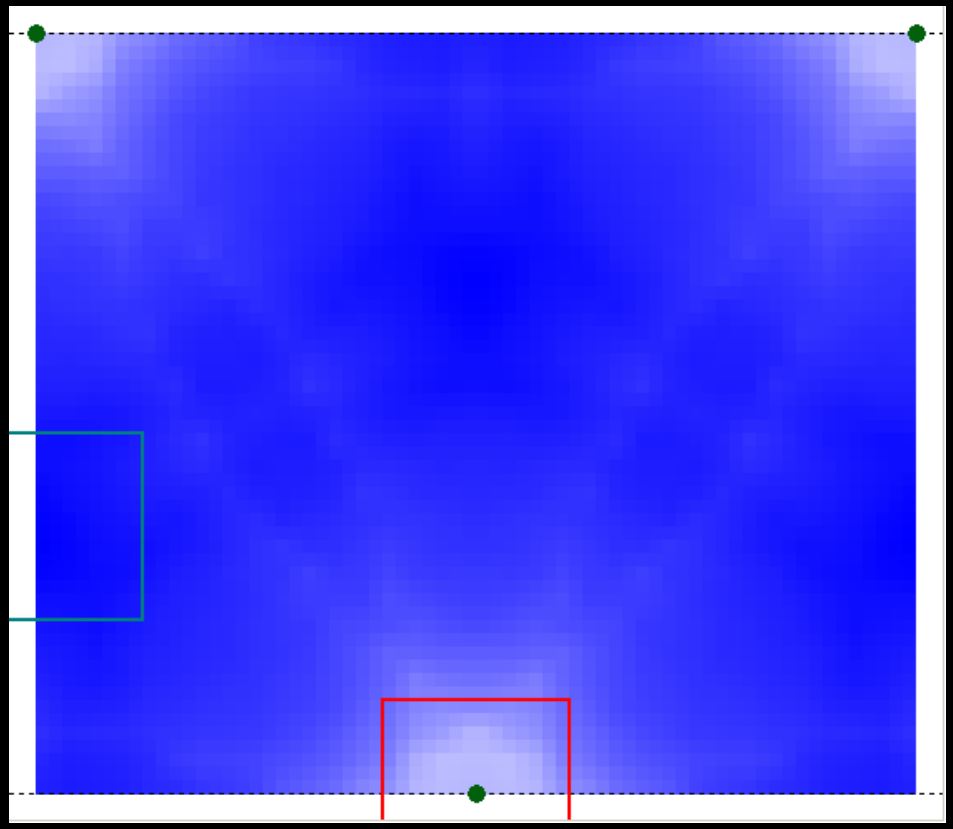






Not all sprinklers are perform equally!

Field Results



Improving Golf Course Irrigation Uniformity

A California Case Study

2003

Conducted by:

The Center for Irrigation Technology at California State University-Fresno

Sponsored by:

The State of California Department of Water Resources

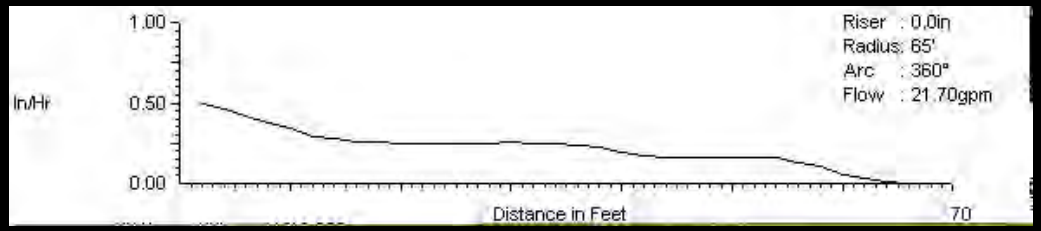
Case Study Overview

- Five sites evaluated *(4-18 and 1-36 hole sites)*
- Locations represent wide range of climatic conditions, cool and warm season turf
  - North San Francisco Bay Area
  - Coastal and Inland Los Angeles County
  - Coastal & Inland San Diego County
- 606 total irrigated acres represented
- 108 golf holes (6-18 hole equivalents)
- Each site had recently replaced 100% of nozzles

Case Study Overview

- Used CIT laboratory or field audit data for before & after nozzle replacement to compare:
  - Distribution Uniformity (DU%)
  - Run Time Multiplier (RTM)
  - Scheduling Coefficient (SC)
- Calculated estimated & actual water use based upon 12 months before and 12 months after nozzle replacement:
  - Metered water use data
  - CIMIS weather station ET
  - Accounted for <u>useful</u> rainfall data

Indoor Profile Testing
Outdoor Audits



Estimated Vs. Actual Water Savings

- The **estimated potential** water savings using **Scheduling Coefficient** was 20% (1.2 vs. 1.5)
- The **estimated potential** water savings using **DU** and a **run-time-multiplier** was 9% (110% applied water w/DU of 85% vs. 119% w/DU of 73%)
- **Actual** average savings achieved by golf courses participating in this was **6%**

Individual Vs. Overall Results

- Individual Courses
  - Gross Water Savings Range:
    - (- 11.3%) to 21.4%
  - Net Water Savings Range (adjusted for useful rainfall)
    - (- 3.1%) to 14.7%
- Overall Average Results
  - Gross Savings of Applied Water
    - 6.5%
  - Net Savings of Applied Water
    - 5.7% (adjusted for useful rainfall)

Superintendents Comments

- Eliminated donuts
- Less numerous and smaller size wet / dry spots
- Able to run sprinklers longer without puddling
- Improved turf quality & playing conditions
- Able to reduce ET demand by 5%
- Reduced hand watering significantly, estimated $8000.00 labor savings

High Efficiency Nozzles

Profile

Metal Nozzles

Underhill Corp.

20505 Crescent Bay Dr.

Lake Forest, CA 92630

866-863-3744 or

949-305-7050

http://www.underhill.us/

Low Heads?

- *LEVELIFT*
  - Improve distribution uniformity
  - Reduce labor (@10 to 15 min per head)
  - Reduce wiring damage
  - Reduce water use
  - Eliminate turf disruption surrounding sprinkler
- 877-465-3835
- http://www.levelift.net/

