New Science in Turf & Irrigation

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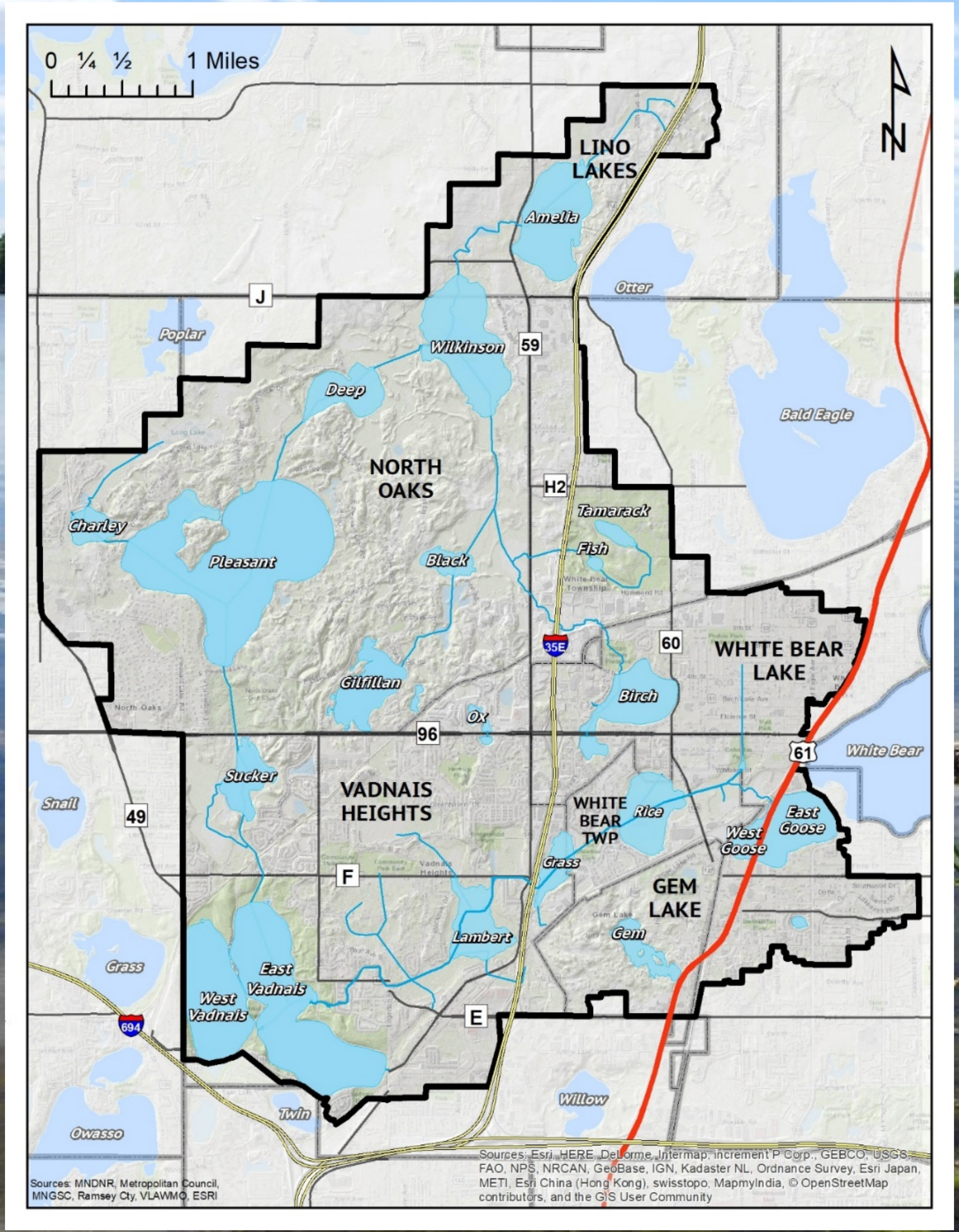
Extension Turfgrass Science

METROPOLITAN COUNCIL

CLEAN WATER LAND & LEGACY AMENDMENT

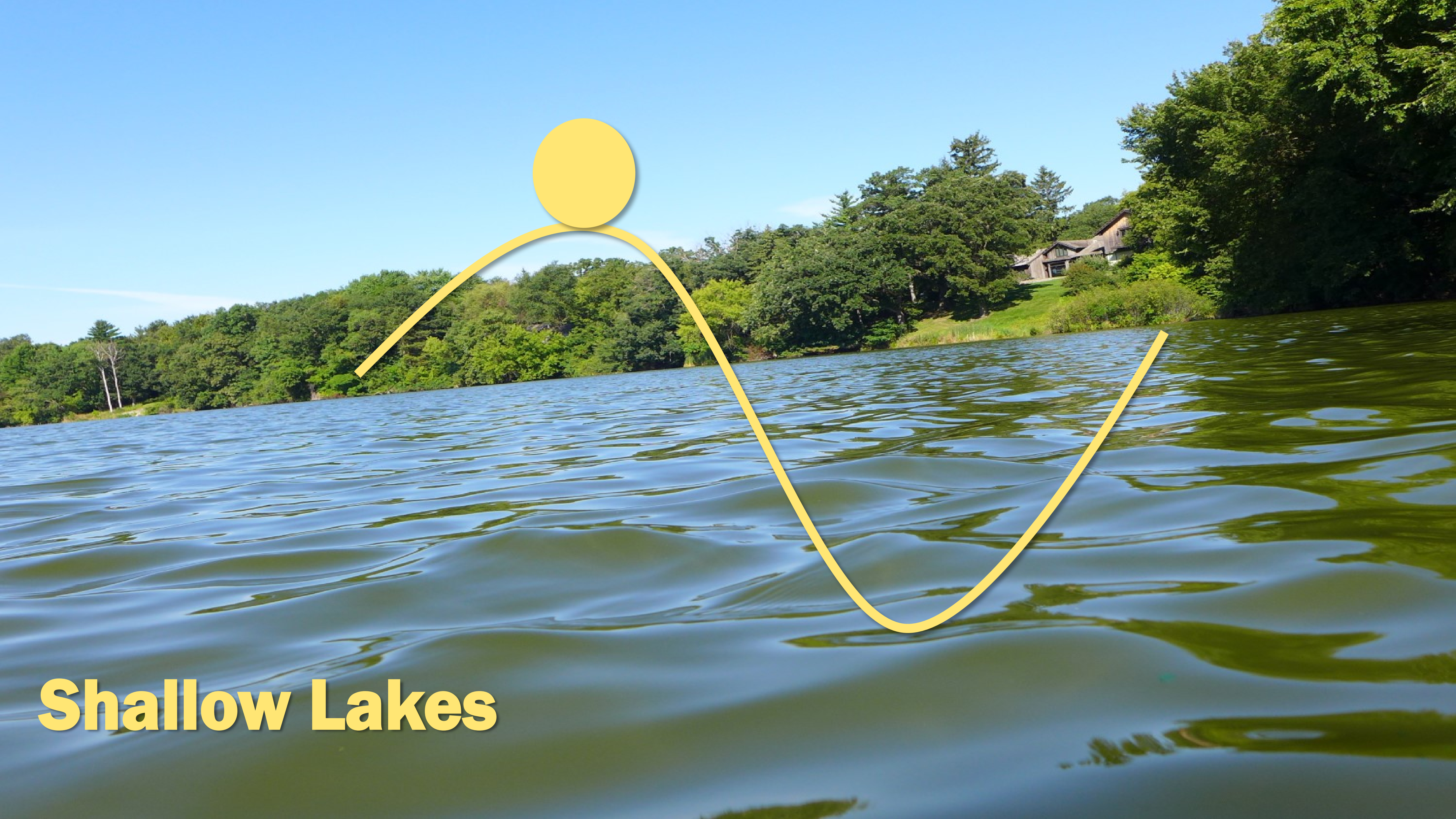


What is VLAWMO?

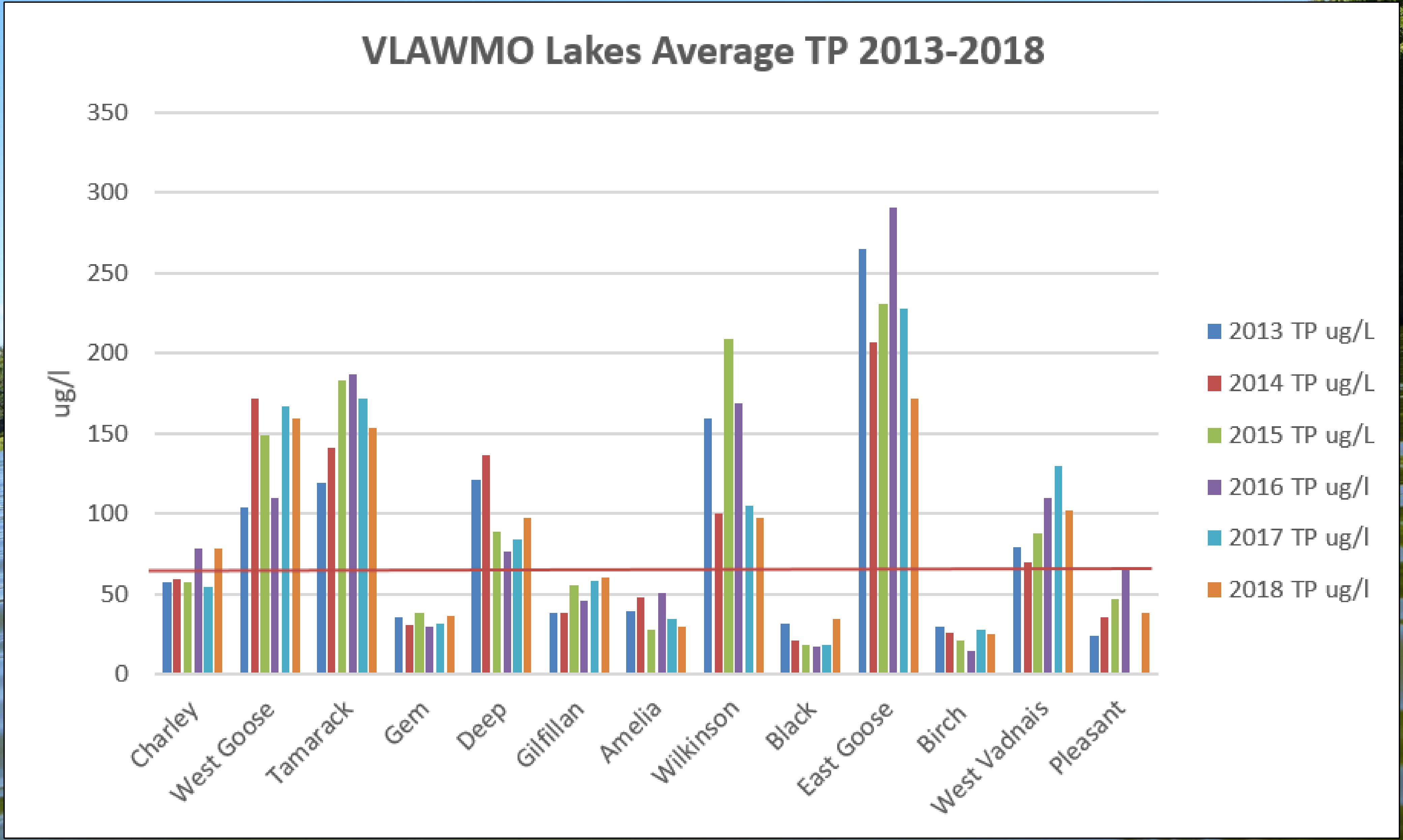
- A local government agency formed in 1983.
- About 25 square miles covering parts or all of Vadnais Heights, Gem Lake, White Bear Lake, White Bear Township, Lino Lakes, and North Oaks.


Wetlands




Shallow Lakes


1 pound of
phosphorus
=
500 pounds of
algae
Old Town
PACK
09


VLAWMO Lakes Average TP 2013-2018
ug/l
350
300
250
200
150
100
50
0
Charley
West Goose
Tamarack
Gem
Deep
Gilfillan
Amelia
Wilkinson
Black
East Goose
Birch
West Vadnais
Pleasant
2013 TP ug/L
2014 TP ug/L
2015 TP ug/L
2016 TP ug/l
2017 TP ug/l
2018 TP ug/l

Cost-share Program


ADOPT
a STORM
DRAIN
Adopt-a-drain.org

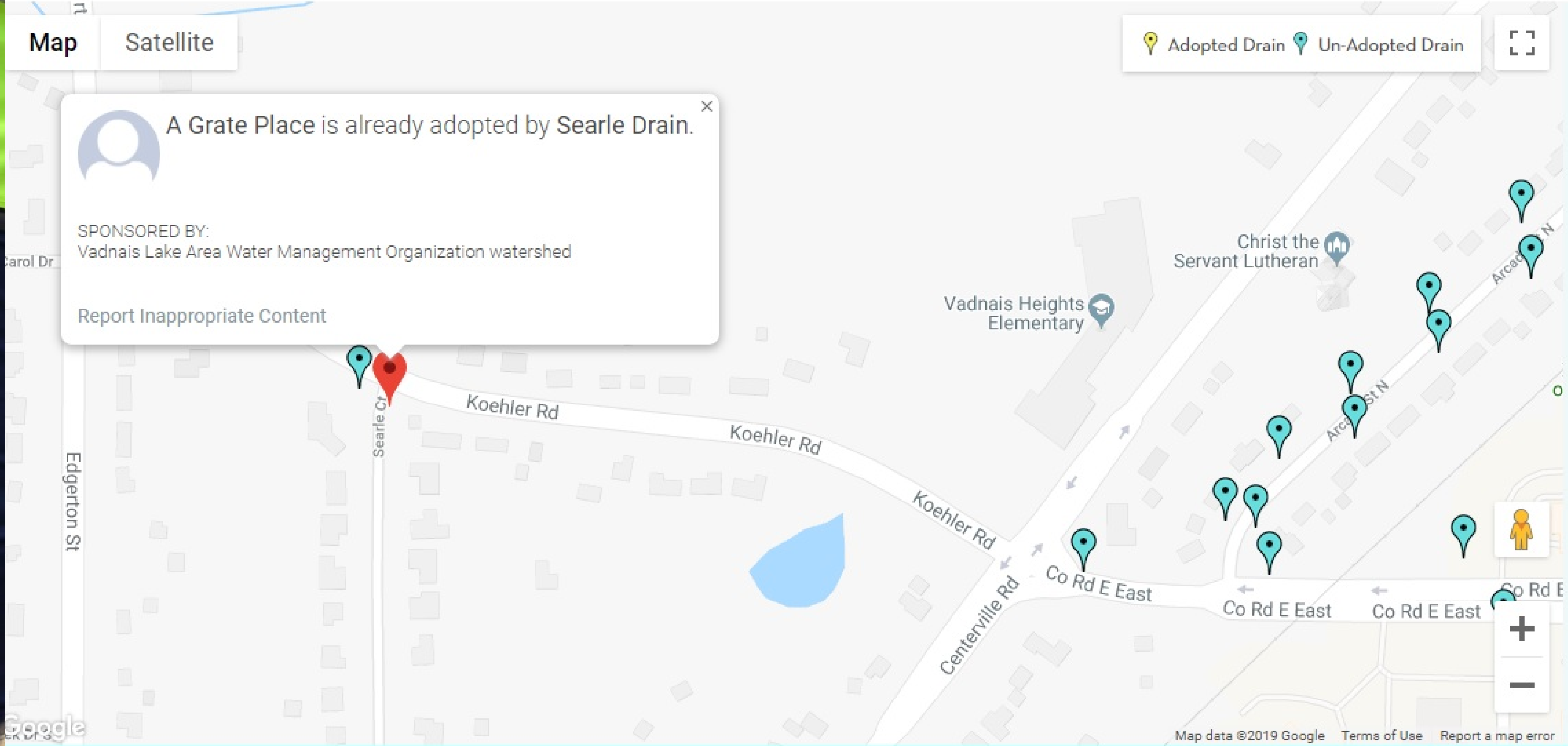
About Adopt-a-Drain | How To Clear a Drain | Why Adopt a Drain | Prevent Runoff Pollution