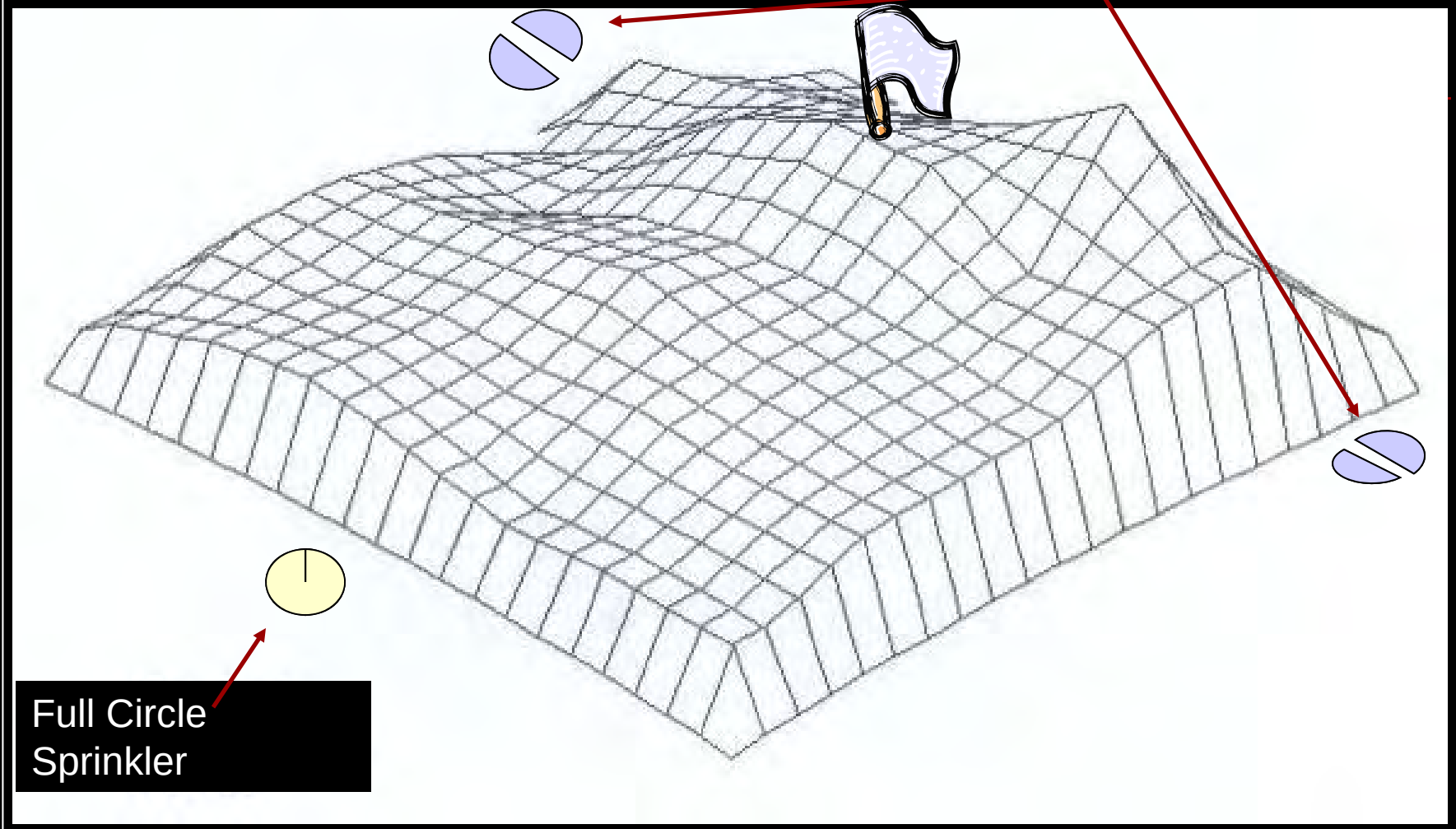
Looked good on paper, but did it work?

“Perfection is not attainable, but if we chase perfection we can catch excellence.”
Vince Lombardi

A Design Created Management Challenge

- Opposing part circle sprinklers to maximize control.
  - Difficult to adjust arc exactly,
  - Cannot control “pause” time on direction change
  - Have a broad spray pattern
- Increased black layer reported on putting green perimeters during grow-in.
- The idea looks good on paper but,,,,,


Wet Spots at Blue Flags
Opposing Part Circle
Heads At Pink Flags
10. 2. 2006 07:21


Opposing Part
Circle Sprinklers
Full Circle
Sprinkler


10. 2. 2006 08:10

Back to Back Part Circle - The Math!

- Assume 60’ spacing / radius or 120 foot diameter
- 3.14 (Pi) X 120’ diameter = 376.8’ circumference
- 360 degrees / 377’ circumference = 1.05’ per degree of rotation
- One 180 degree rotation @ 1.5 minutes (90 seconds) = approximately 2 degrees per second or 2.1 feet per second.

- Measured 2 to 4 second pause while changing direction in field.
- Assume a 3 second pause while changing directions = 3X application over 2.1 foot wide area.
- If arc adjustments overlap slightly they result in an overlap 2x overlap plus the pause factor.

Daily Vs Infrequent ET Replacement

"I do not question the power of our weapons and the efficiency of our logistics; I cannot say these things delight me as they seem to delight some of our officials, but they are certainly impressive."

J. William Fulbright, US Senator (Vietnam War Era)
Member Senate Foreign Relations Committee

Trivia Question:

- Where in the United States does it “rain” between 0.25” and 0.30” each day during the month of July?
- That would be on just about every Southwestern U.S. Desert Golf Course / Landscape replacing ET on a daily basis,,, it just happens to be manmade rain applied through sprinklers.
- Essentially through irrigation we have created a rainforest in the desert.
  - Officially need 100” precipitation to qualify as a rainforest (100” / 365 = 0.274” per day average)

Southwest Peak July ET

	Annual Rainfall	Annual ET	Wettest Month	Highest ET	Daily Avg.
Los Angeles	16.90”	38.96”	Feb. 3.55”	July 6.13”	0.20”
San Francisco	19.76”	33.40”	Jan. 4.14”	July 4.99	0.16”
Palm Springs	8.01”	48.28”	Feb. 1.49”	July 8.90”	0.29”
Reno	8.30”	28.67”	Jan. 1.20”	July 6.21”	0.20”
Las Vegas	5.10”	48.77”	Jan. 0.61”	July 9.24”	0.30
Salt Lake City	15.67”	31.18”	Apr. 1.81”	July 6.92”	0.22
Denver	14.81”	18.93”	May 2.53”	July 4.42”	0.14
Phoenix	9.02”	56.75”	Aug. 1.56”	July 10.11”	0.33
Tucson	13.42”	46.66”	Aug. 3.14”	July 8.11”	0.26

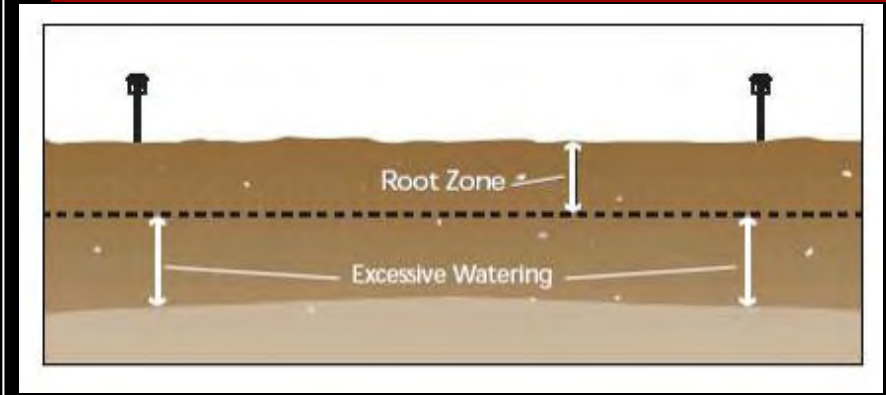
Source: Rainfall / Evaporation Data - The Toro Company

Soil Properties

Soil Texture	Available Water (In Water / In Soil)	Basic Infiltration Rate (inches / hour)	Management Allowed Depletion% (MAD)
Clay	0.15	0.12	30
Silty Clay	0.16	0.18	40
Clay Loam	0.20	0.25	40
Silty Clay Loam	0.20	0.25	50
Sandy Clay Loam	0.15	0.20	50
Sandy Clay	0.16	0.12	50
Silt	0.17	0.40	50
Silt Loam	0.20	0.43	50
Loam	0.17	0.54	50
Sandy Loam	0.12	0.75	50
Loamy Sand	0.07	0.88	50
Fine Sand	0.06	1.25	60

Source: Irrigation Association Certified Golf Irrigation Auditor's Handbook

Uniformity, efficiency and scheduling for salt management



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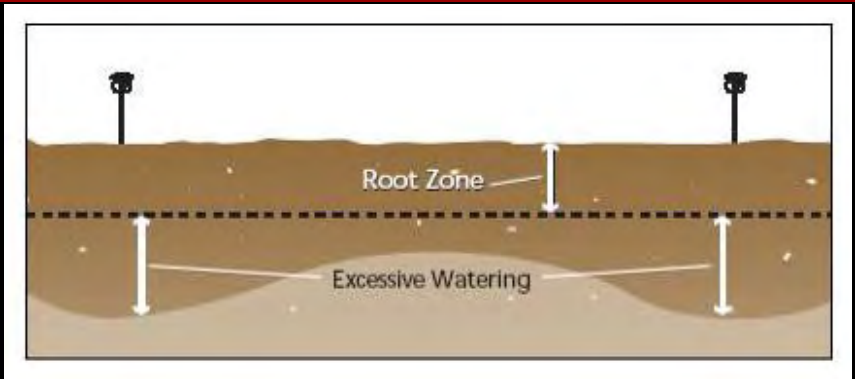