ADOPT a STORM DRAIN

104,050 lbs debris collected

4,472 hours spent

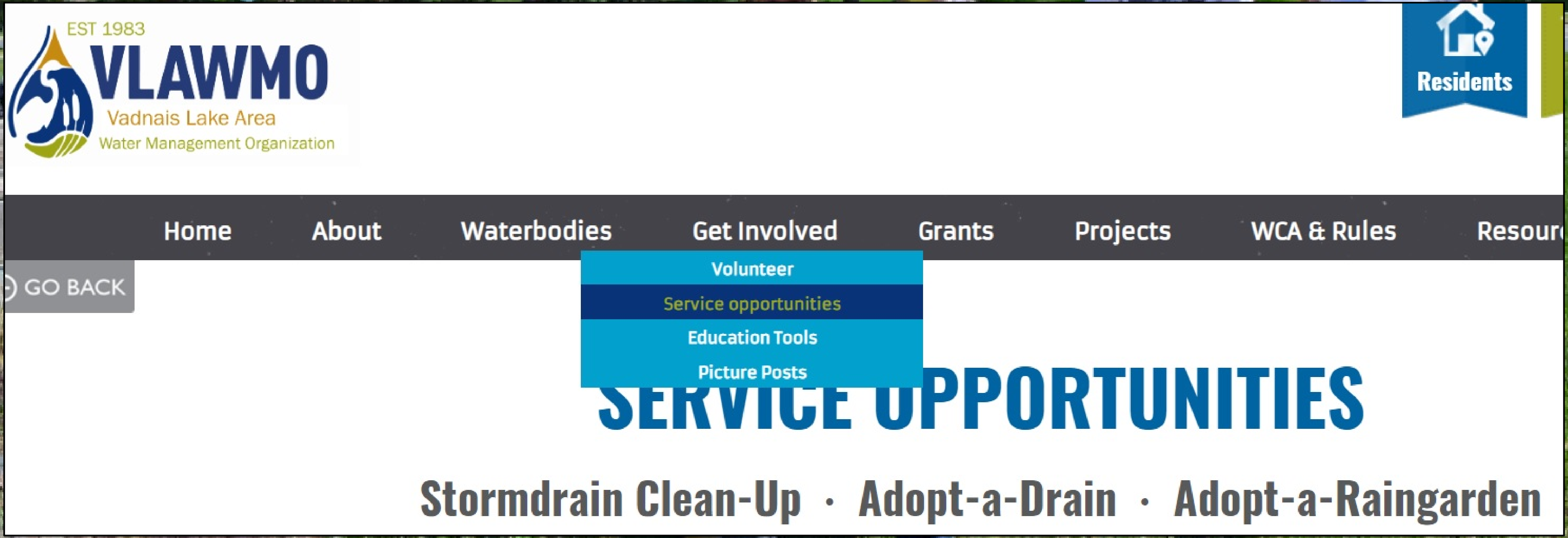
4,026 adopters



Enter

800 County Road E E

Adopt-a-Raingarden



WAV
WATERSHED ACTION VOLUNTEERS

- Project-based volunteering
- Citizen advisory
- Convenient one-and-done
- Flyers or public surveys


Connect with us!
www.VLAWMO.org
Blog, news, events, resources,
seasonal email newsletter,
WAV newsletter

Benefits of Turfgrass Lawns

- Beard and Green, 1994

- **Environmental / Functional**
  - Erosion control, Dust prevention, Glare reduction, Heat dissipation, Carbon sequestration, Noise abatement, Groundwater recharge
- **Recreational**
  - Low-cost surface, Physical health, Safe surface, Social harmony
- **Aesthetic**
  - Beauty, Enhanced quality of life, Improved mental health, Increased property values

Why is water conservation important?

- Environmental sustainability
- Resource competition (Agriculture, Industry, Commercial / Residential)
- Decreasing supply → Increasing demand (urbanization)
- Utility Costs ($$$)
- Plant Health

Lawn Irrigation

- **Increased scrutiny**
  - Rising urbanization leads to competition for freshwater resources
  - Outdoor water use is visible to public
    - Irrigation during rain
    - Irrigation runoff onto impervious surfaces
  - Lawn rebates & removal

HOME & GARDEN

His grass is greener: Minneapolis homeowner rips out lawn, puts in artificial turf

A southwest Minneapolis man has let go of his lawn mower and embraced artificial turf.

By Suzanne Ziegler Star Tribune | MAY 30, 2018 — 10:07PM

RICHARD TSONG-TAATARII – STAR TRIBUNE

Larry Lee said he's used to people slowing down as they drive by his house in southwest Minneapolis. Passers-by even reach out and touch his lawn, intrigued by its year-round perfection.

Everyone else's lawn may be a mushy yellow-brown in early spring, but Larry Lee's southwest Minneapolis yard is a vibrant, glorious green. In the summer, the only dandelions are in his neighbors' yards.

His lawn is so perfectly green that people who drive by slow down to stare.

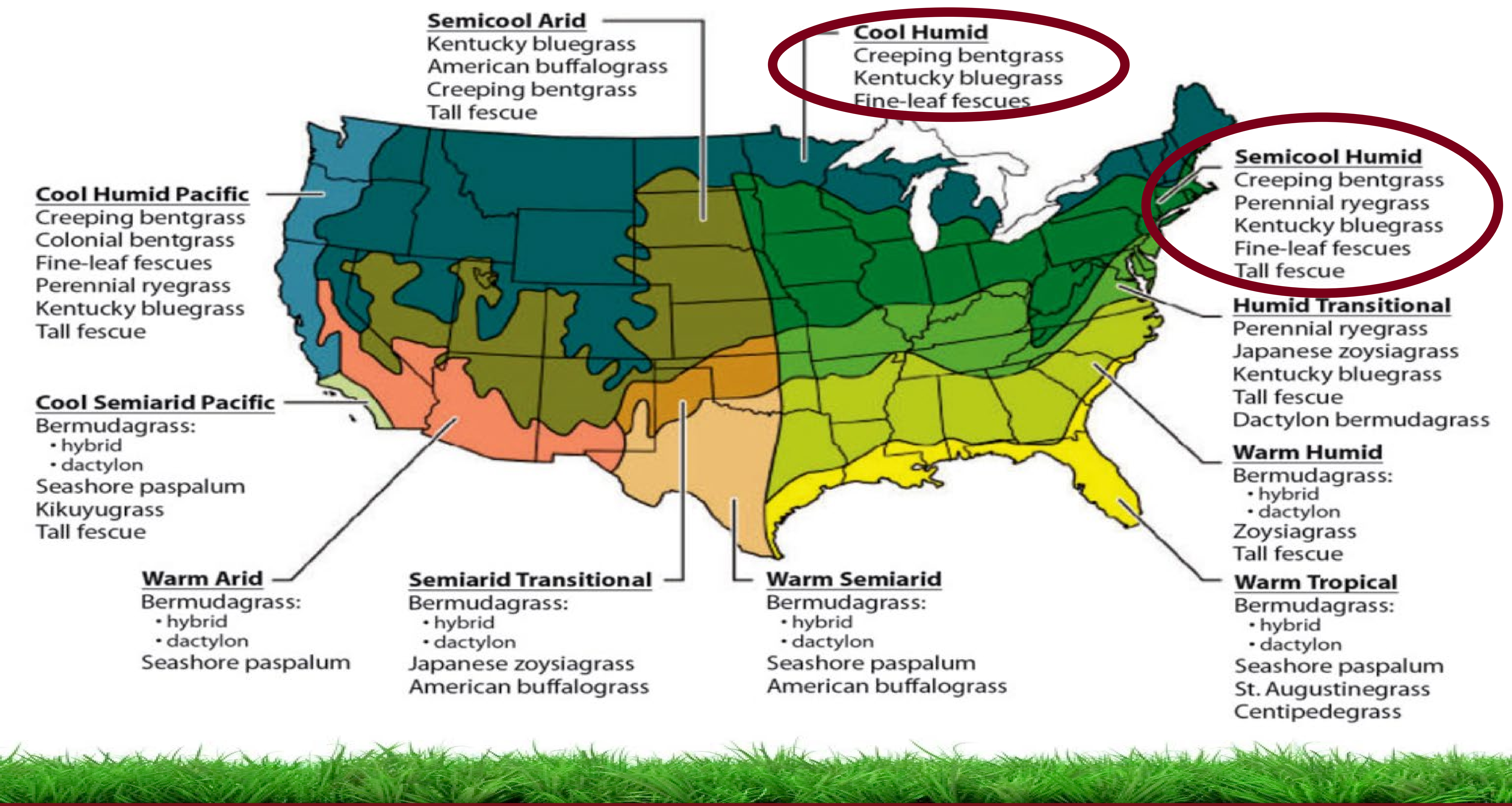
Lawn Irrigation

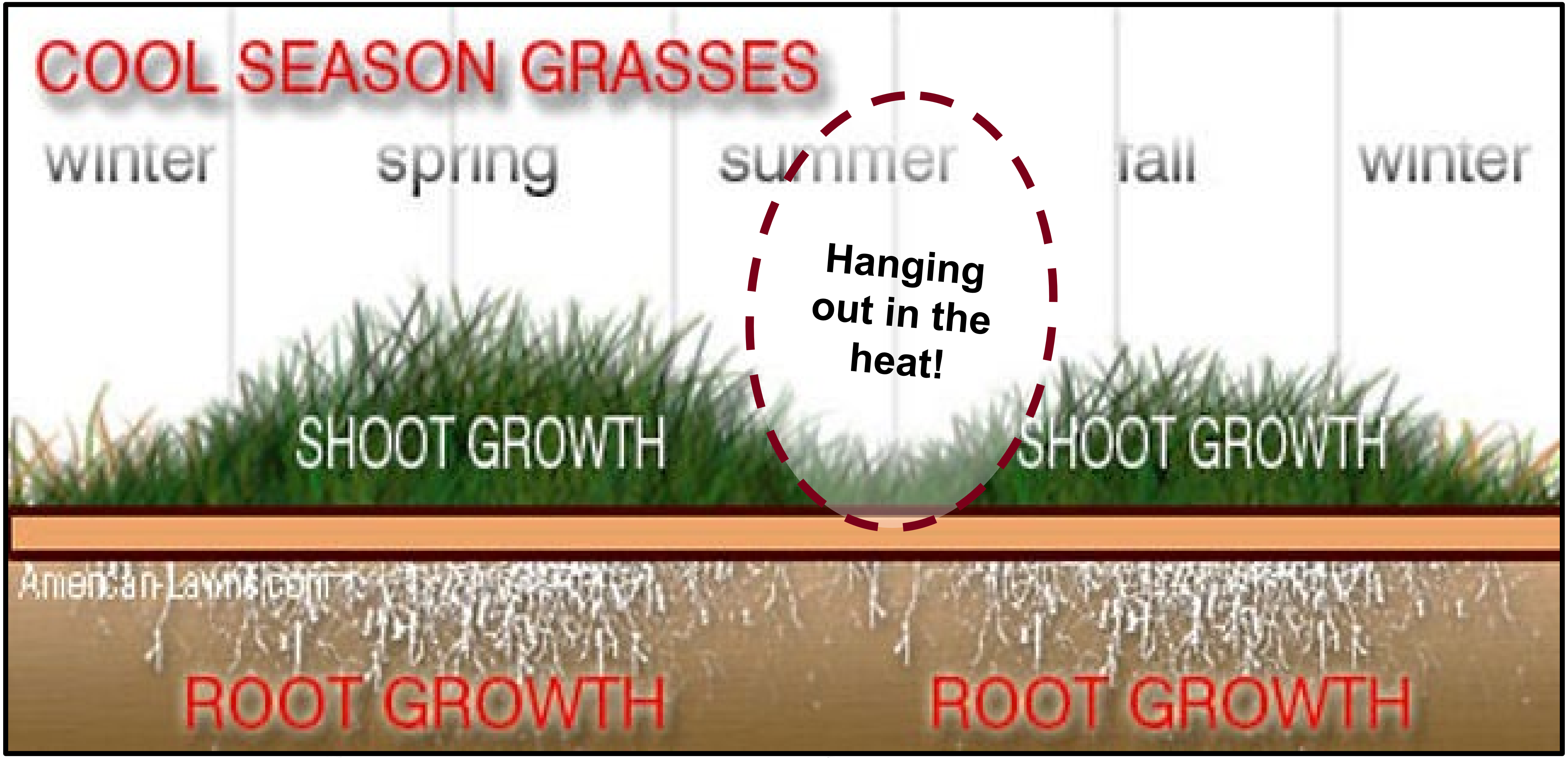
Lawn Irrigation

- **Water-Efficiency requires use of Best Management Practices**
  - Turfgrass selection
  - Cultural practices
    - Mowing, Fertilization, Cultivation, Pesticide management
  - Irrigation: auditing and sensor/smart technologies
- **NO SILVER BULLET!**

Turfgrass water requirements

- **Vary among turfgrass species and varieties**
  - Drought-resistant varieties and cultivars
  - All shapes, sizes, colors
  - Leaf texture, waxy leaf blades, leaf hairs, growth habit
- **Are aesthetic problems due to drought or something else?**
  - Shade tolerance, Fertility requirements, Mowing height tolerance, Soil compaction, ...


Semicool Arid
Kentucky bluegrass
American buffalograss
Creeping bentgrass
Tall fescue
Cool Humid
Creeping bentgrass
Kentucky bluegrass
Fine-leaf fescues
Cool Humid Pacific
Creeping bentgrass
Colonial bentgrass
Fine-leaf fescues
Perennial ryegrass
Kentucky bluegrass
Tall fescue
Semicool Humid
Creeping bentgrass
Perennial ryegrass
Kentucky bluegrass
Fine-leaf fescues
Tall fescue
Humid Transitional
Perennial ryegrass
Japanese zoysiagrass
Kentucky bluegrass
Tall fescue
Dactylon bermudagrass
Cool Semiarid Pacific
Bermudagrass:
• hybrid
• dactylon
Seashore paspalum
Kikuyugrass
Tall fescue
Warm Humid
Bermudagrass:
• hybrid
• dactylon
Zoysiagrass
Tall fescue
Warm Arid
Bermudagrass:
• hybrid
• dactylon
Seashore paspalum
Semiarid Transitional
Bermudagrass:
• hybrid
• dactylon
Japanese zoysiagrass
American buffalograss
Warm Semiarid
Bermudagrass:
• hybrid
• dactylon
Seashore paspalum
American buffalograss
Warm Tropical
Bermudagrass:
• hybrid
• dactylon
Seashore paspalum
St. Augustinegrass
Centipedegrass


COOL SEASON GRASSES
winter
spring
summer
fall
winter
Hanging out in the heat!
SHOOT GROWTH
SHOOT GROWTH
AmericanLawns.com
ROOT GROWTH
ROOT GROWTH

Turfgrass Water Conservation

- **Cool-season turfgrasses for Minnesota Lawns**
  - Tall fescue ← **Drought and Shade Tolerant**
  - Kentucky bluegrass
  - Perennial Ryegrass
  - Fine fescues ← **Very Low-Maintenance, Drought and Shade Tolerant**
  - Rough bluegrass
  - Supine bluegrass

  Rough bluegrass and Supine bluegrass ← **Poorly drained areas**

- Select turf-type and drought-tolerant improved varieties

How much water do lawns require?

- **Turfgarss water requirements relative to performance and quality standards** (rather than production or yield standards such as in agriculture, consumer horticulture, etc.)