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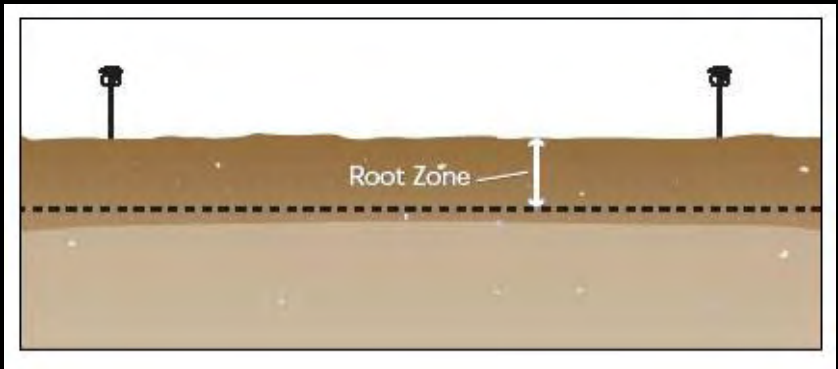

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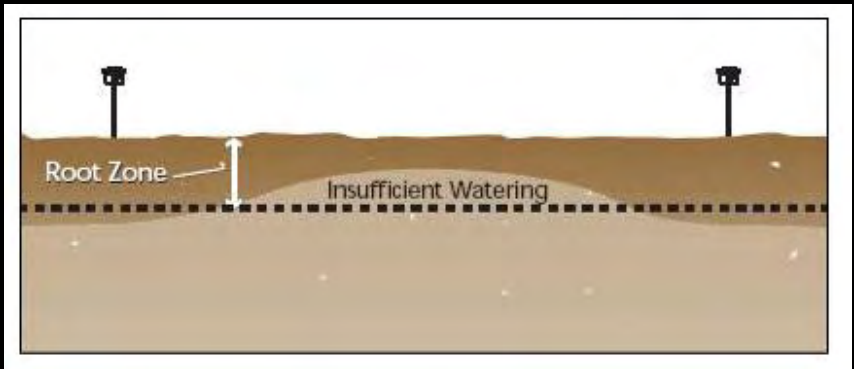
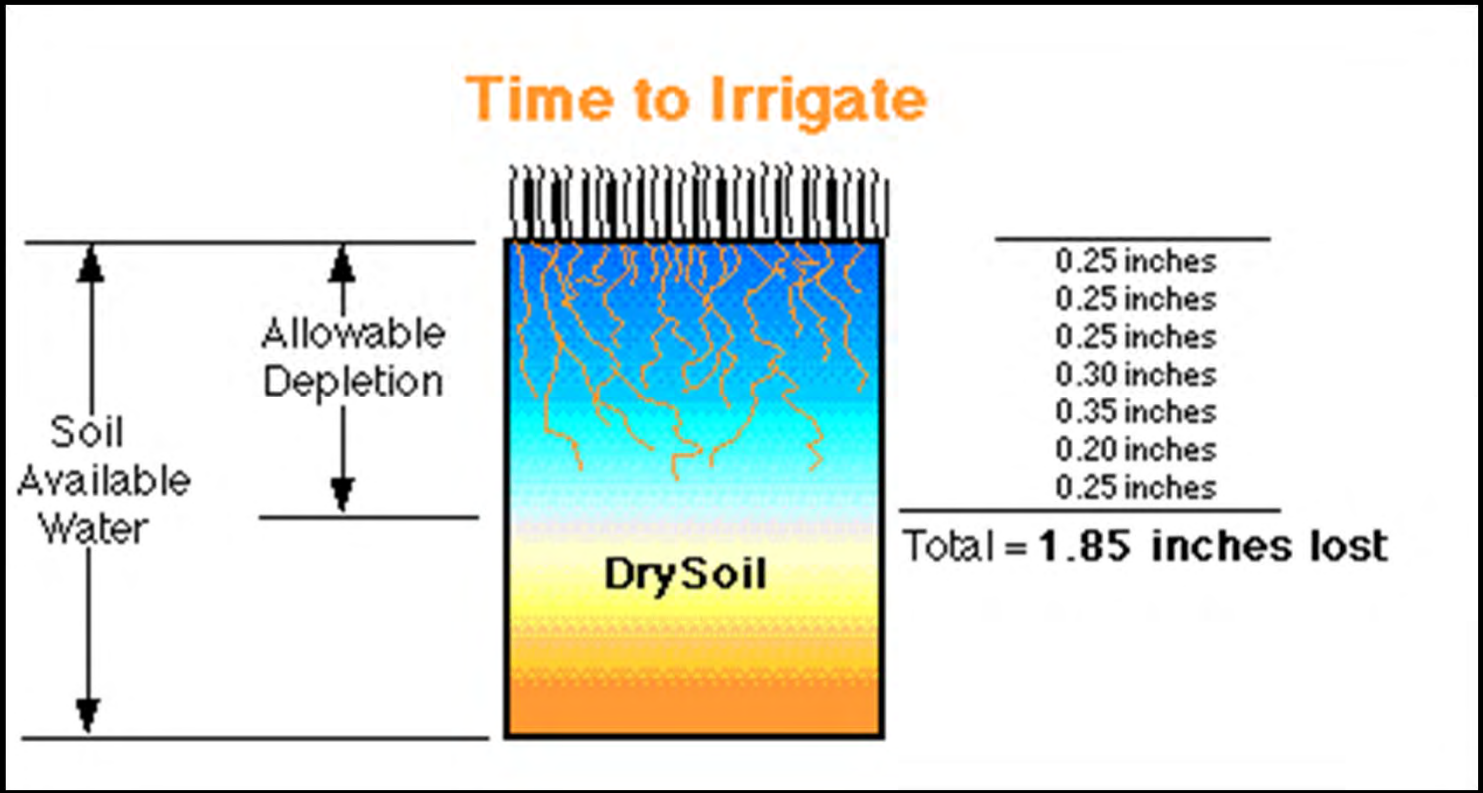


Good Efficiency & Poor Uniformity

Highest concentrations of salts will be at the leading edge of the wetting front

Deep and Infrequent Scheduling

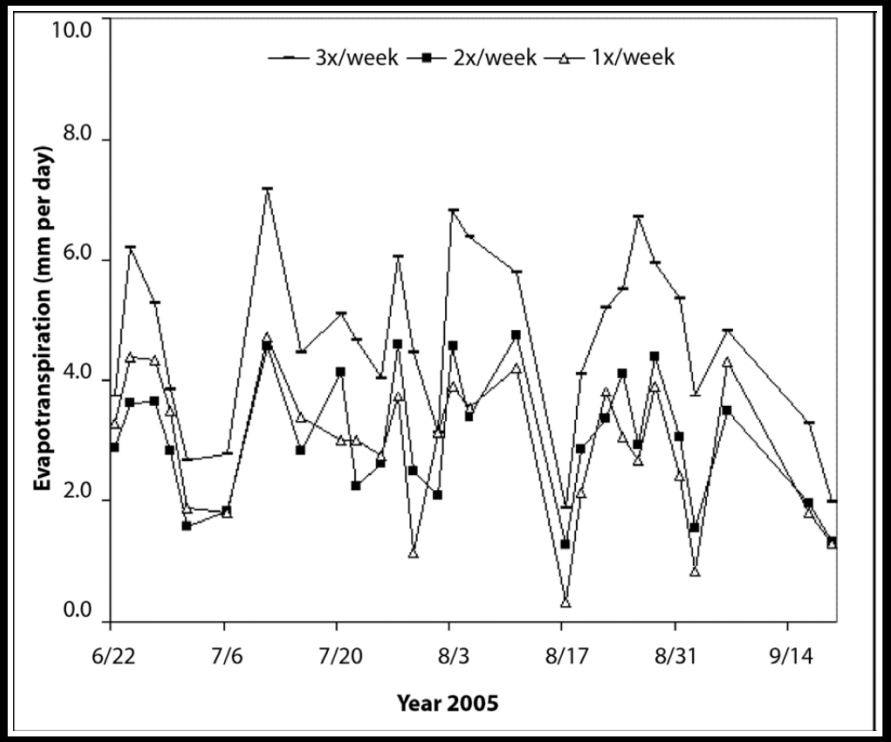


Trivia Question:

- Is daily ET replacement adjusted by a Kc an efficient strategy for water conservation? (True or False)
- **False!!** Research has shown deep and less frequent applications can save up to 33% to 35% over less frequent applications

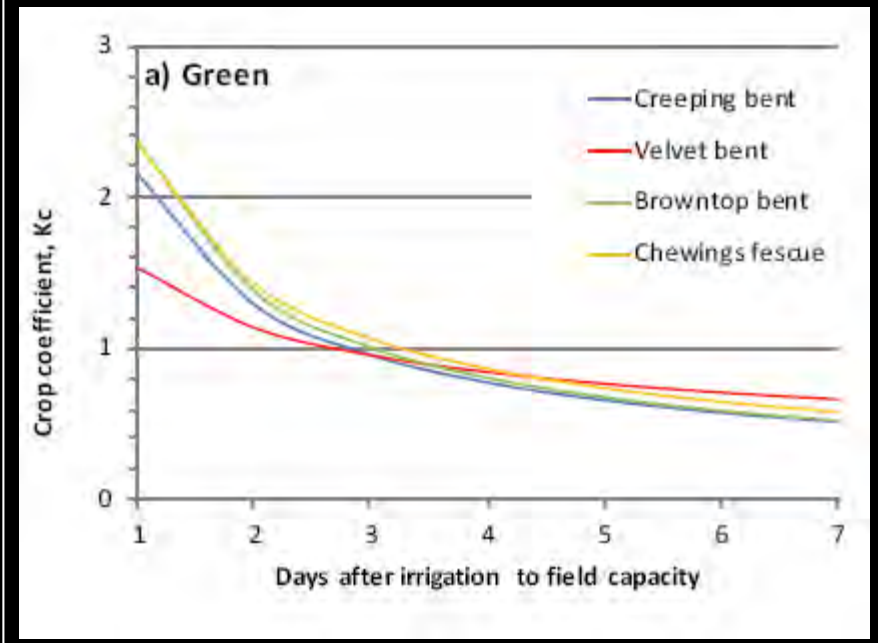
Water use and irrigation frequency.

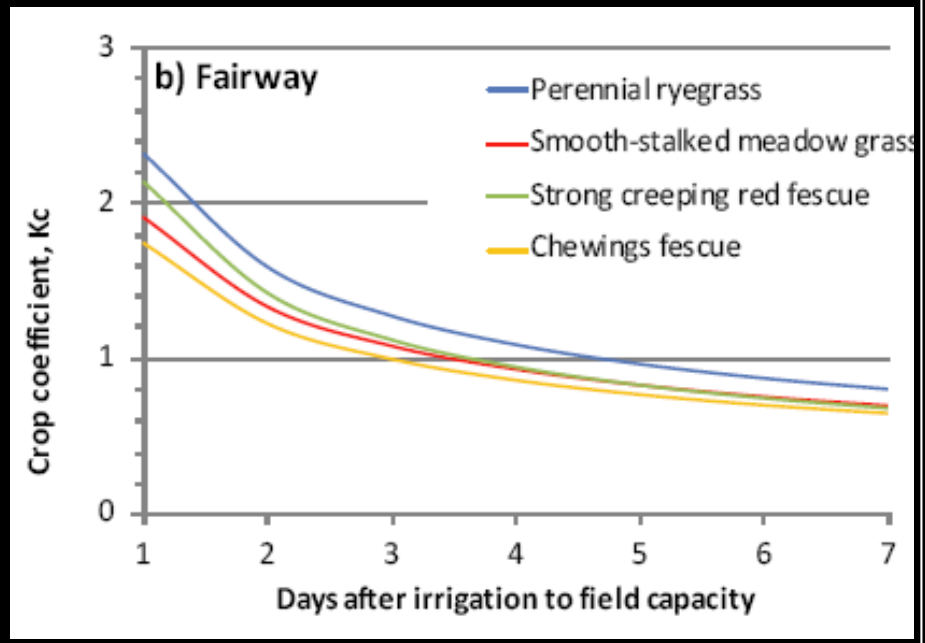
Figure 11.1. Evapotranspiration rate of creeping bentgrass (cv. Penncross) irrigated once per week (1x), twice per week (2x), and three times per week (3x). The test was performed in turfgrass grown in loamy soil and mowed at 3/8 inch height in field plots at the Rutgers University Turfgrass Research Farm, North Brunswick, New Jersey.



Source: Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes

Water Use after Irrigating to Field Capacity





Scandinavian Turfgrass Environmental Research Foundation (STERF)
"Irrigation of Turf on Golf Courses a Greenkeepers guide to understanding theory and practice."
http://www.sterf.org/Media/Get/1232/irrigation-of-turf-on-golf-courses.pdf

Water Use, Irrigation Amount & Frequency

- Turf with free access to water has a much higher transpiration rate than if growing on dry soils.
- Water consumption on first day after irrigation to field capacity is 2 to 3 times higher than average consumption on the next 5 days.
- The crop coefficient, kc, varies with water content of the soil.

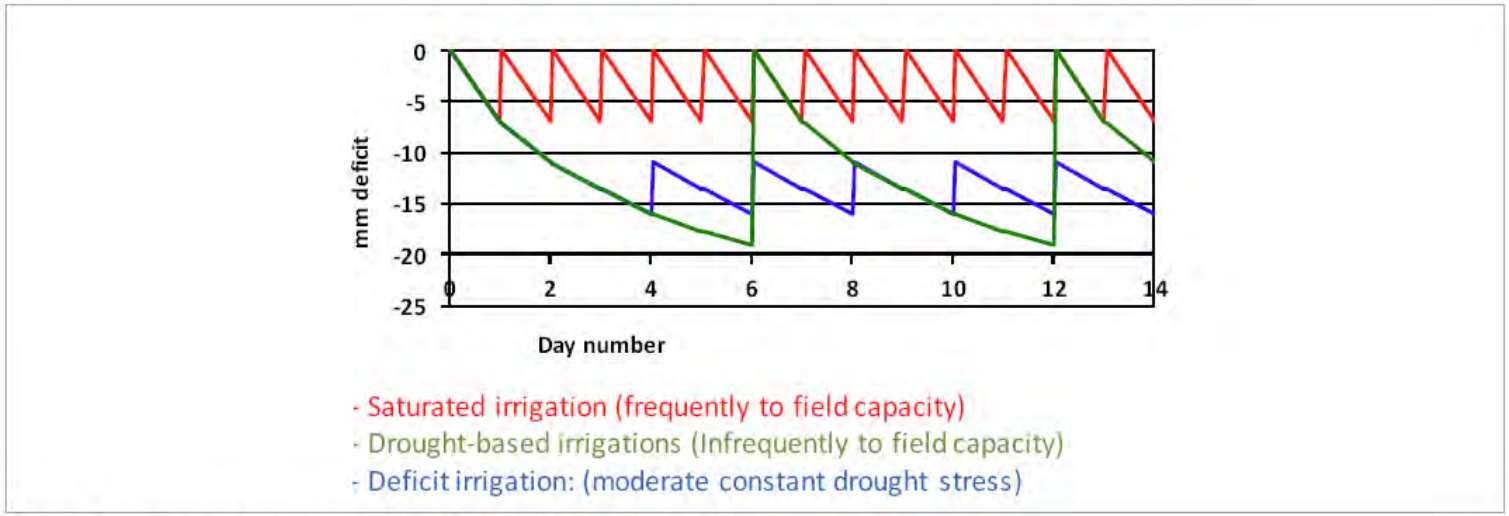


Figure 5. Illustration of three principally different irrigation strategies.

Irrigation Strategy	Visual turf quality (1-9)	Dry Spots % of plot area	Daily height increment (mm)	Ballroll, measured with a short stimpmeter (cm)	Hardness measured with a Clegg-hammer (gravities)
1. Field capacity, 6x per week	6.3 a	6 b	0.9 a	100 a	71 c
2. Field capacity, 2x per week	6.1 a	6 b	0.9 a	102 a	74 bc
3. Field capacity, 1x per week	5.4 ab	13 ab	0.8 a	100 a	79 b
4. Deficit, 6x per week	6.4 a	8 b	0.9 a	101 a	76 bc
5. Deficit, 2x per week	5.8 ab	11 b	0.9 a	100 a	75 bc
6. Deficit, 1x per week	4.9 b	27 a	0.8 a	103 a	85 a

Table 4. Impacts of different turf irrigation scheduling strategies based on irrigation experiments conducted in 2011 on a green with creeping bentgrass 'Independence '. It was irrigated to field capacity or to approximately 70% of field capacity at different intervals. Within each column, figures followed by the same letter are not significantly different (significance level: $P < 0.10$)

Irrigation Strategy	Water consumption during experimental period (63 days)	Water consumption relative to daily irrigation to field capacity
1. Field capacity, 6x per week	358	100
2. Field capacity, 2x per week	233	65
3. Field capacity, 1x per week	173	48
4. Deficit, 6x per week	123	34
5. Deficit, 2x per week	127	36
6. Deficit, 1x per week	106	30

Table 5. Water consumption of creeping bentgrass 'Independence' at different irrigation strategies on a golf green at Bioforsk Landvik in 2011.. The accumulated reference ET during the 63 day period was 174 mm.

Do DU Figures Lie?

Figures Don’ t Lie, But Liars Do Figure

.

Mark Twain

Distribution Uniformity, *Known known*, *known unknown* or *unknown unknown*?

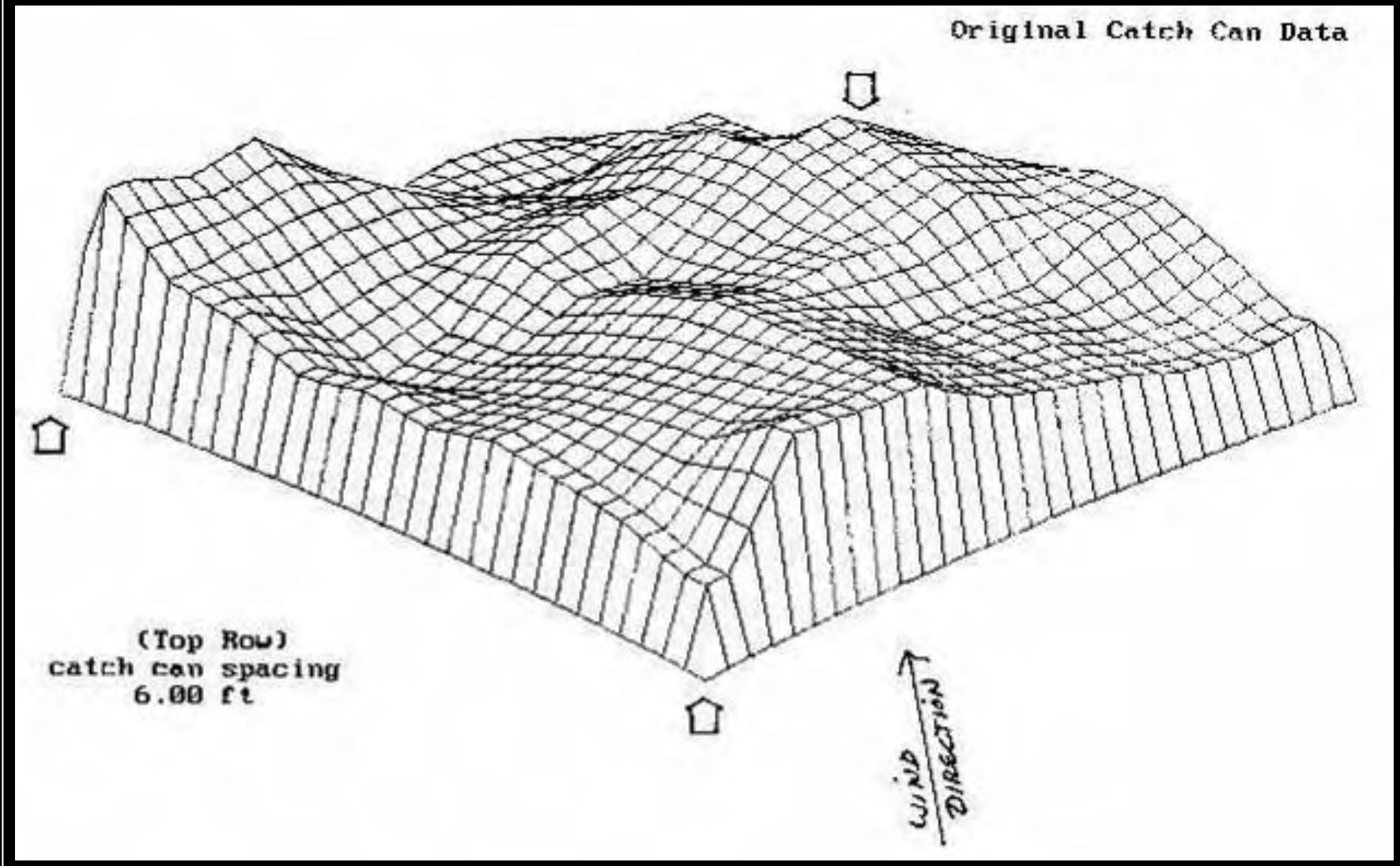
Golf Sprinkler Performance (Rotary Sprinklers)	*Excellent (Achievable)*	*Very Good*	*Good (Expected)*	*Fair*	*Poor (Needs Improvement)*
Cal Poly ITRC[1]	≥85%	80%	75%	65%	≤60%
Irrigation Association[2]	≥80%		70%		≤55%

1. **Landscape Irrigation Auditors Manual Developed by Cal Poly Irrigation Training & Research Center for California Department of Water Resources.**
2. **Irrigation Association Certified Golf Irrigation Auditors Manual**


78% DULQ
68 – 81% Range
11. 19. 2001


DULQ 82%
76 – 85% Range
7. 25. 2002 08 : 27


77% DULQ
67-77% Range
7. 30. 2002 06:59


Original Catch Can Data
(Top Row)
catch can spacing
6.00 ft
WIND DIRECTION

High DULQ but,,,

- Visible turf quality issues
- Repeated wet patterns near sprinkler across property
- Hard data shows similar wet areas near sprinkler

Original data (Rectangular Catch Can Spacing) Units are milliliters.

Row/Col	1	2	3	4	5
1	70	57	51	51	58
2	43	56	51	55	41
3	51	61	47	51	51
4	50	60	52	53	49
5	60	52	60	54	54

Catch can volume = 2.548 cubic meters
Discharge volume = 1.788 cubic meters
Catch Efficiency = 142.5 percent

Catch measurements are in milliliters
Catch Can Area: 10258 sq. mm
Test duration: 19 min. Discharge: 1.57 l/s (24.9 gpm)
Wind Speed: 0.00 m/s Direction: 0 deg from N
Grid Spacing: 14.50 ft

S T A T I S T I C S for O R I G I N A L D A T A

Average Net Application	53.52	ml	Test duration:	19 min.
Average Deviation from Mean	4.50	ml	Discharge:	1.57 l/s
Standard Deviation	6.06	ml		
Skew	0.45			
Kurtosis	4.33			
Average Net Application	16.5	mm/hr	(0.65 in/hr)	
Average Deviation from Mean	1.4	mm/hr	(0.05 in/hr)	
Average Gross Application	3.7	mm	(0.14 in)	
Average Net Application	5.2	mm	(0.21 in)	
Average Depth Highest 10%	6.2	mm	(0.24 in)	
Average Depth Lowest 10%	4.3	mm	(0.17 in)	
Average Depth Low Quarter	4.6	mm	(0.18 in)	
Average Depth Low Half	4.8	mm	(0.19 in)	
App. Eff. Low Quarter (AELQ)	124.7	%		
App. Eff. Low Half (AELH)	130.4	%		
Distribution Uniformity	87.5			