- Total amount of water required/utilized for plant growth, includes water lost by transpiration and evaporation from soil and plant surfaces

NTEP

National Turfgrass Evaluation Program

NTEP.ORG

a-listturf.org

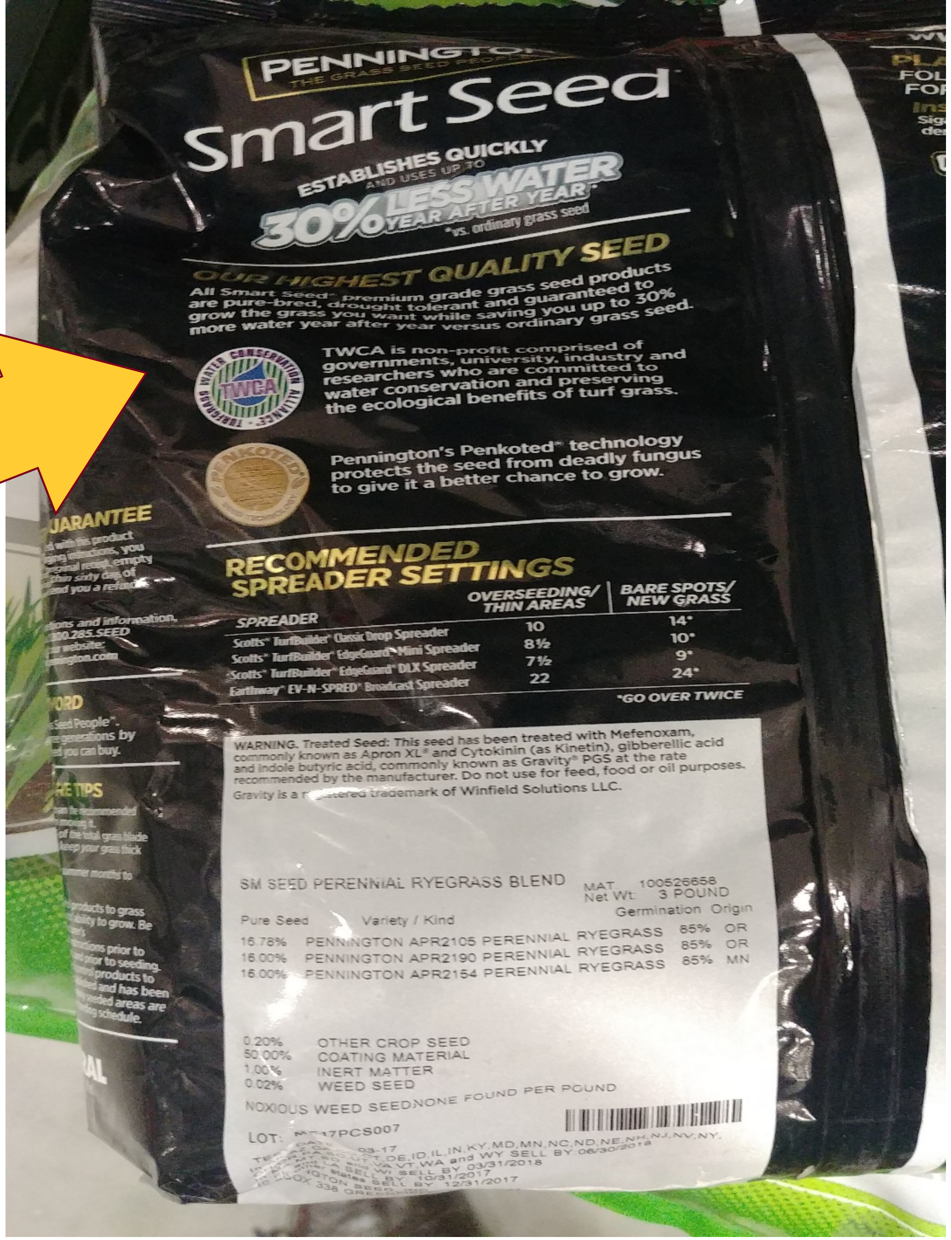
tgwca.org

lowinputturf.umn.edu

TURFGRASS WATER CONSERVATION ALLIANCE

TWCA

tgwca.org

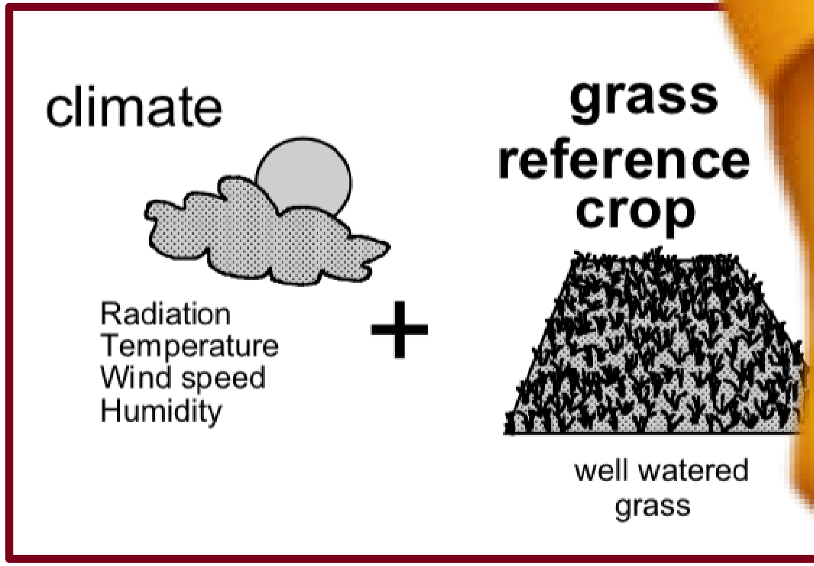


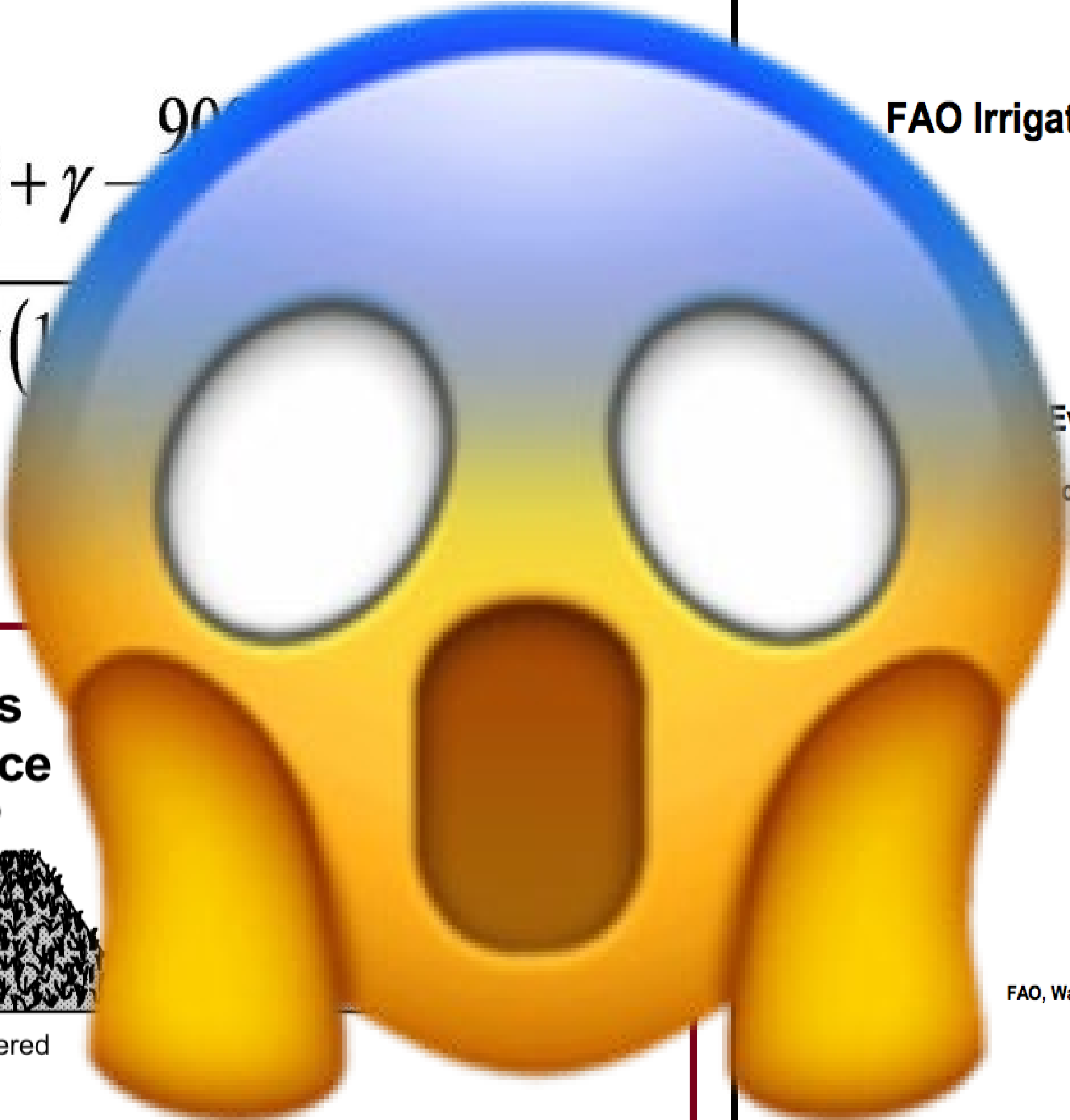
Improving Irrigation-Efficiency

Lawn water requirements influenced by **environmental conditions:**

- **Evaporation:** water loss from soil surface
- **Transpiration:** water loss from plant surfaces (similar to perspiration in humans)
- Irrigation should match ≤ evapotranspiration **(ET)**
- Environmental conditions influencing ET:
  - Solar radiation (sunlight), Temperature, Humidity, Wind, Precipitation

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \ldots}{\Delta + \gamma(\ldots}$$





FAO Irrigation and Drainage Paper

No. 56

Crop Evapotranspiration

computing crop water requirements)

by
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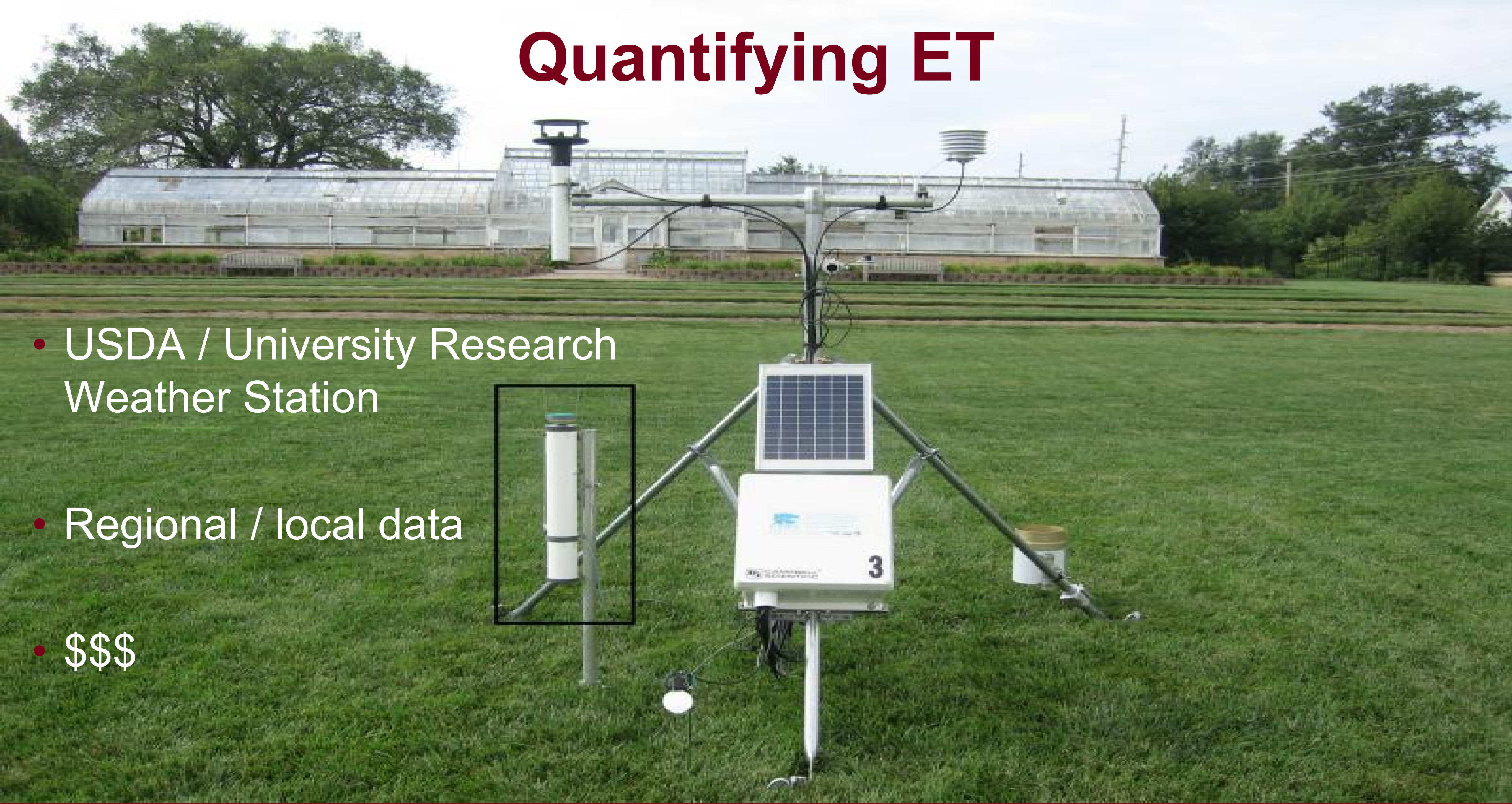
FAO, Water Resources, Development and Management Service
Rome, Italy

Quantifying ET

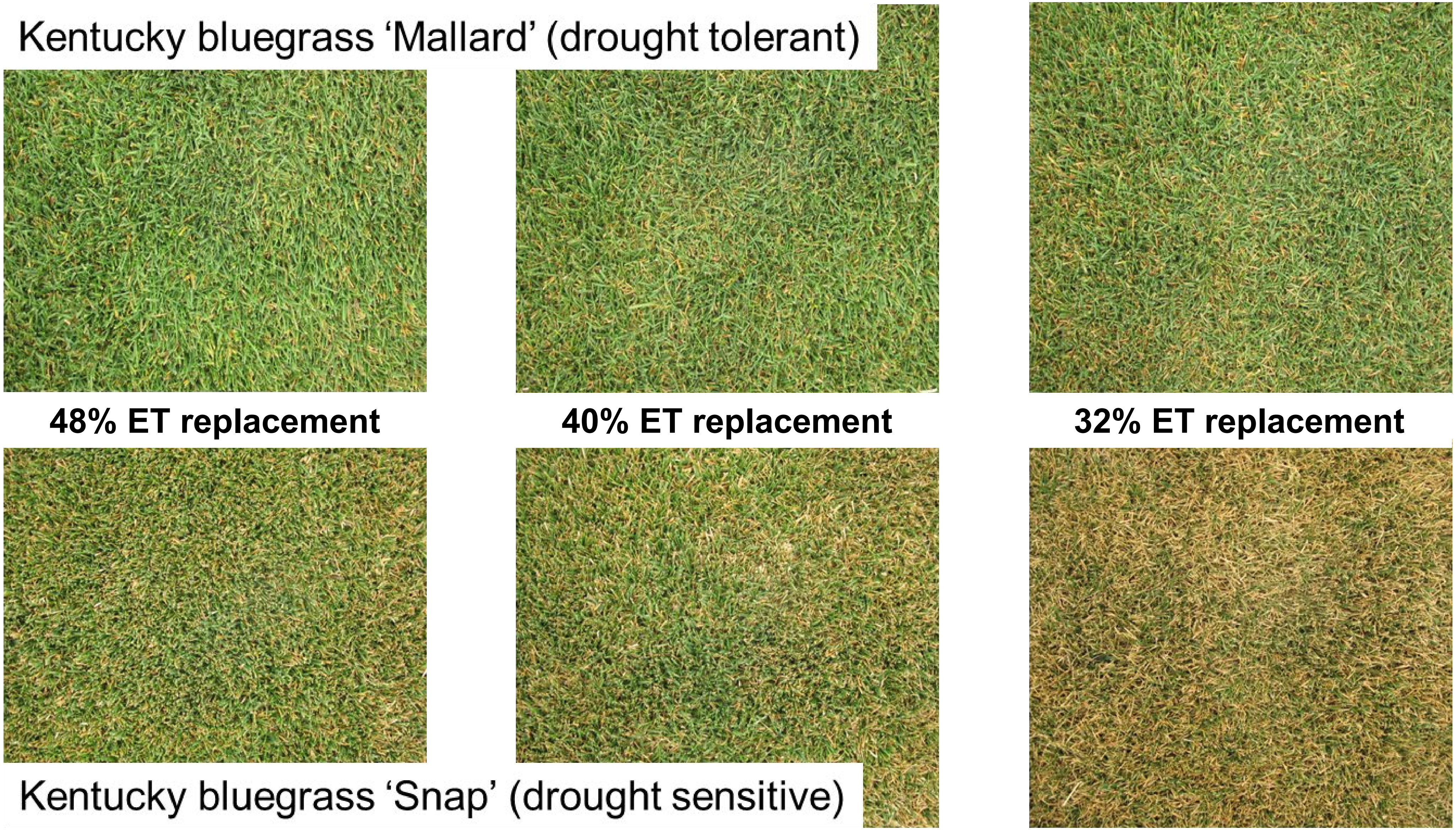


- USDA / University Research Weather Station
- Regional / local data
- $$$

Quantifying ET

- Personal weather stations (on-site data)
- Ambient Weather WS-2902A Smart WiFi Weather Station
- $170 (amazon.com)


www.tgwca.org
TWCA


Kentucky bluegrass 'Mallard' (drought tolerant)
48% ET replacement
40% ET replacement
32% ET replacement
Kentucky bluegrass 'Snap' (drought sensitive)

lowinputturf.umn.edu

Low Input Turf Using Fine Fescues

Currently, Kentucky bluegrass and perennial ryegrass are the two primary species used for turf in the northern United States. These species provide a high quality turf when managed with sufficient inputs; however, there has been increasing attention drawn to the negative aspects of higher input turfs, including the excessive use of water, fertilizer, fossil fuels, and pesticides.