Coefficient of Uniformity (CU):

CU from Christiansen	91.6	CU from Low Half	91.6
CU from Std. Dev.	91.0	CU from Distr. Unif.	92.1
CU for alternate offsets	95.7		

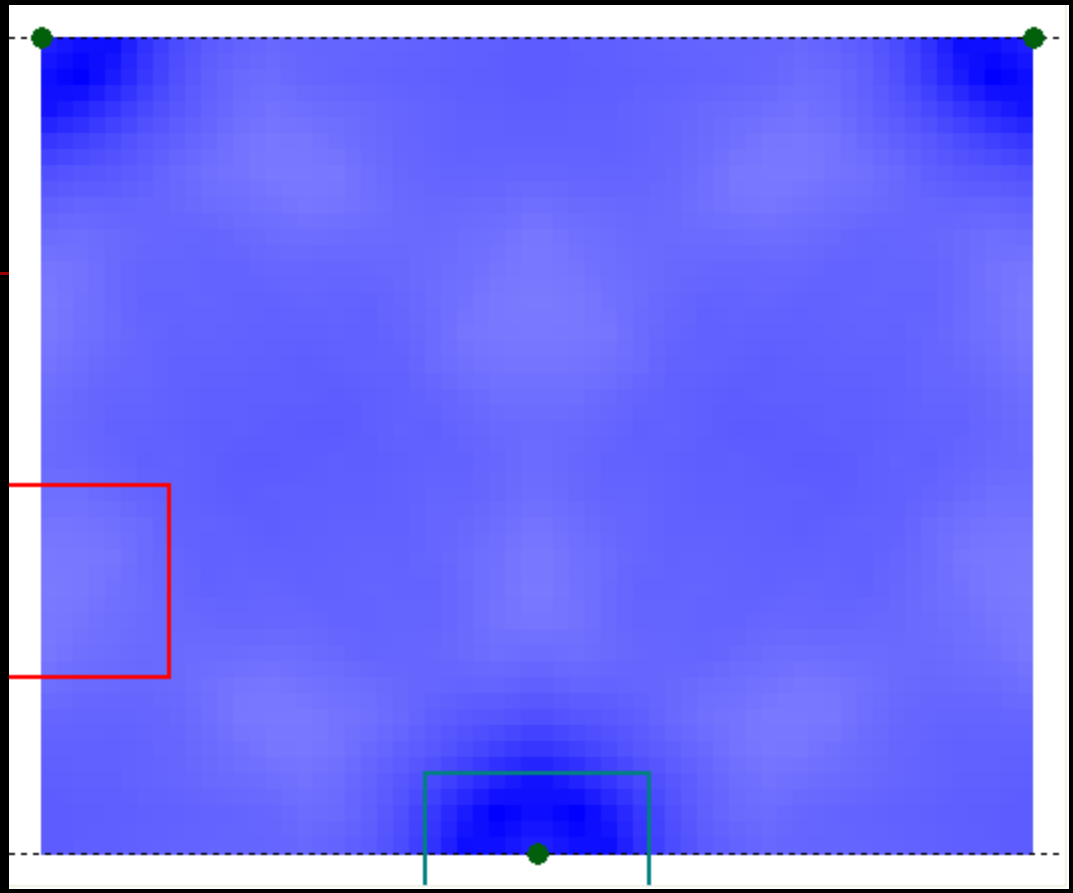
Ave. vol./sprinkler spacing 2.55 cu.m (89.9 cu.ft)

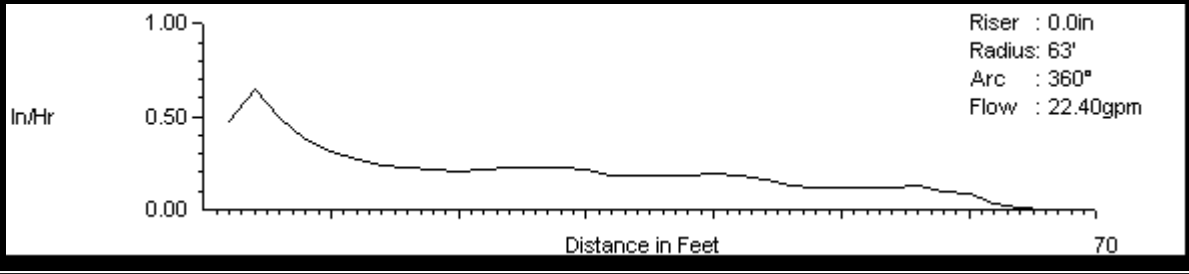
Ranking of values (values have been multiplied by 1):

41	43	47	49	50			
51	51	51	51	51	51	52	52
53	54	54	55	56	57	58	60
60	60	61	70				

“Case” Study

- CIT DATA
  - SC 1.1
  - DU 90%
  - CU 93%

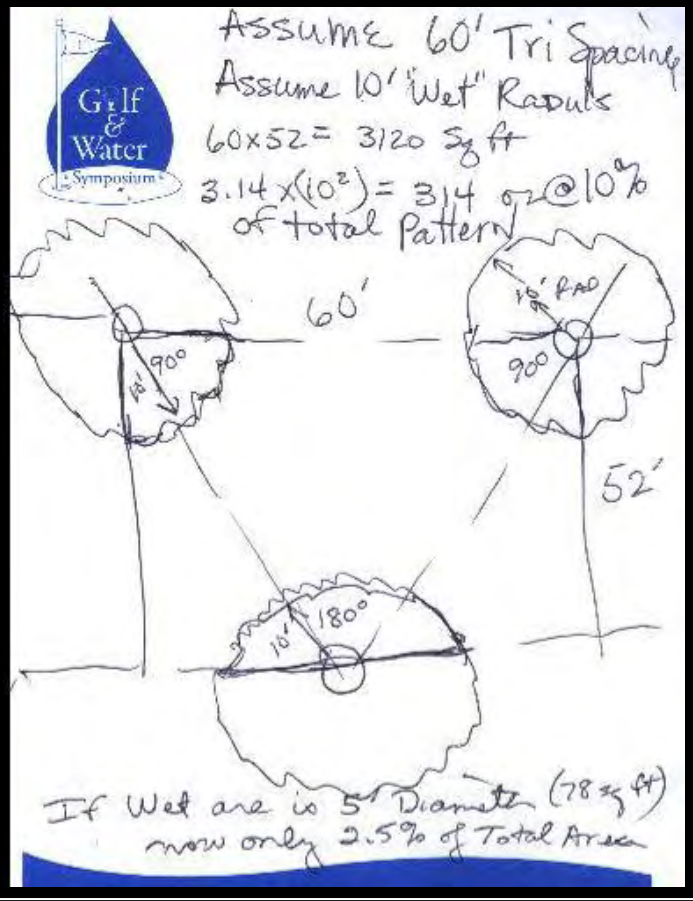




And then the *Light* Came On!

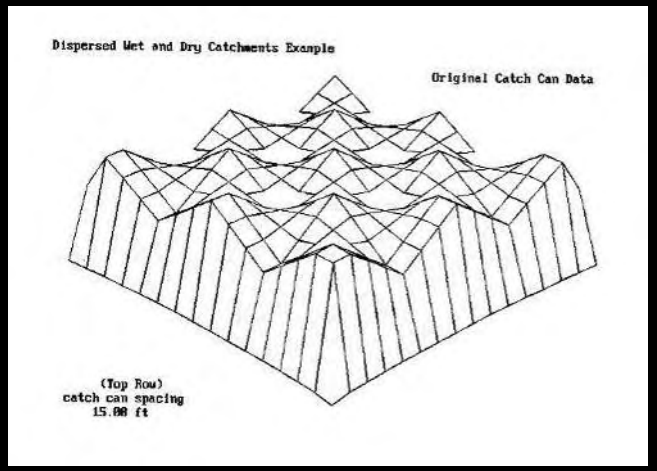
(*Coors Light* that is: I told you it was a Case Study.)