The fine fescues – strong creeping red fescue, slender creeping red fescue, Chewings fescue, hard fescue, and sheep fescue – can be a solution to these challenges. Fine fescues are species of turfgrass that need less water, mowing, and fertilizer. These traits make the fine fescues a sustainable alternative to some of the traditionally used turfgrasses.

The next challenge is to identify ways to facilitate adoption of these fine fescues on private and public landscapes. Our team recently received a $5.4 million grant from the U.S. Department of Agriculture's (USDA) National Institute of Food and Agriculture (NIFA) to discover what is stopping homeowners from using fine fescues and how new varieties can be bred to overcome those obstacles. Our transdisciplinary approach will address social, marketing, technological, landscape management, and genetic barriers.

This project is a joint venture by participants from the University of Minnesota, Rutgers University, Purdue University, Oregon State University, University of Wisconsin and the USDA-ARS. It is funded by the USDA Specialty Crops Research Initiative (SCRI).

Campus Demo Plots

Click here for more information on campus demonstration plots.

Twitter




Living Laboratory
LOW-MAINTENANCE
TURFGRASS
It all adds up.
Reducing the amount of water and fertilizer needed to maintain a pleasing and functional campus.
italladdsup.umn.edu/livinglab
University of Minnesota

Salt-tolerant Fine Fescue at Governor's Mansion

Consumer-available seed mixtures drought trial

Two-year research trial at UMN St. Paul campus TROE center

- 29 different seed mixtures containing various turfgrass species
  - Kentucky bluegrass, Perennial Ryegrass, Tall Fescue, Fine Fescue, Annual Ryegrass, Rough Bluegrass, Alkaligrass
- Two mowing heights
  - 2.0-inches vs. 3.5-inches
- 60 days of drought (no irrigation or rain)
- 28 days of irrigation and/or rain (2x weekly)

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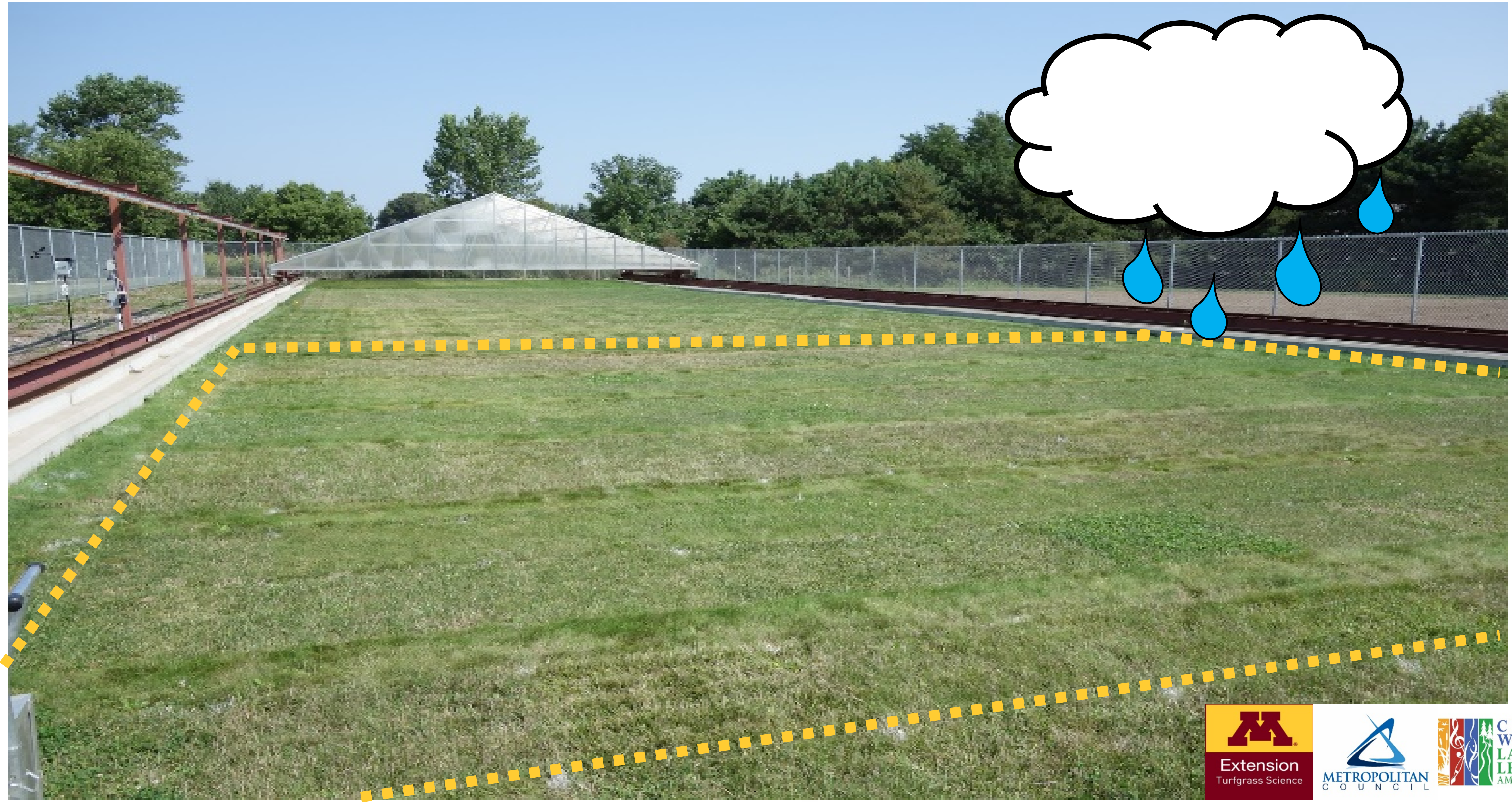

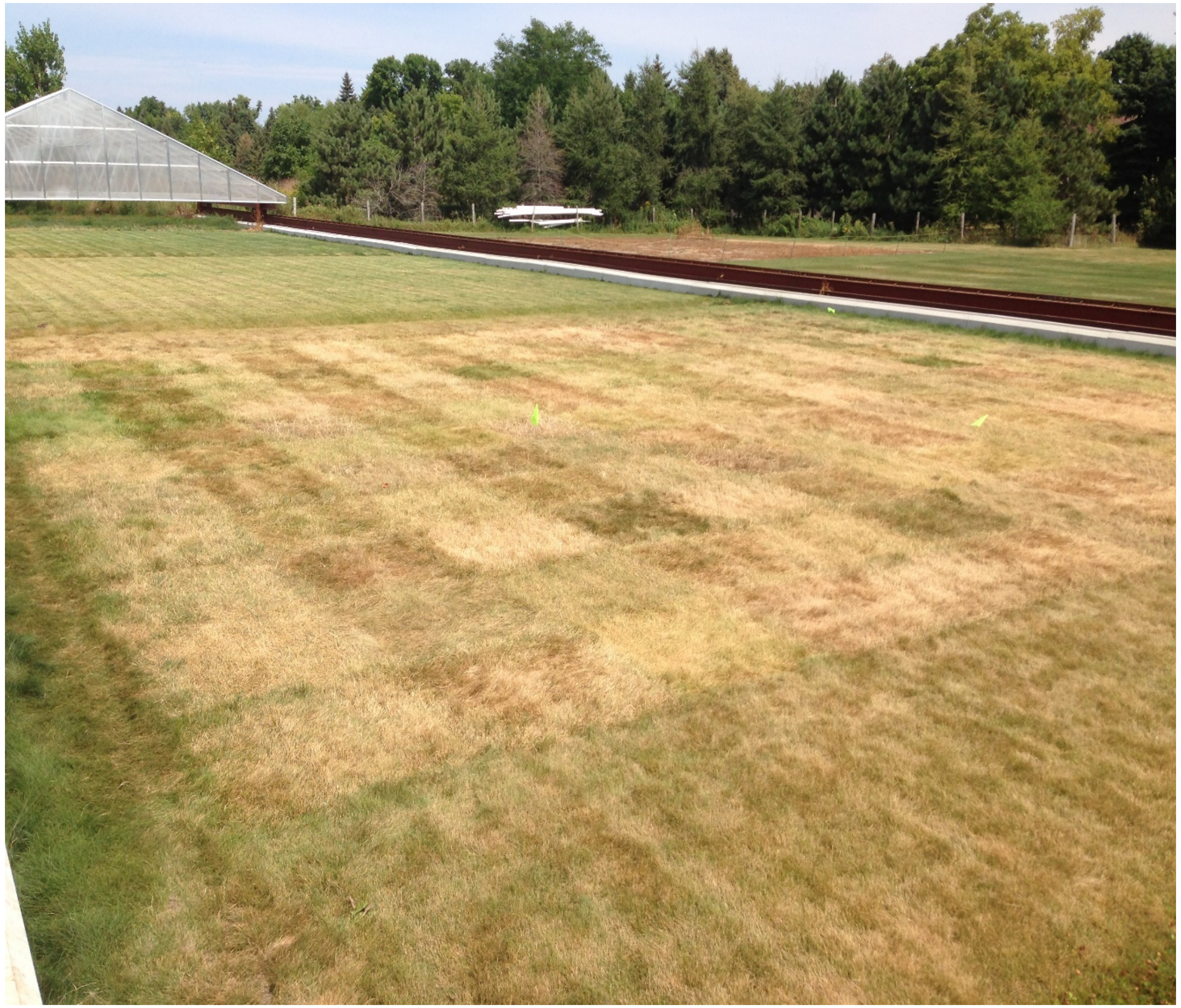

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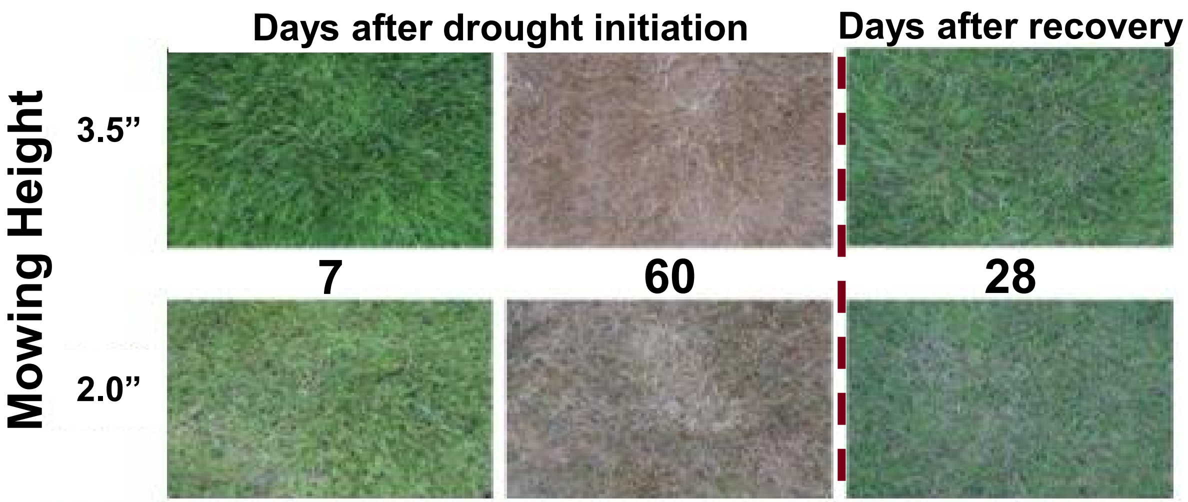
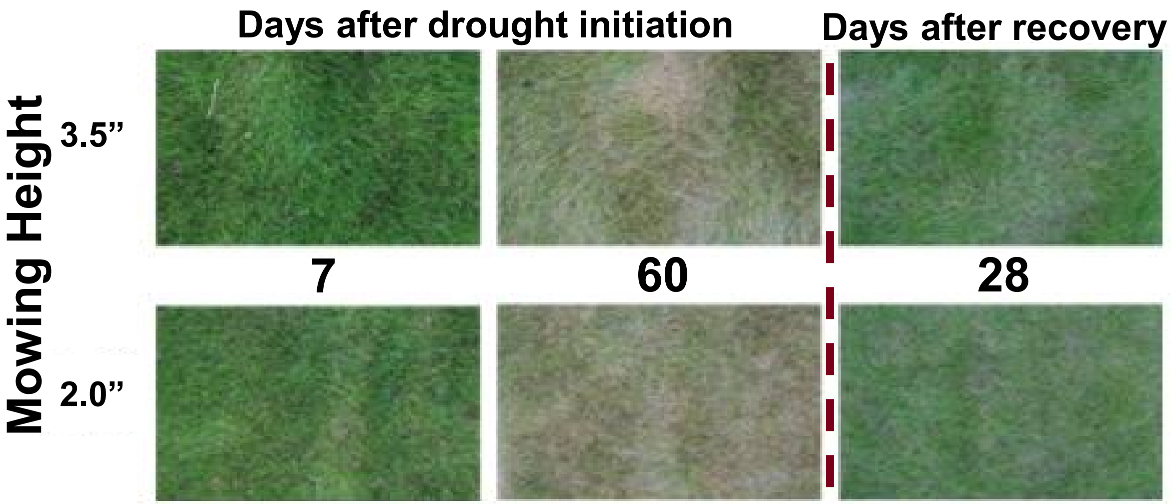
Consumer-Available Turfgrass Mixtures under Drought Stress and during Recovery

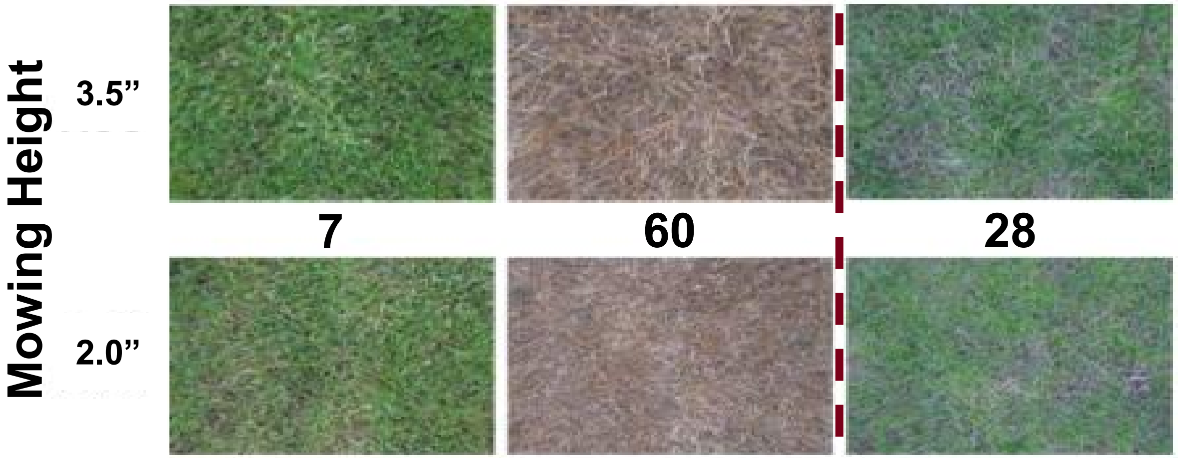
Perennial ryegrass dominant mixture



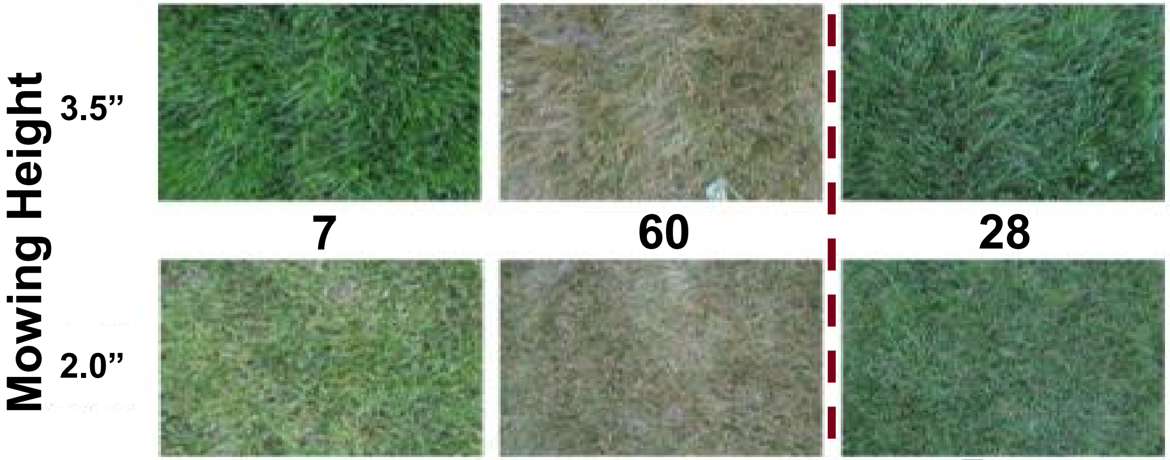
Fine Fescue dominant mixture



Perennial ryegrass, rough bluegrass and alkaligrass



Tall Fescue dominant mixture



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CLEAN WATER LAND & LEGACY AMENDMENT