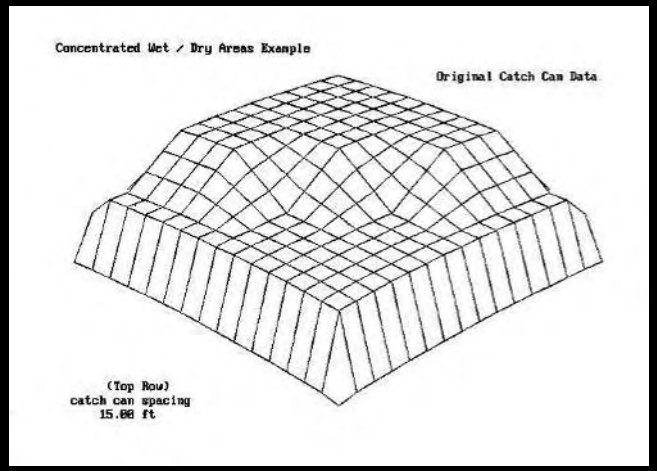
- DULQ = Avg. LQ / Average
  - (It compares **driest** 25% to the average application.)
- But this problem is the wettest 10%, driest 25% is very uniform and comparable to the remaining 90% of the pattern,,,,
- LQDU “dilutes” the high values into the total average delivering a false positive



Are Better Evaluation Methods or Formulas Needed?

- Can we develop better measuring tools to evaluate sprinkler performance than CU, DU, or SC?





Examples of 3D graphics results where dryer application areas are dispersed (left) versus concentrated (right). Both graphics represent: 75.3% CU and 74.3% DU_{LQ}.

Preparing for the worst with a *Drought Plan*

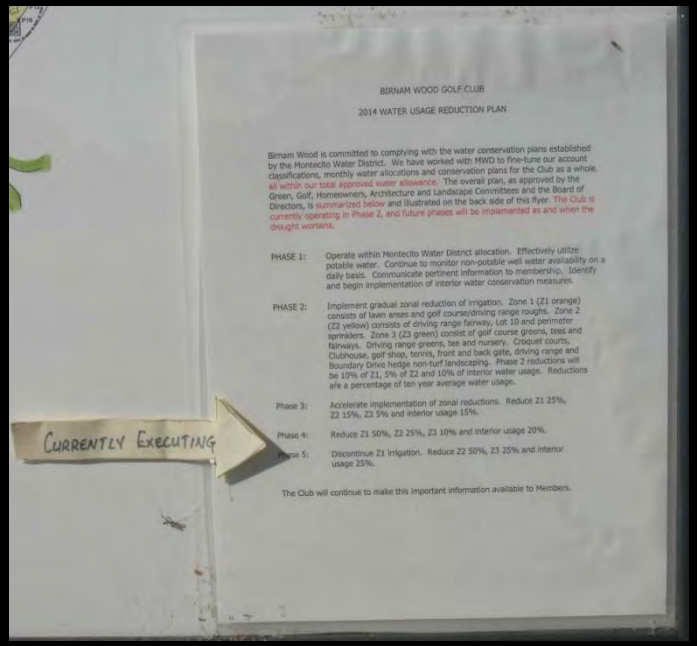
Failing to plan is planning to fail!

Alan Lakein – Author

Develop a Written Drought Plan

- Prepare for rationing and prioritize areas
  - Greens,
  - Fairway and/or landing areas,
  - Tees
  - Rough,
  - Identify specimen trees in areas where water is cut off to the turf and plan to deep irrigate with a tree root feeder.

Formal Drought Plan



BIRNAM WOOD GOLF CLUB

2014 WATER USAGE REDUCTION PLAN

Birnam Wood is committed to complying with the water conservation plans established by the Montecito Water District. We have worked with MWD to fine-tune our account classifications, monthly water allocations and conservation plans for the Club as a whole, all within our total approved water allowance. The overall plan, as approved by the Green, Golf, Homeowners, Architecture and Landscape Committees and the Board of Directors, is summarized below and illustrated on the back side of this flyer. The Club is currently operating in Phase 2, and future phases will be implemented as and when the drought worsens.

PHASE 1: Operate within Montecito Water District allocation. Effectively utilize potable water. Continue to monitor non-potable well water availability on a daily basis. Communicate pertinent information to membership. Identify and begin implementation of interior water conservation measures.

PHASE 2: Implement gradual zonal reduction of irrigation. Zone 1 (Z1 orange) consists of lawn areas and golf course/driving range roughs. Zone 2 (Z2 yellow) consists of driving range fairway, Lot 10 and perimeter sprinklers. Zone 3 (Z3 green) consist of golf course greens, tees and fairways. Driving range greens, tee and nursery. Croquet courts, Clubhouse, golf shop, tennis, front and back gate, driving range and Boundary Drive hedge non-turf landscaping. Phase 2 reductions will be 10% of Z1, 5% of Z2 and 10% of interior water usage. Reductions a/e a percentage of ten year average water usage.

Phase 3: Accelerate implementation of zonal reductions. Reduce Z1 25%, Z2 15%, Z3 5% and interior usage 15%.

Phase 4: Reduce Z1 50%, Z2 25%, Z3 10% and interior usage 20%.

Phase 5: Discontinue Z1 irrigation. Reduce Z2 50%, Z3 25% and interior usage 25%.

The Club will continue to make this important information available to Members.

CURRENTLY EXECUTING

Permanent Irrigated Acreage Reduction

Maintenance Practices Affect Water Use

- Plant growth regulators. (11% to 44% Savings Reported)
- Mowing Height & Frequency
  - Perennial Rye when HOC raised from 1” to 2”, 37% increase
  - Common Bermuda HOC raised from 1” to 6”, 60% increase
  - Creeping Bent HOC raised from ¼” to 1”, 56% increase
  - Creeping Bent mowed 1x/14 days 41% more H2O than 6X/wk,
- Excessive N fertility increased H2O use (13%-KGB)
- Sufficient K enhances drought recovery
- Aeration enhanced infiltration & stress tolerance but increased water use temporarily.
- Wetting agents 28%-71% savings, effects gone 4 WAT

Combining Products - Preliminary

- 2016 California Study combined effects of Nitrogen + Primo + Revolution at 40% & 70% ETo Replacement
  - Bermudagrass significantly affected by lack of N fertilization
  - Turf recovered quickly after the first N app.
  - No difference between ETo replacements until early July.
  - At 40% ETo revolution treatments had acceptable quality for 2 months, after July 8 quality became unacceptable.
  - Revolution alone or in combination with Primo Maxx showed consistently better quality than plots without Revolution
  - Preliminary results suggest sufficient bermudagrass fertilization (5 lb N/M/YR) & regular Primo Maxx & Revolution use may be tools to manage bermudagrass with less water

Figure 1. Quality of plots irrigated at 70%ET_0 treated with either Primo Maxx, Revolution, a combination of the two or untreated. 2016. Riverside, CA.