Consumer-available seed mixtures drought trial

Two-year research trial at UMN St. Paul campus TROE center

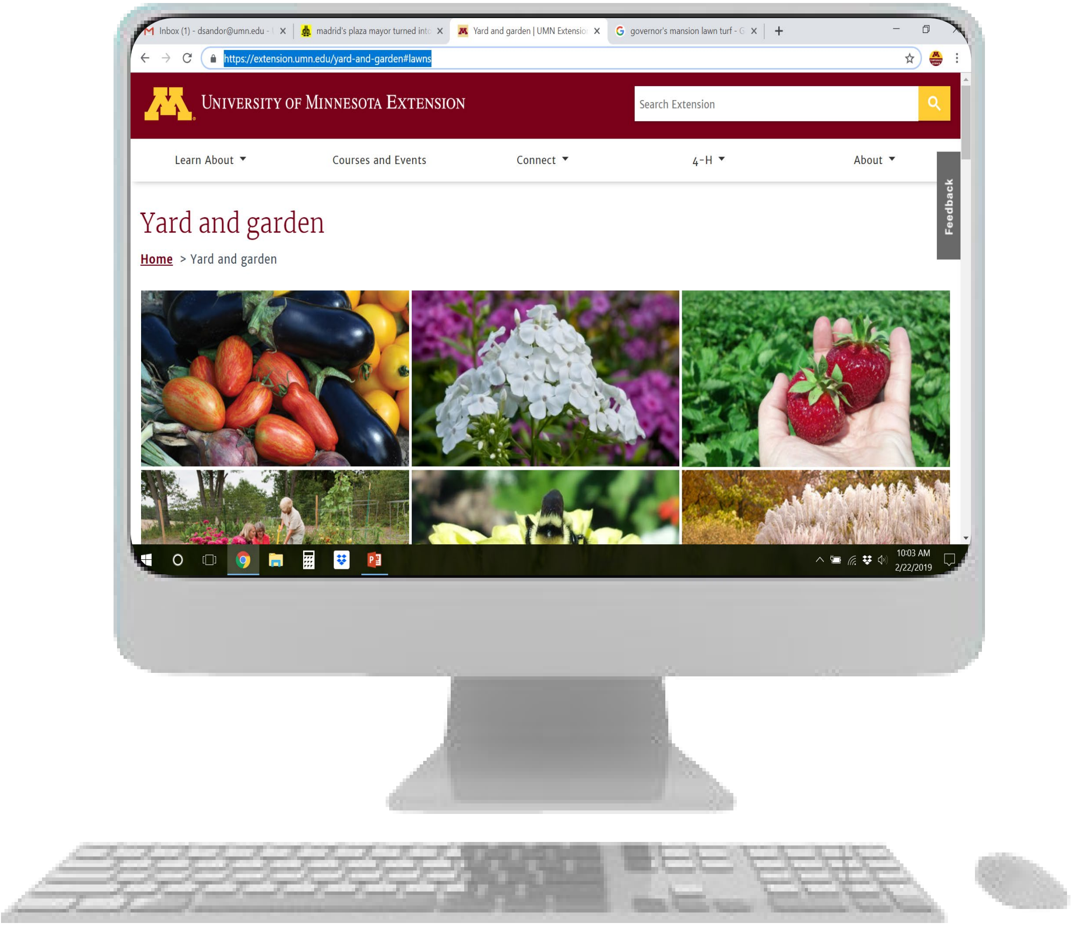
- Mixtures containing high percentage of Tall Fescue, Fine Fescue, and / or Kentucky Bluegrass, mowed at higher mowing heights, performed better under drought stress.

- Mixtures containing higher percentage of Perennial Ryegrass, or Annual Ryegrass, or Rough bluegrass are less drought-resistant.

- All seed mixtures recovered after the 28-day recovery period

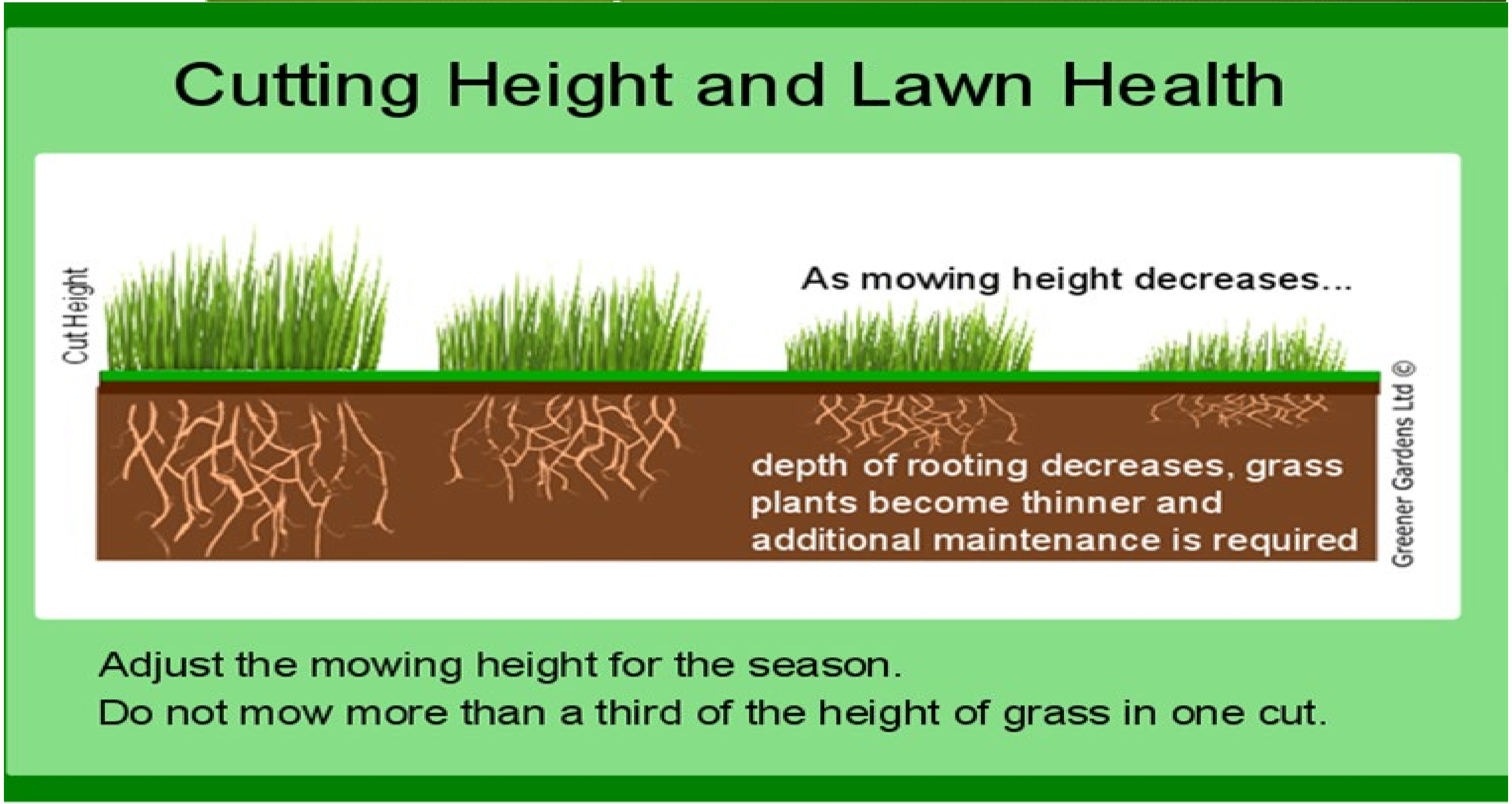
Lawn water requirements

- **Dependent on cultural practices**
  - Mowing (height & timing)
  - Fertility (product & timing)
  - Aerification/Cultivation (soil moisture, infiltration/drainage)
  - Pest Management (product & timing)



extension.umn.edu/yard-and-garden#lawns

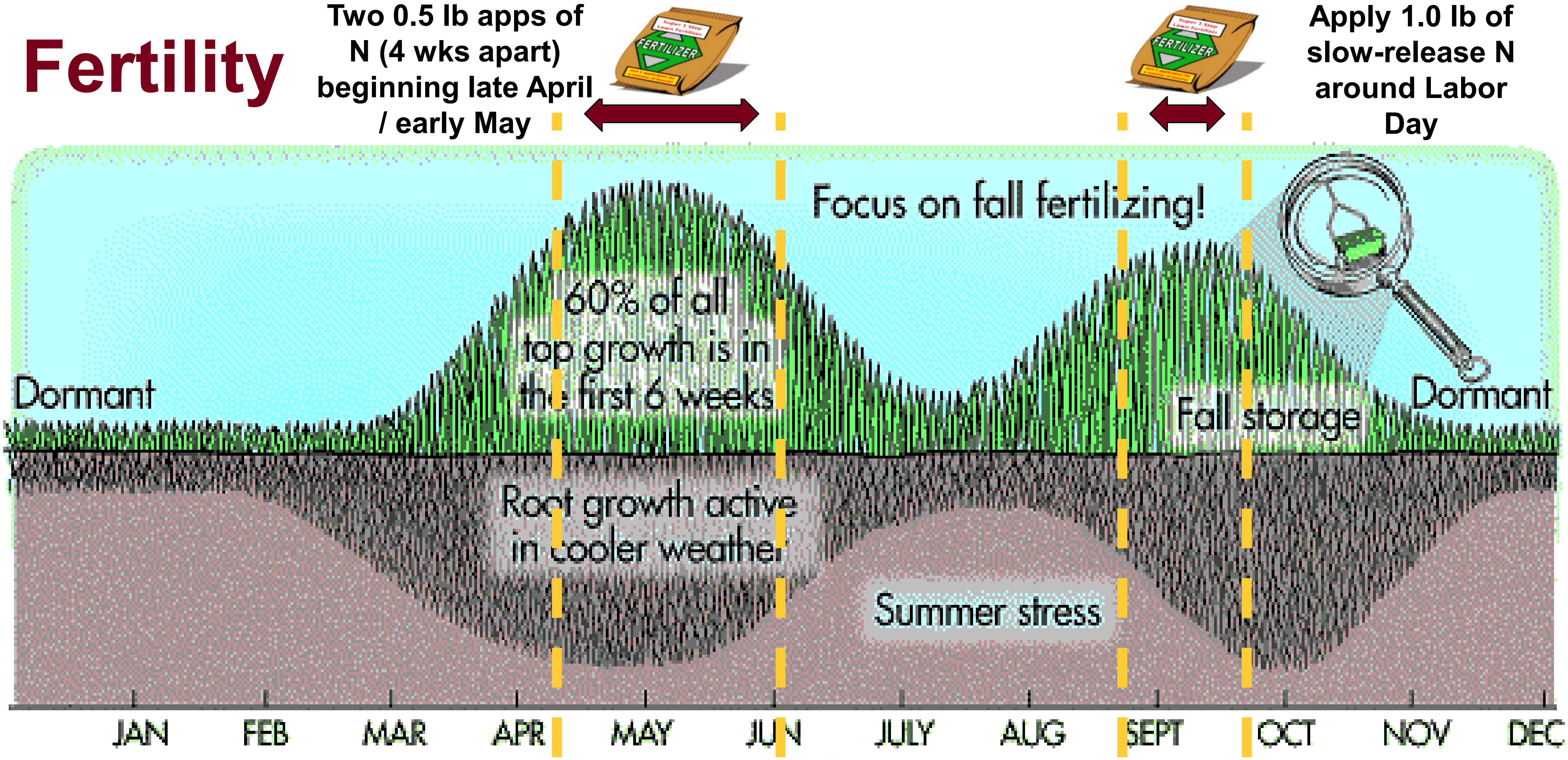
Mowing


Cutting Height and Lawn Health
Cut Height
As mowing height decreases...
depth of rooting decreases, grass plants become thinner and additional maintenance is required
Greener Gardens Ltd ©
Adjust the mowing height for the season.
Do not mow more than a third of the height of grass in one cut.

Fertility

Two 0.5 lb apps of N (4 wks apart) beginning late April / early May

Apply 1.0 lb of slow-release N around Labor Day



Fertility

Below is a table that outlines when and how much nitrogen is recommended for established lawns based on the amount of maintenance required for the lawn.

Nitrogen recommendations for established lawns

Maintenance level and practices		Total annual nitrogen to apply			Number and timing of applications
Soil organic matter	Low	Medium	High	Organic	
	High	**maintenance**			
Watered, clippings removed	4 lbs N/1000 sq ft/ year	3.5 lbs N/1000 sq ft/ year	3 lbs N/1000 sq ft/ year	2.5 lb N/1000 sq ft/ year	Four annual applications: Aug, Sept, early-Oct, May-June
Watered, clippings returned	3 lbs N/1000 sq ft/ year	2.5 lbs N/1000 sq ft/ year	2 lbs N/1000 sq ft/ year	1.5 lbs N/1000 sq ft/ year	Three annual applications: Aug, Sept, May-June
	Medium	**maintenance**			
Some watering, clippings removed	3 lbs N/1000 sq ft/ year	2.5 lbs N/1000 sq ft/ year	2 lbs N/1000 sq ft/ year	1.5 lbs N/1000 sq ft/ year	Three annual applications: Aug, Sept, May-June
Some watering, clippings returned	2 lbs N/1000 sq ft/ year	1.5 lbs N/1000 sq ft/ year	1 lb N/1000 sq ft/ year	0.5 lb N/1000 sq ft/ year	Two annual applications: Sept, May-June
	Low	**maintenance**			
No watering, clippings returned	1 lb N/1000 sq ft/ year	1 lb N/1000 sq ft/ year	0.5 lb N/1000 sq ft/ year	0.5 lb N/1000 sq ft/ year	One annual application: Sept

Soil organic matter levels: Low = less than 3.1%; Medium = 3.1 – 4.5%; High = 4.6 – 19%; Organic soils = more than 19%. If soil organic matter level is not known, guidelines for medium soil organic matter can be used. Assuming each application does not exceed 1 lb N/1,000 sq ft (for annual applications of 1.0 lb N or greater).

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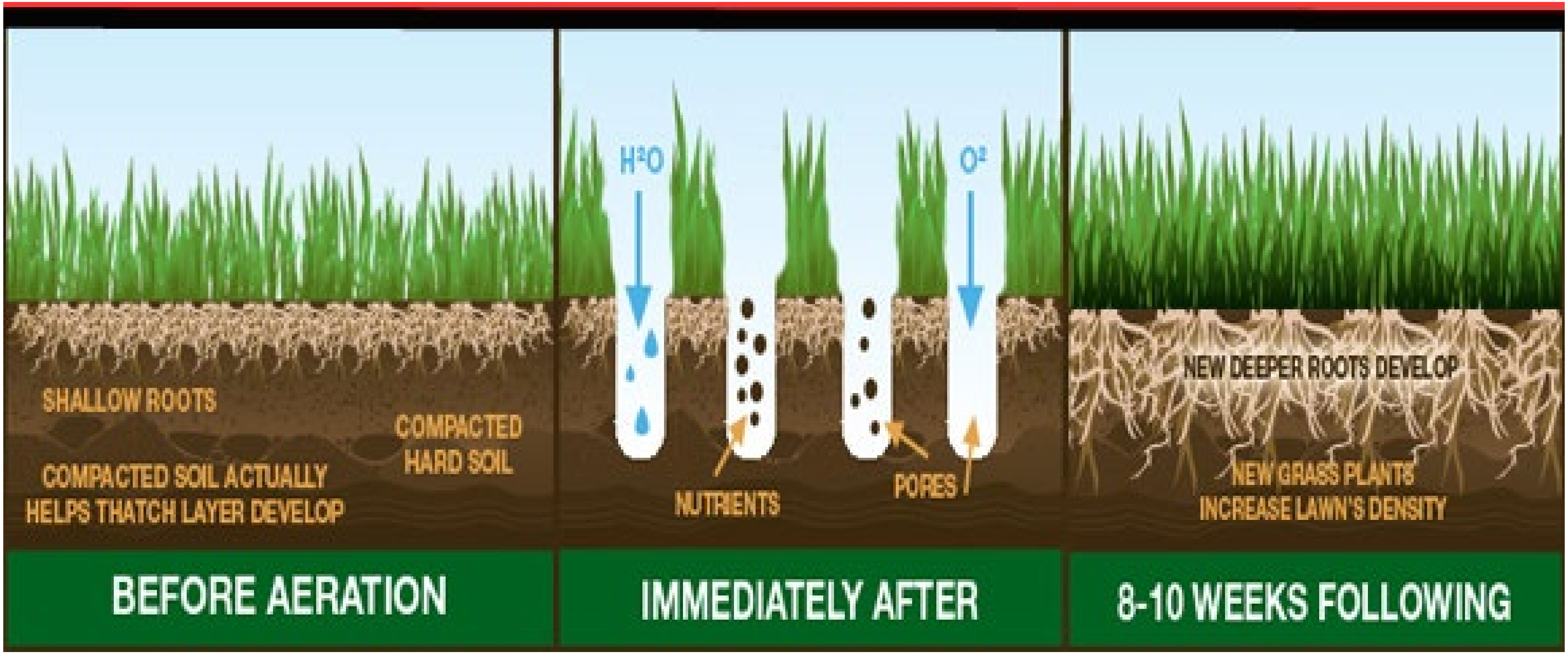
Turfgrass Science

extension.umn.edu/lawn-care/fertilizing-lawns

Cultivation (aerification)

Cultivation (aerification)



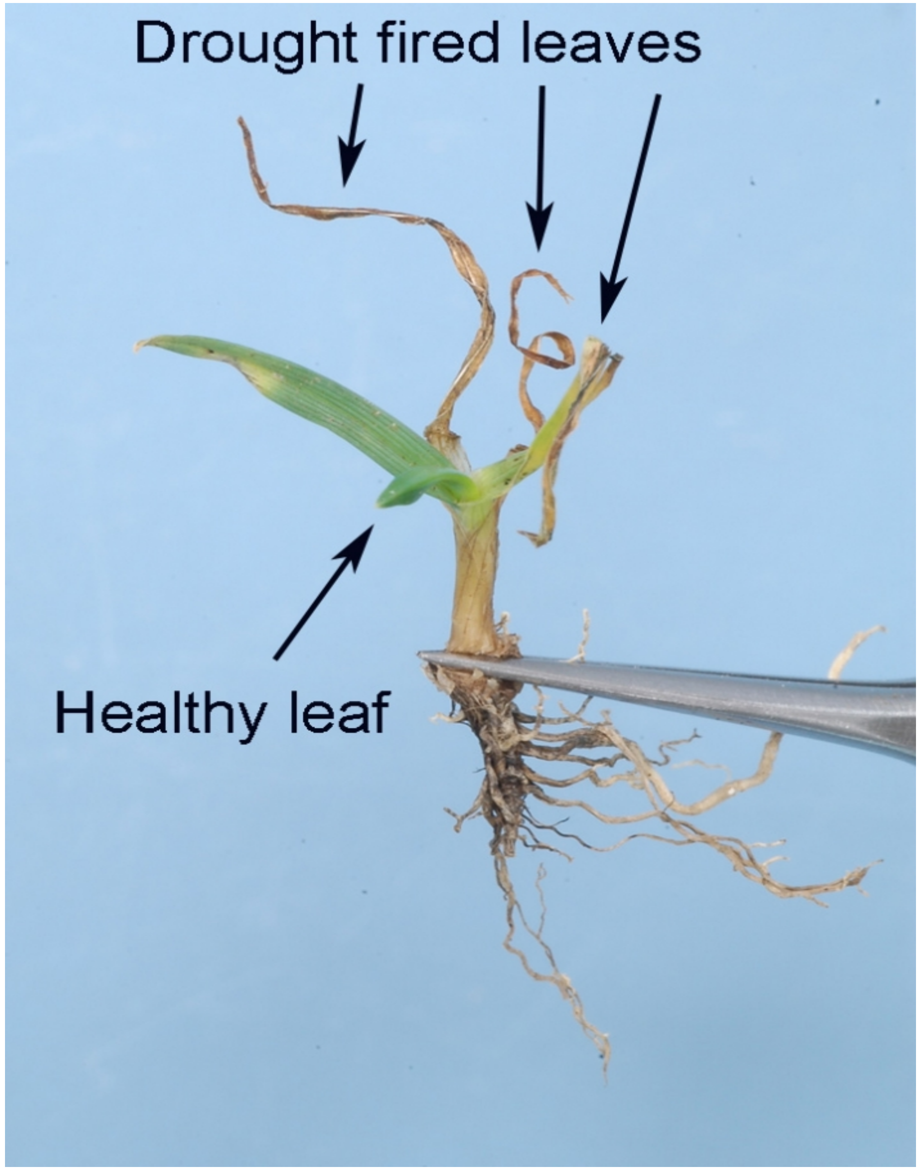
Irrigation Timing

- **How can I know when the soil moisture is low?**

- **Turf Wilting and Leaf Firing**
  - Leaves rolling / folding
  - Tan / Brown leaves

- Visible foot-printing, tire tracks, bluish-gray coloring, screw driver test, ...

- **Irrigation Sensors and Technologies**



Drought fired leaves
Healthy leaf

Sprinkler System Components

- **Timer / Controller**
  - Old timers vs new timers (SMART)
  - irrigation.org/swat
- **Pipe & Valves (zones)**
  - Will be dependent on the number of zones in the system
- **Heads & nozzles**
  - sprays, rotors, multi-stream rotors
  - Different application efficiencies
  - Don’t mix & match on the same zone!

Sprays

Rotors

Multi-stream Rotors

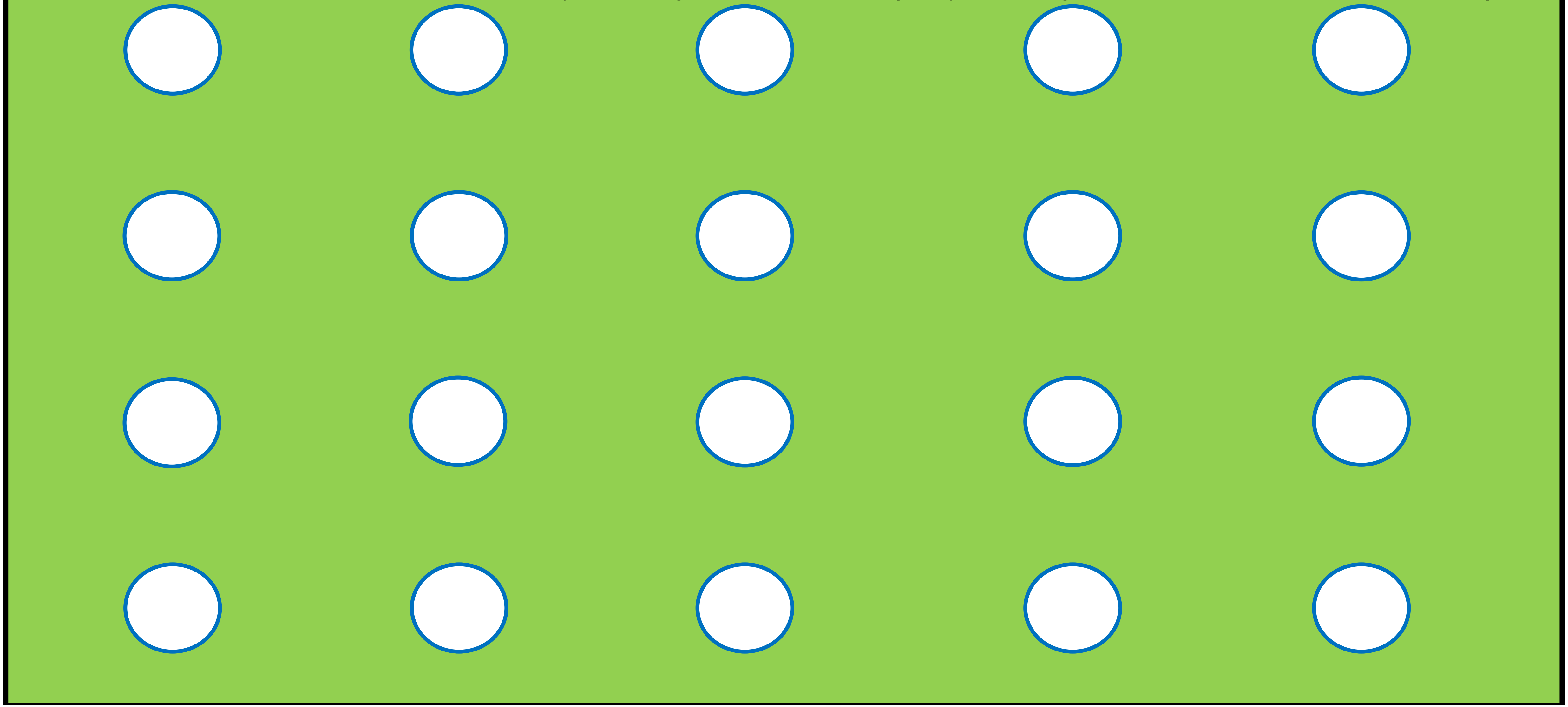
Conducting an Irrigation Audit

Conducting an Irrigation Audit

- Inspect zones for leaking / broken and misaligned heads
- Try to do this during periods of low wind (e.g., early morning; < 6 mph) be sure to record / make note of wind speed.
- Uniformly lay out catch cups (graduated cups, tuna cans, etc.) in a grid pattern. Minimum of 20 cups/cans.
- Run irrigation system for 20 minutes minimum
  - Can run for < 20 mins (e.g., 10, 12, 15) but will potentially be less representative of realistic output

Conducting an Irrigation Audit

Set out catch cups uniformly in a grid-pattern (any straight-sided cans will work)



Volume of water recorded in each catch-cup after irrigation ran for 20 minutes

0.20”	0.20”	0.20”	0.20”	0.15”
0.15”	0.25”	0.25”	0.20”	0.10”
0.15”	0.25”	0.25”	0.20”	0.10”
0.15”	0.20”	0.20”	0.10”	0.10”

Conducting an Irrigation Audit

Calculating Precipitation Rate (in/hr)

- Record the inches (volume) of water in each cup and calculate the average amount for all 20 cups
- Multiply the avg. amount by 3 (20 mins x 3 = 60 mins = 1 hour) to get precipitation rate
- **Example (from previous slide):**
  - Total collected after 20 mins: 3.6 inches
  - Average amount collected: 3.6 inches / 20 cups = 0.18 inches
  - Zone precipitation rate: 0.18 × 3 = 0.54 in / hr **(e.g., ~ 0.5 in per hour)**
- **RUNTIMES WILL DIFFER ZONE TO ZONE, AND PROPERTY TO PROPERTY**
- Increase PR by adjusting/changing nozzles, increasing pipe size, adjusting head spacing, etc... Note wind conditions as well, may need to re-run audit

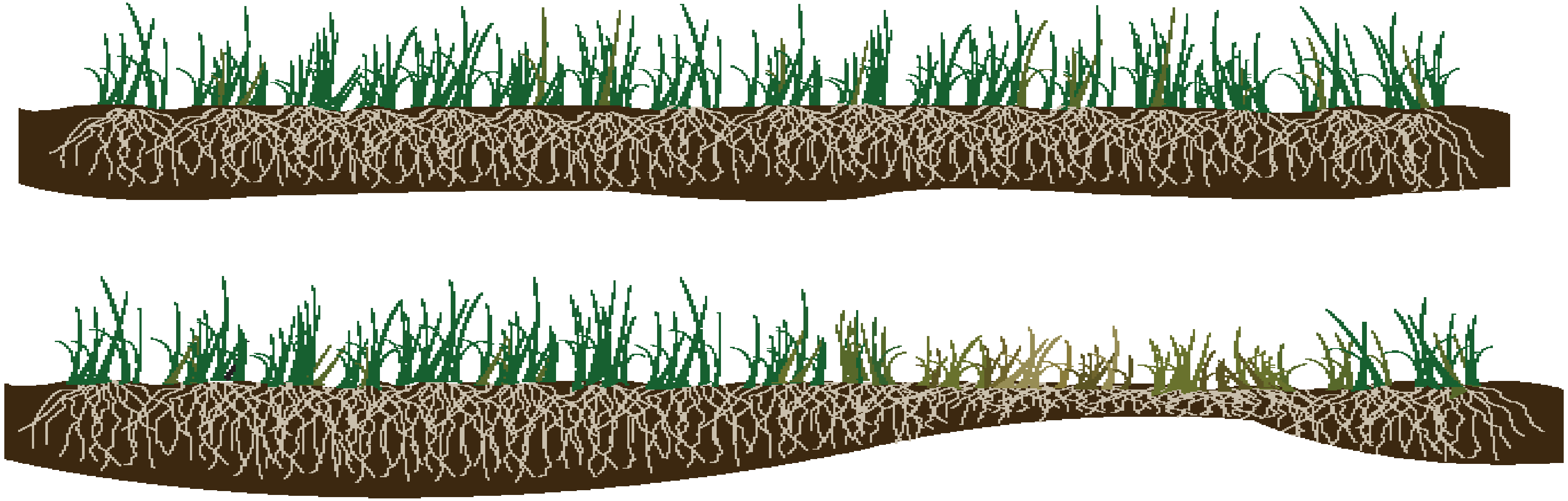
Conducting an Irrigation Audit

<u>Calculating Distribution Uniformity</u>

- Tells you if your system is over-watering or under-watering in certain areas of the zone

Good

Poor



Conducting an Irrigation Audit

Calculating Distribution Uniformity

- For uniformity calculations take the average depth from the lowest 25% of catch cups and divide that average by the overall average depth of all cans.
  - Example from previous slide: Lowest Quarter collection = 0.10 inches
  - 0.11 inches / 0.18 inches = 61.1 % Distribution Uniformity

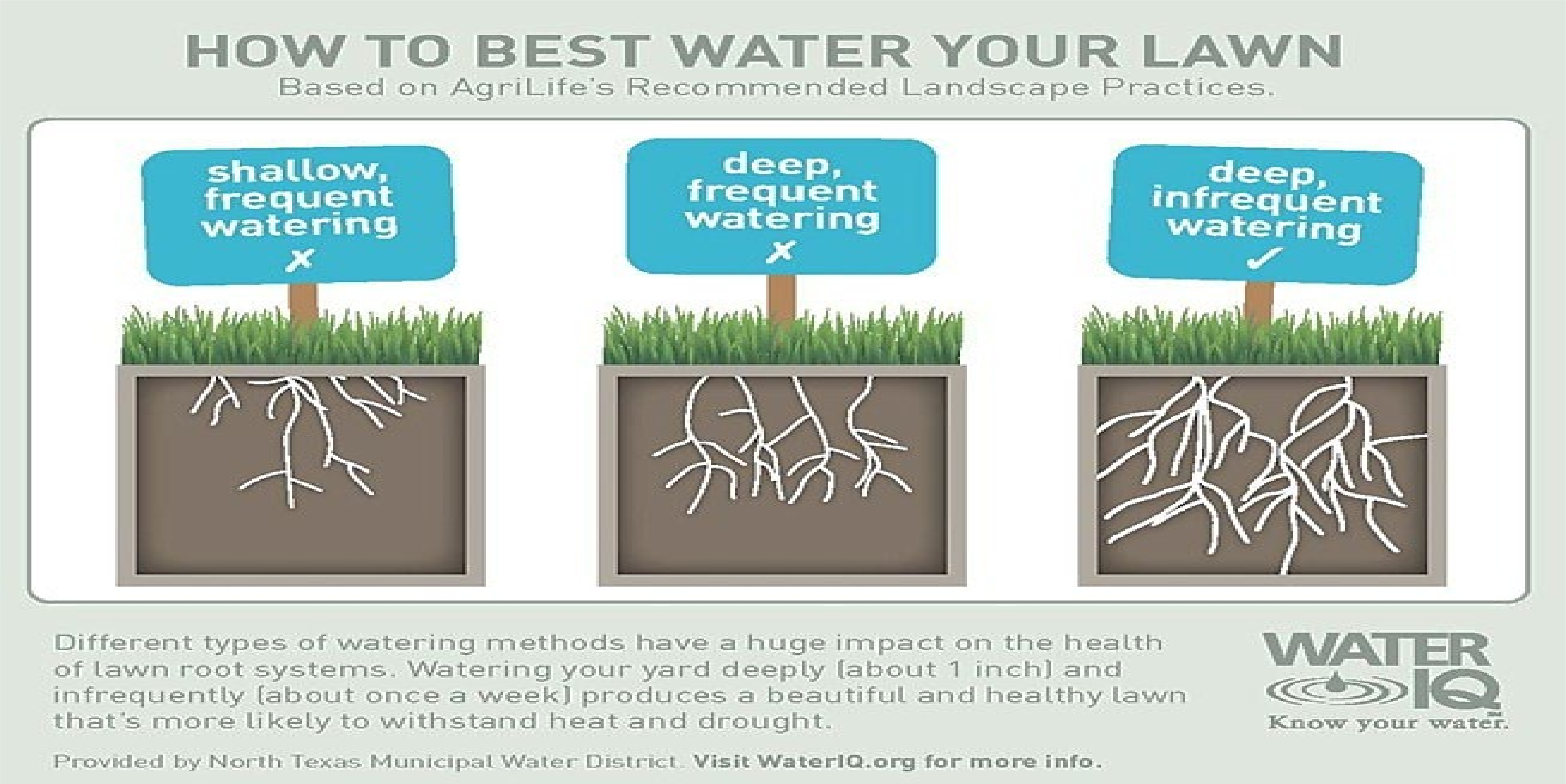
- Irrigation systems with lower than 60% uniformity should be adjusted for more uniform coverage

Table 13.1. Turfgrass and landscape sprinkler system field audit performance rankings by distribution uniformity and sprinkler type[a]

Sprinkler type (typical use)	Distribution uniformity (DU_{LQ}) and expected system performance				
	Excellent (achievable)	Very good	Good (expected)	Fair	Poor (needs improvement)
Multiple-stream gear and impact rotors (golf and large turfgrass areas)	85%	80%	75%	65%	55%
Single-stream gear and impact rotors (medium-sized landscape and turfgrass areas)	75%	70%	65%	60%	50%
Fixed-spray heads (small lawns and landscapes)	70%	65%	55%	50%	40%

[a] Developed by Cal Poly Irrigation Training and Research Center at California State Polytechnic University, San Luis Obispo. Funded by California Department of Water Resources and the Metropolitan Water District of Southern California. Adapted from Walker et al. 1988.

Irrigation Volume (amount)



Irrigation Timing

- **1-inch per week during drought period**
  - Deep and infrequent
  - Two 0.5-inch applications (alt. three 0.33-inch apps)
- **Cycle and Soak to prevent runoff**
  - Heavy Loam and Clay soils
- **Conduct Irrigation Audit to determine run-time**
- **Rain Sensors, Smart Controllers, Soil Moisture Sensors**


Hunter
SOIL-CLIK
Soil Sensor
TORO
WaterTec S100
Soil Moisture Sensor
READ / SET
BYPASS
WETTER
DRYER
BUSY
DRY / ALLOW
BASE-LINE
Never Over-Water or Under-Water Again!
Sensors just make sense.
24-Hour Soil-Moisture Monitoring
RAIN BIRD
SMRT-Y
Soil Moisture Sensor

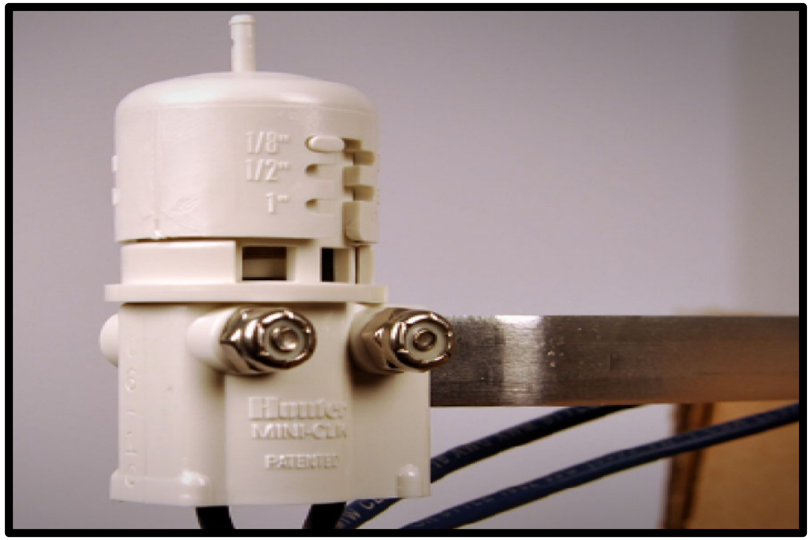
Rain Sensors

- ~ $20 to $30

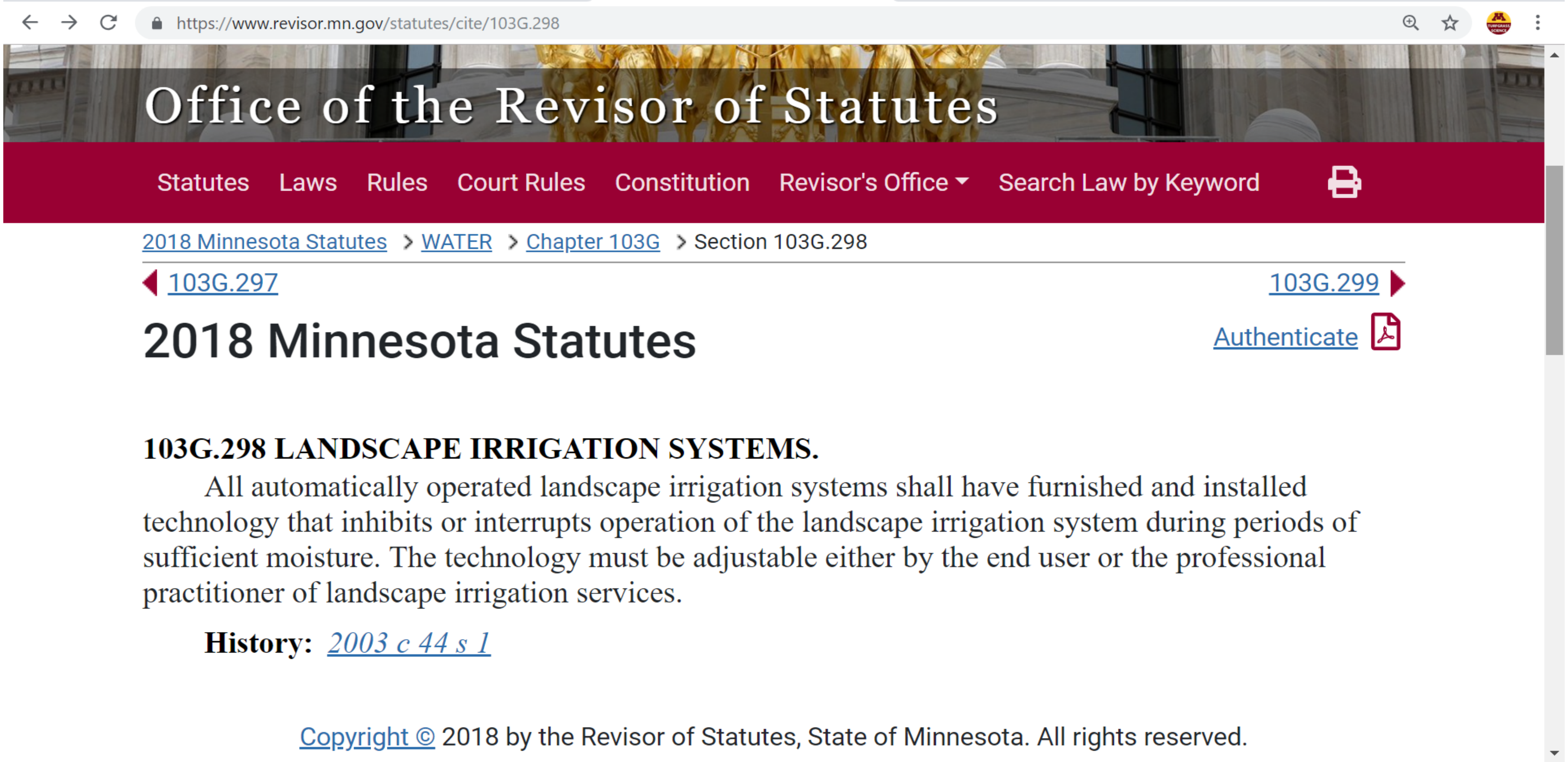
- Bypass irrigation
  - Shutoff sprinkler system immediately or
  - Rainfall threshold shutoff (precip. inches)

- Common RS use cork disks which swell upon wetting which triggers a signal to irrigation controller to bypass scheduled irrigation

- Ventilation window influences amount of time system remains in bypass mode



Rain Sensors

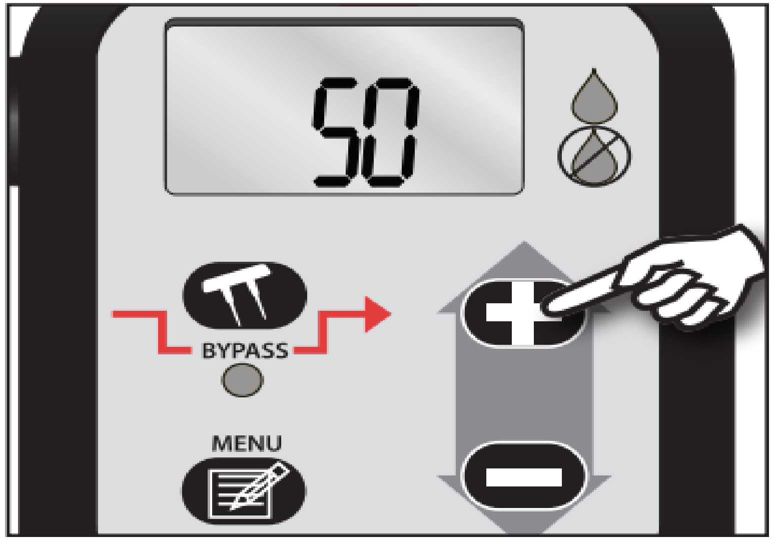


Soil Moisture Sensors

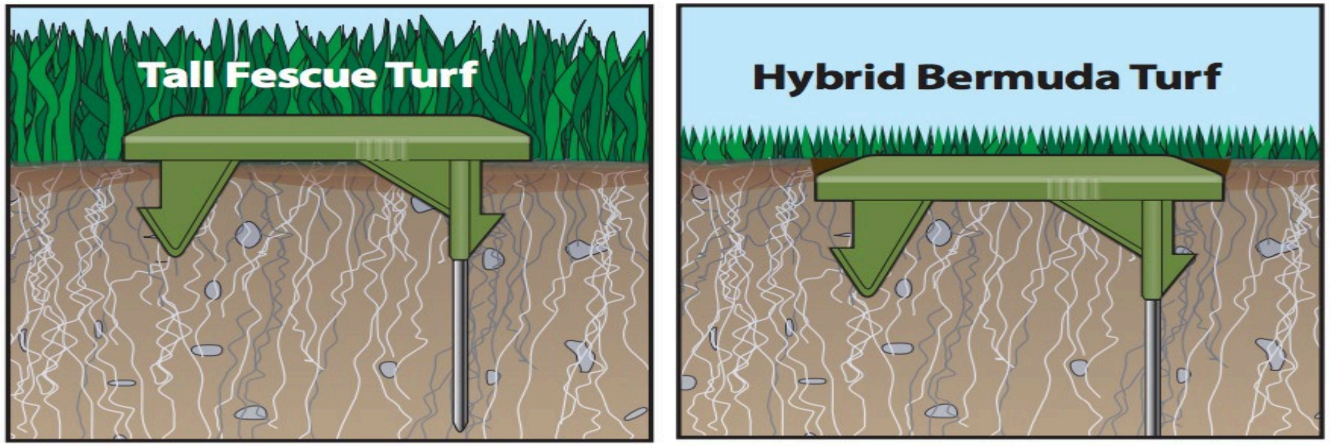
- **Continuously monitor soil water content**
  - Bypass scheduled irrigation event
  - Estimates soil moisture (%) threshold

- **Bypass irrigation when soil moisture (%) is above the moisture threshold**
  - Default-calibrated or user-adjusted moisture threshold

- ~ $120 to $160



For close-cut turf varieties, such as Hybrid Bermuda, the top of the sensor must be installed at grade level to prevent damage by mowing equipment.




WET CONDITIONS
DRY CONDITIONS
SOIL MOISTURE LEVEL
SOIL MOISTURE LEVEL (%)
Watering SUSPENDED
MOISTURE THRESHOLD
Watering ALLOWED
WATERING EVENTS
= ALLOWED
= SUSPENDED


1
Select ideal location
2
Wire sensor to nearby valve
3
Wire the SMRT-Y interface to the irrigation controller
4
Perform the auto-set function

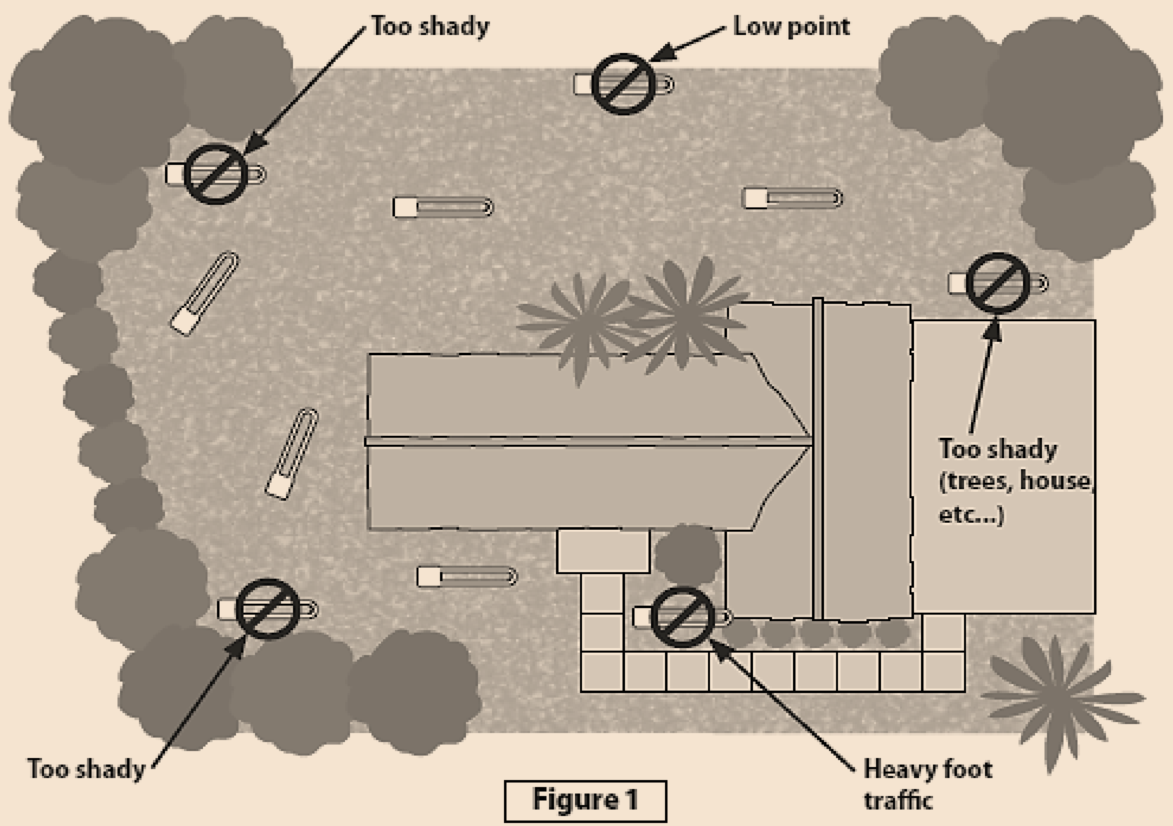


Figure 1

Sensor Location Selection

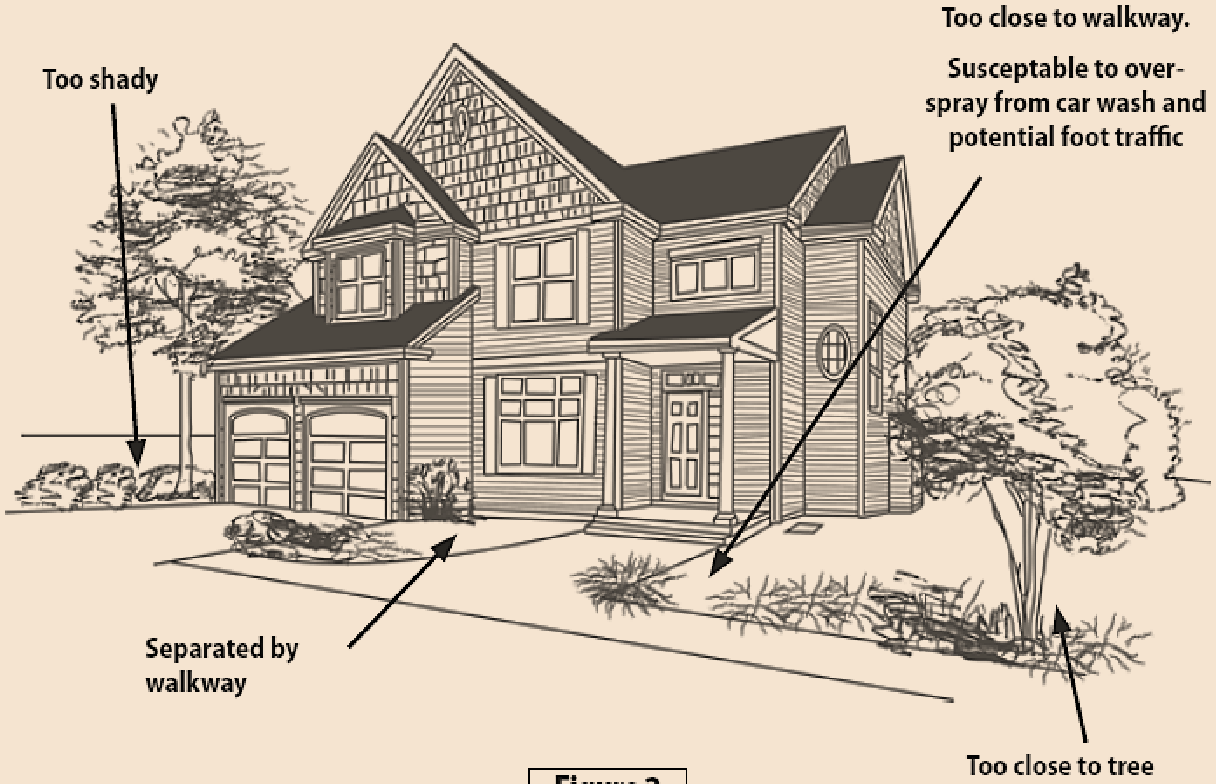


Figure 2

Unacceptable Sensor Locations

Controller is **OFF** even though dial is in **RUN** position (user-interface reads **'Watering Suspended'**)

Controller is **OFF** even though dial is in **RUN** position.


Control (no sensor)


Rain Bird RS


Hunter RS


Toro SMS


Rain Bird SMS

Hypothetical Water Usage and Financial Return on Investment over 17 weeks

(for 10,000 sq. ft lawn)

Irrigation sensor	Irrigation	Water saved	Irrigation cost†	Cost difference	ROI
	--- gal ---	--- gal ---	--- US$ ---	--- US$ ---	--- US$ ---
No Sensor (Control) (n=34)‡	105,975	-------	461	-------	-------
Rain Bird RSD-BEx (RS) (n=27; Avg. MSRP $25)§	84,156	21,819	366	95	**70**
Hunter Mini-Clik (RS) (n=26; Avg. MSRP $26)	81,039	24,936	353	108	**82**
Toro Precision Soil Sensor (SMS) (n=13; Avg. MSRP $138)	40,520	65,455	176	285	**147**
Rain Bird SMRT-Y (SMS) (n=10; Avg. MSRP $144)	31,169	74,806	136	325	**181**

† Cost of water for irrigation within Fayetteville city limits is $4.35 / 1,000 gallons. (City of Fayetteville, AR 72701)

‡ n= represents average number of annual irrigation events allowed by the treatment during the three-year study.

§ Average MSRP (US$) among RS and SMS utilized in the study are obtained from Amazon.com (accessed 4 Dec. 2018). Prices may vary depending on supplier and/or website.

Smart Controllers

- Large residential or Commercial properties
- Utilize weather station data from regional / nearby weather stations, or add-on weather stations (personal weather stations, airports, regional/USDA labs)
  - Adjust runtimes based on environmental conditions (i.e., ET)
- Many work with smartphones and utilize Wi-Fi
- Cost(s) dependent on number of zones

SkyDrop

Rachio

Smart Controllers

Rain Bird LNK Wi-Fi Module +
Rain Bird Smartphone App

Toro Evolution

Hunter Hydrawise +
Hydrawise Smartphone App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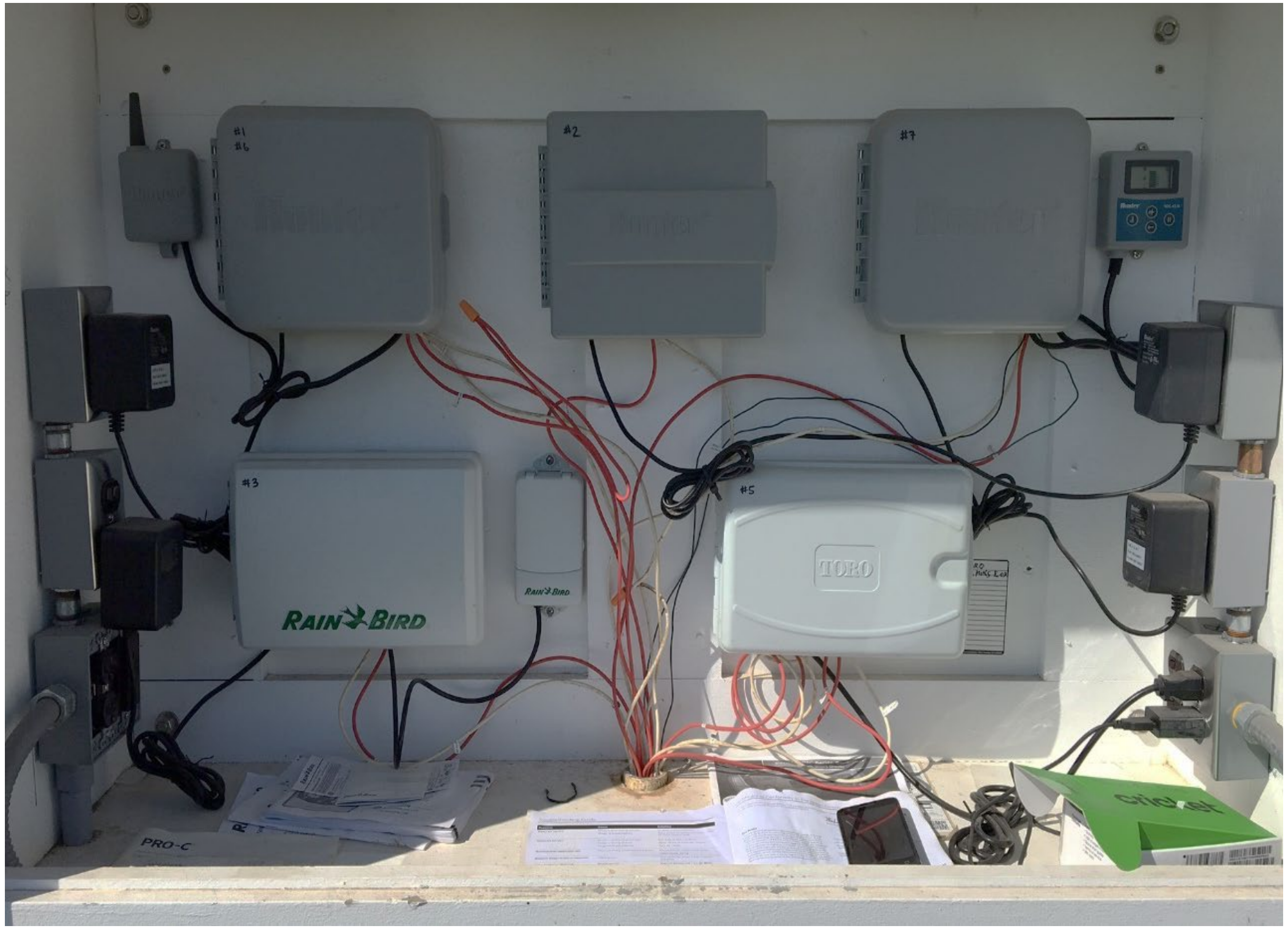
Eric Watkins @erictwatkins · 10 Oct 2018

Turf students at UMN learning about smart irrigation technology from @RazorbackTurf

5



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Irrigation Treatment	2017 Water Use†	Reduction	2018 Water Use‡	Reduction
	gallons (inches)	%	gallons (inches)	%
Control	12,962 (18.0)		14,323 (19.9)	
Hunter Hydrawise (smart controller)	8,732 (12.1)	33	10,305 (14.3)	28
Toro Evolution (smart controller - weather sensor)	5,160 (7.6)	60	7,855 (10.9)	45
Manual Irrigation	1,197 (1.7)	91	2,144 (3.0)	85
Hunter Soil-Clik (soil moisture sensor)	2,207 (3.1)	83	2,594 (3.6)	82

† 2017 trial ran from July 15th to October 19th (97 days). It is likely some irrigation ran that was unaccounted for and was not part of the scheduled program (such as following fertilizer applications or for demonstration purposes).

‡ 2018 trial ran from 04 June to 05 October (124 days).

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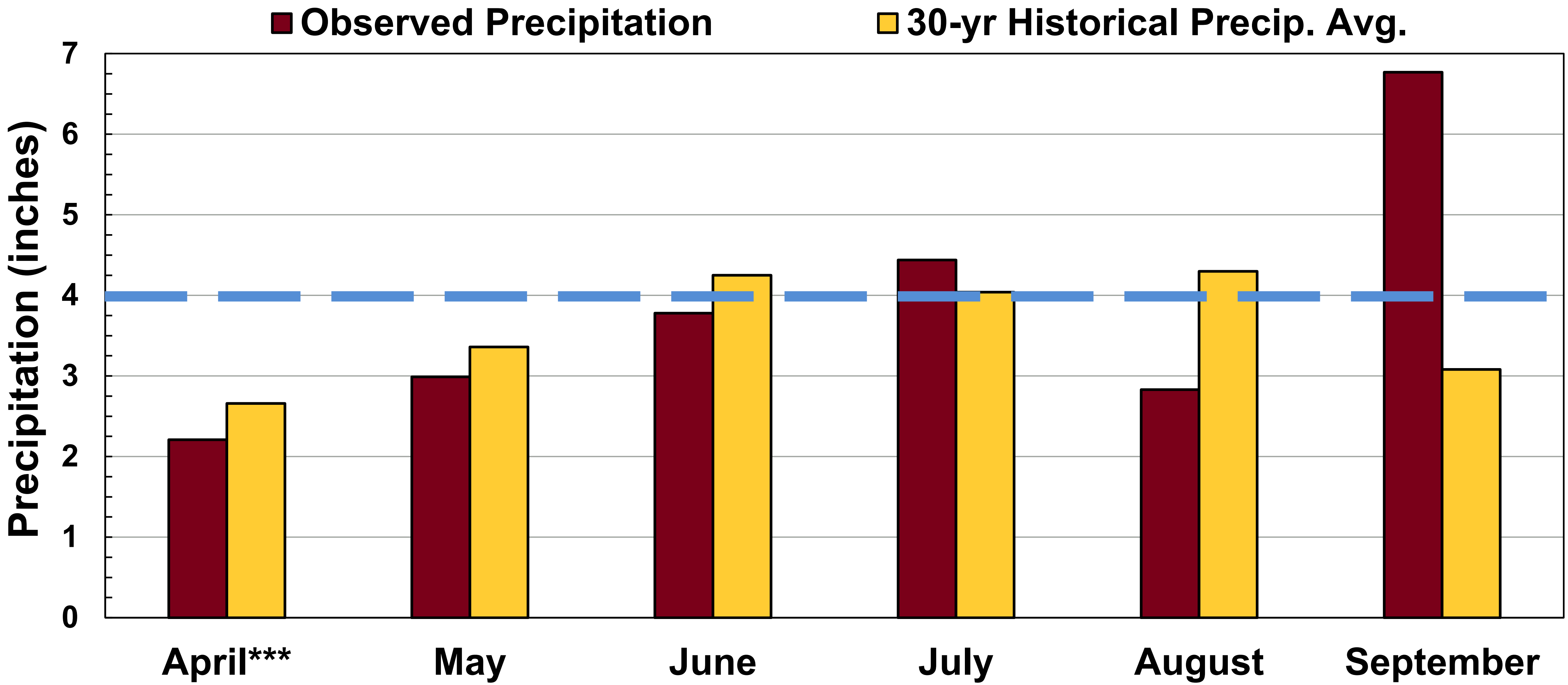
2018 Twin Cities Monthly Precipitation



*** **26.1 inches snow** observed April 2018 (1981-2010 April norm: 2.5 inches)

Source: GHCND:USW00014922; https://www.ncdc.noaa.gov/cdo-web/datatools/normals


21 August 2018


04 September 2018

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Summary

- Water use is one of the biggest challenges facing consumers, utilities, government agencies, and the turfgrass industry
- Use of BMPs for water conservation will improve water-use efficiency
- Consider drought-resistant turfgrass species and proper cultural practices to reduce irrigation demands
- Upgrade to Soil Moisture Sensors and / or Smart Controllers
- Audit Irrigation Systems Annually (spring) and keep sprinkler system ‘OFF’ until absolutely necessary.
- **No Silver Bullet**

Further Reading

- Carrow (2006), Can we maintain turf to customers' satisfaction using less water? Agricultural Water Management. 80:117-131
- UF IFAS extension publications on ET (ABE343; AE459) and smart irrigation technologies & sensors (ABE325; AE437; AE446; and AE460)
- Kneebone, W.R., D.M. Kopec, and C.F. Mancino. 1992. Water requirements and irrigation. In D.V. Waddington, R.N. Carrow, and R.C. Shearman, editors, Turfgrass. Agron. Monogr. 32 Turfgrass. ASA, CSSA, and SSSA, Madison, WI. p. 441-472.
- Leinauer, B. and D.A. Devitt. 2013. Irrigation science and technology. In: J.C. Stier, B.P. Horgan, and S.A. Bonos, editors, Agronomy Monograph 56 Turfgrass: Biology, Use, and Management. American Society of Agronomy, Crop Science Society of America, Soil Science Society of America: Madison, WI. p. 1075-1131.
- Huang, B. 2008. Turfgrass water requirements and factors affecting water usage. In: J. B. Beard and M. P. Kenna, eds., Water quality and quantity issues for turfgrasses in urban landscapes. Council for Agricultural Science and Technology, Ames, IA. p. 193-204.

QUESTIONS?

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