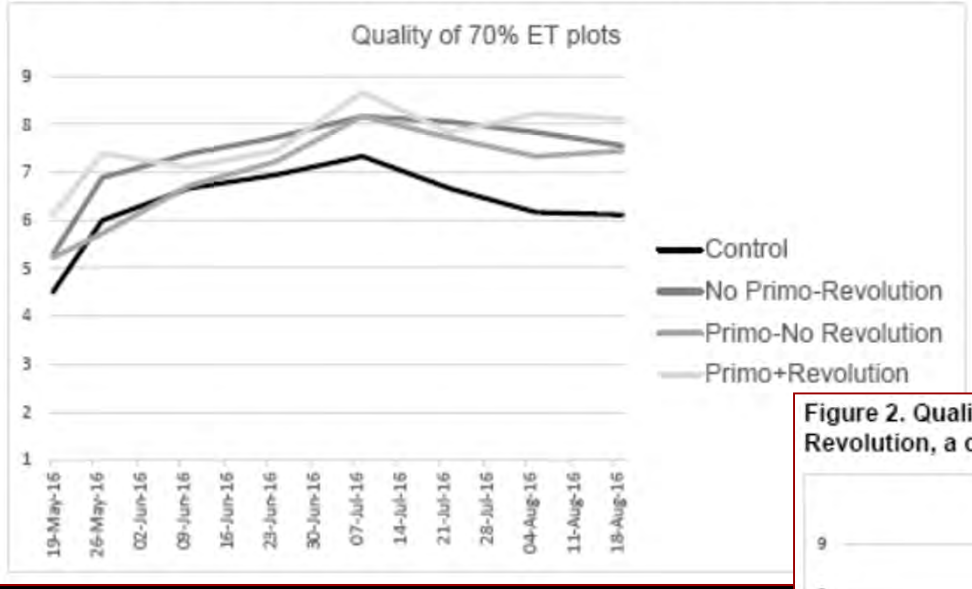
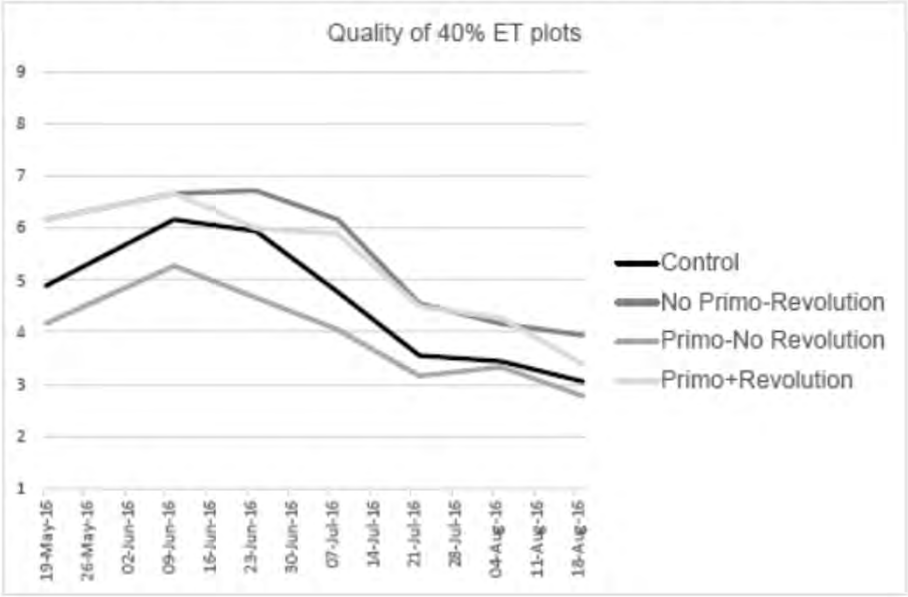


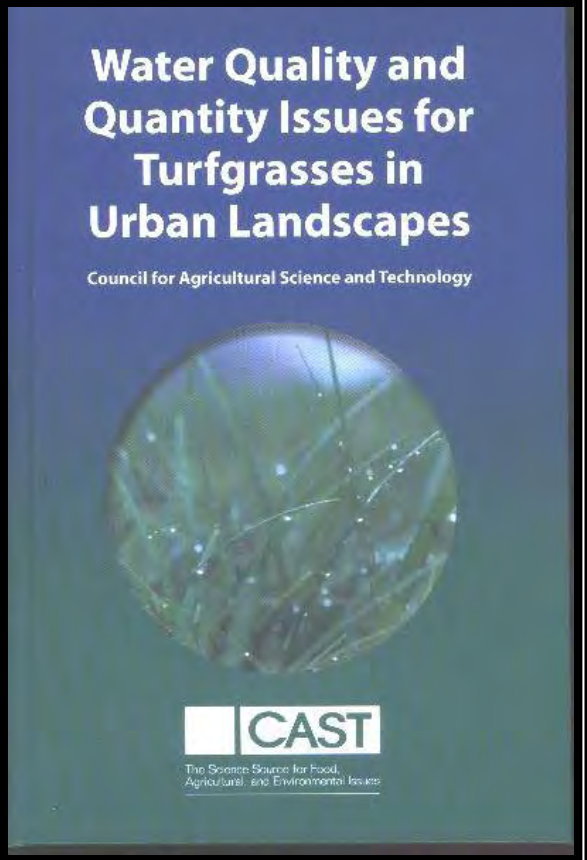
Figure 2. Quality of plots irrigated at 40%ET_0 treated with either Primo Maxx, Revolution, a combination of the two or untreated. 2016. Riverside, CA.



Educate Yourself and Your Membership About Water Issues

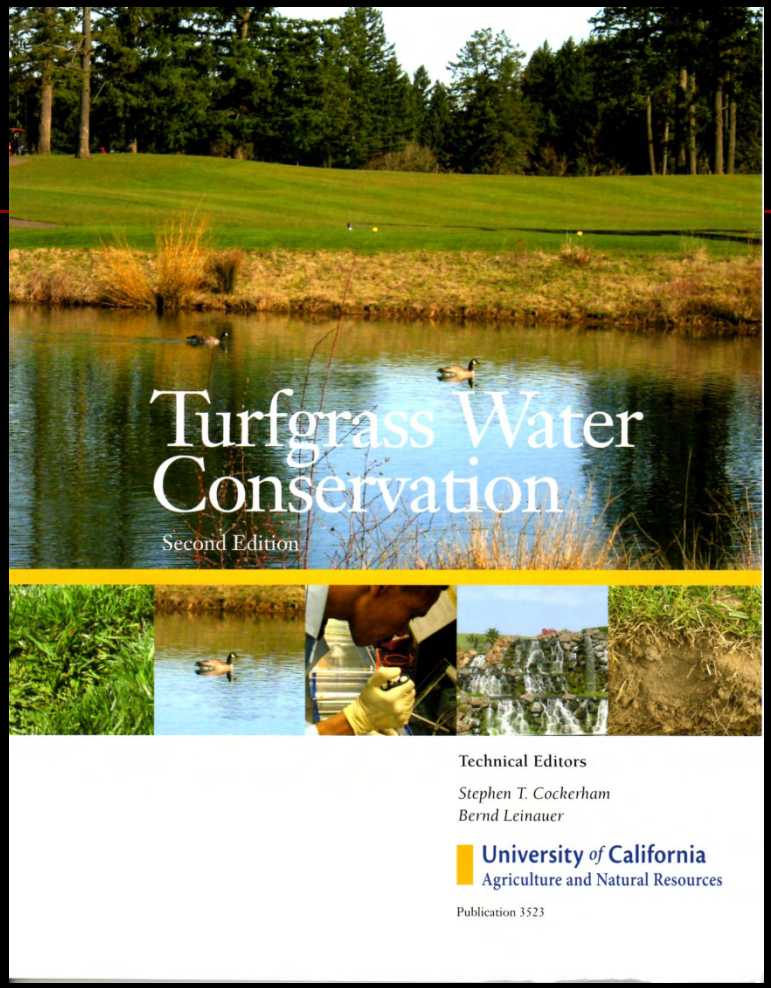
Reference Book

- *Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes*.
  - $35 Hardcopy
  - $25 PDF
- Published by:
  - The Council for Agricultural Science and Technology
  - 4420 West Lincoln Way
  - Ames, Iowa 50014
  - www.cast-science.org



Reference Book

- **University or California Agriculture and Natural Resources Publications**
- **Turfgrass Water Conservation 2nd Ed. Publication Number:** 3523 ($24.00) 2011
- 1-800-994-8849
- http://anrcatalog.ucdavis.edu/



Online Resources

- USGA Green Section
  - Green Section Record http://turf.lib.msu.edu/gsr/
  - Water Resource Center http://www.usga.org/course-care/water-resource-center.html
  - USGA Water Management Tools: http://www.usga.org/course-care/water-resource-center/water-management-plans.html
- University of California
  - UCCE http://ucanr.org/
  - UCR Turf (CA Turfgrass Culture) http://turfgrass.ucr.edu/ https://agops.ucr.edu/turf/
- University of Arizona (Tucson)
  - http://turf.arizona.edu/
- New Mexico State University
  - Turfgrass Research, Extension & Education: http://aces.nmsu.edu/programs/turf/

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Parting Thought: