Texas Cooperative
EXTENSION
The Texas A&M University System

B-6165
9/05

Turf Irrigation
and
Nutrient Management

Turf Irrigation and Nutrient Management Reference Manual

by

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Table of Contents

How to Use This Manual

This manual is designed to serve as a reference guide for landscape professionals on irrigation and nutrient management of turf. Each chapter covers a separate topic and includes the following sections:

1. Summary Box: Lists the steps involved to complete each calculation or action.
2. Definitions: Defines all terms used in the section.
3. Instructions: Detailed explanations of each step listed in the summary box.
4. Calculations: Two methods are shown using the same example problem – the equation method and the table method, presented in the form of a quick reference table ("Quick Table") including these components or columns:
   a. #: Line number of the table
   b. Variable: The variable being calculated or the action being undertaken
   c. Value Units: The values being used in the particular example.
   d. Source: Where the values came from or how the calculation is done. Numbers shown in this column refer to the line number of the table.

Irrigation Water Management

Predicting Turf Water Requirements

Step 1: **Determine Local ET_o**

Step 2: **Select Turf Coefficient (T_c)**

Step 3: **Determine Adjustment Factor (A_f)**

Step 4: **Calculate Water Requirement Definitions**

Definitions

Adjustment Factor (A_f) — a modification of the crop coefficient (in percent). An adjustment factor is used to reduce water application for allowable stress, for microclimates such as excessive shade or sun, and according to the landscape manager's personal preferences.

Allowable stress — a factor reflecting an "acceptable" turf quality when water supply is reduced. Allowable stress varies according to individual preferences and by location requirements. Research has shown that turf water supply can be reduced by 40% or more and still maintain acceptable appearance for most sites.

Cool season turfgrasses — turfgrasses, such as tall fescue and ryegrass, adapted to cooler climates.

Evapotranspiration (ET) — a measurement of plants' total water needs, including water lost to the atmosphere through evaporation from the soil surface and due to transpiration.

Potential evapotranspiration (ET_o) — potential water use by a cool season grass growing 4 inches tall under well-watered conditions. It is used as a reference to which the water requirements of other plants can be related. ET_o varies with climate as a function of temperature, relative humidity, wind speed and solar radiation. Different locations have different ET_o rates due to changes in climate. (ET_o is sometimes written as "PET".)

Turf coefficient (T_c) — a factor used to relate ET_o to the actual water use by a specific type of plant or turf. The turf coefficient, T_c reflects the percentage of ET_o that a specific plant or turf type (such as bermudagrass hay) requires for maximum growth.

Warm season turfgrasses — turfgrasses, such as Bermudagrass, St. Augustinegrass and Zoysiagrass, adapted to warmer climates.

Detailed Instructions for Predicting Turf Water Requirements

Step 1: **Determine Local ET_o** — Appendix A gives average monthly ET_o for 19 major cities in Texas. The Agricultural Program of Texas A&M University System has ET_o (or "PET") networks that use the Internet to report current daily ET_o throughout Texas. One such network is TexasET (*http://texaset.tamu.edu*). Be sure to check TexasET for possible updates to average ET_o data.

Step 2: **Select Turf Coefficient (T_c)** — Warm season turfgrasses use up to 60% of ET_o, while cool season grasses can use up to 80% of ET_o. Table 1 gives monthly T_c values for the 19 major cities in Texas for warm season, cool season, and warm season turfgrasses overseeded with ryegrass, and for sports turf.

Table 1. Turf coefficients.

warm season	0.6
cool season	0.8
sports turf	0.8

Step 3: **Determine Adjustment Factor (A_f)** — T_c represents the maximum amount of ET_o that turfgrasses will use. However, many plants, especially turfgrass, can survive on much less water without showing signs of stress or reducing quality. For this reason, the crop coefficient is adjusted to represent "allowable stress" or "plant quality" needs of a site. For example, buffalograss can survive on much less water than can St. Augustinegrass, though both are warm

season grasses. Thus, A_f for buffalograss may be as low as 0.4, while A_f for St. Augustinegrass may reach only 0.6.

Microclimates also will influence water use, especially in small landscapes. Certain areas around buildings or under trees may receive more shade and require less water than areas under full sun. Wind speed also influences water use. For example, areas between buildings may experience a "venturi effect," resulting in high winds that increase plant transpiration. To make up for such losses, more water must be applied.

Step 4: **Calculate Water Requirement** — Calculate water use in turfgrasses.

$$WR = ET_o \times T_c \times A_f \qquad \text{(Equation 1)}$$

Where:
- WR – Water requirement (inches)
- ET_o – Potential evapotranspiration
- T_c – Turf coefficient (wdecimal)
- A_f – Adjustment factor (decimal)

Example 1:
- ET_o = 7.96 inches per month
- T_c = 0.6
- A_f = 1
- WR = 7.68 x 0.6 x 1
- WR = 4.78 inches per month

Example 1: Quick-Table A. Table Water Requirement

#	Variable	Value	Units	Source
1	Potential Evapotranspiration (ER_o)	7.96	inches per month	Appendix A - ET_o Table
2	Turf Coefficient (T_c)	0.6	decimal	Appendix A - K_c Table
3	Adjustment Factor (A_f)	1	decimal	Site specific, professional judgement (shade, slope, etc.)
4	Water Requirement (WR)[1]	4.78	inches per month	#1 x #2 x #3

[1]Water requirement for a warm season turfgrass grown in San Antonio in the month of July (assuming no rainfall).

Determining Irrigation Frequency

Step 1: **Measure Effective Root Zone (D)**

Step 2: **Determine Soil Type and Soil Water-Holding Capacity (SWHC)**

Step 3: **Calculate Plant Available Water (PAW)**

Step 4: **Calculate Irrigation Frequency**

Definitions

Plant available water — amount of water in the effective root zone (in inches) "available" for plant uptake. (Determined by the difference in moisture content at field capacity and at permanent wilting point, times managed allowable depletion or MAD).

Effective root zone — depth (in inches) of root zone that contains approximately 80% of total root mass.

Irrigation frequency — number of irrigation events per week.

Managed allowable depletion (MAD) — how dry the soil is allowed to become between irrigations (50% for most turfgrasses).

Soil type (texture) — soil classification categories such as sand, clay, loam, etc.

Soil water-holding capacity — amount of water (in inches) that can be "held" or stored per foot of soil depth.

Detailed Instructions for Determining Irrigation Frequency

***Step 1:* Measure Effective Root Zone** — Many factors restrict root development. Root depths may vary because of physiological differences among plants. Other factors that influence root zone depth include high water tables, shallow soils, changes in soil type, compaction, irrigation, fertilization and cultural practices.

For irrigation scheduling, we use the effective root-zone depth, the depth containing about 80% of the total root mass and excluding the deeper "tap" or "feeder" roots. In order to obtain an accurate determination of root zone depth, samples should be taken in several locations, since soil type and composition can vary significantly within a landscape.

***Step 2:* Determine Soil Type and Soil Water-Holding Capacity** — Soil types vary in the amount of water that can be "stored" or "held" in the root zone. Fine-textured soils, such as clays, have high soil water-holding capacities, while coarse-textured soils, such as sands, exhibit low soil water-holding capacities. Table 2 gives typical water-holding capacities by soil type, in inches of water per foot of soil.

Managed allowable depletion (MAD) defines the amount of water that a plant can deplete from the soil without plant stress. Turf can extract only about 50% of total water available in their root zones without showing stress. Table 3 gives plant available water (in inches) for a MAD of 50% in a 2-inch, a 4-inch, and a 6-inch root zone for typical sand, loam and clay soils.

Table 2. Typical water-holding capacity (inches of water per foot of soil)

Soil Texture	At field capacity	At permanent wilting point	Soil Water-Holding Capacity	Plant Available Water (50% MAD)
Sand	1.0 - 1.4	0.2 - 0.4	0.8 - 1.0	0.45
Sandy Loam	1.9 - 2.3	0.6 - 0.8	1.3 - 1.5	0.70
Loam	2.5 - 2.9	0.9 - 1.1	1.6 - 1.8	0.85
Silt Loam	2.7 - 3.1	1.0 - 1.2	1.7 - 1.9	0.90
Clay Loam	3.0 - 3.4	1.1 - 1.3	1.9 - 2.1	1.00
Clay	3.5 - 3.9	1.5 - 1.7	2.0 - 2.2	1.05

Table 3. Plant available water for three root zone depths at 50% MAD

Soil Texture	Soil Water-Holding Capacity (inches of water per foot of soil)	Available Water @ 50% MAD (inches of water per foot of soil)	Available Water @ 50% MAD (inches of water per inch of soil)	Total Plant Available Water (inches water)		
				2″ Root Zone	4″ Root Zone	6″ Root Zone
Sand	0.90	0.45	0.038	0.076	0.15	0.23
Loam	1.70	0.85	0.071	0.14	0.28	0.43
Clay	2.10	1.05	0.088	0.18	0.35	0.53

Step 3: **Calculate Plant Available Water (PAW)** — The total amount of water available to a plant is defined by the following relationship:

$$PAW = D \times SWHC \times MAD \qquad \text{(Equation 2)}$$

Where: PAW – Plant available water in the root zone (inches)
D – Effective root zone depth (feet)
SWHC – Soil water-holding capacity (inches of water per foot of soil)
MAD – Managed allowable depletion (decimal)

Example 2: D = 0.42 feet
SWHC = 1.8 inches per foot
MAD = 0.5
PAW = 0.42 x 1.8 x 0.5
PAW = 0.38 inches

Step 4: **Calculate Irrigation Frequency** — Irrigation frequency is determined on a weekly basis. The number of irrigations per week is calculated from total weekly water requirement and amount of plant available water as follows:

$$I = \frac{WR}{PAW} \qquad \text{(Equation 3)}$$

Where: I – Number of irrigations per week (rounded to next whole number)
WR – Water requirement (inches per week)
PAW – Plant available water in root zone (inches)

Example 3: WR = 1.2 inches per week
PAW = 0.38 inches
I = 1.2/0.38
I = 4 irrigations per week

Example 3: Quick Table B. Irrigation Frequency

#	Variable	Value	Units	Source
1	Effective Root Zone Depth (D)	5	inches soil	Soil probe measurements
2	Soil Water-Holding Capacity (SWHC)	1.8	inches per foot	Table 1, loam soil
3	Managed Allowable Depletion (MAD)	0.5	decimal	MAD for turf (50%)
4	Plant Available Water (PAW)	0.38	inches of water	(#1 ÷ 12 inches/foot) x #2 x #3
5	Monthly Water Requirement (WR)	4.78	inches per month	Quick Table A
6	Weekly Water Requirement (WR)	1.25	inches per week	#5 ÷ 4 weeks
7	Irrigation Frequency (I)	4	number of irrigations per week	#6 ÷ #4, rounded to next whole number

Determining Station Runtimes

Step 1: **Calculate Turf Water Requirement (WR)**

Step 2: **Calculate Plant Available Water (PAW)**

Step 3: **Calculate Irrigation Frequency (I)**

Step 4: **Determine Precipitation Rate (PR)**

Step 5: **Calculate Station Runtimee**

Definitions

Precipitation rate — measurement in inches per hours of how fast an irrigation system applies water to a landscape.

Station — sprinkler group on a common valve that may be part of an automated irrigation system and that operates at the same time.

Runtime — how long a station is operated during an irrigation event.

Detailed Instructions for Determining Station Runtime

Step 1: **Calculate Turf Water Requirement (WR)** — (see page 3)

Step 2: **Calculate Plant Available Water (PAW)** — (see page 5)

Step 3: **Calculate Irrigation Frequency (I)** — (see page 5)

Step 4: **Determine Precipitation Rate (PR)** — Precipitation rate measures how fast an irrigation system applies water to a landscape. There are three primary methods for determining precipitation rates: manufacturers' specifications, catch can tests and meter readings. Details of each method are provided in the next chapter.

Station precipitation rates often vary within an irrigation system due to such factors as poor sprinkler alignment, spray trajectory and pressure fluctuations. Because different types of irrigation equipment have different precipitation rates, it is necessary to determine precipitation rates for each station on an irrigation system.

Step 5: **Calculate Station Runtime** — Station Runtimes can be calculated from water requirement, irrigation frequency and precipitation rate, using the following equation:

$$RT = \frac{WR \times 60}{I \times PR} \qquad \text{(Equation 4)}$$

Where:	RT	–	Station Runtime (minutes)
	WR	–	Water requirement (inches per week)
	I	–	Number of irrigations per week
	PR	–	Precipitation rate (inches per hour)

Example 4:	WR	=	1.2 inches per week
	I	=	3 irrigations per week
	PR	=	0.5 inches per hour
	RT	=	(1.2/3 x 0.5) x (60 minutes/1 hour)
	RT	=	48 minutes

Example 4: Quick-Table C. Determining Station Runtime				
#	Variable	Value	Unit	Source
1	Turf Water Requirement (WR)	1.2	inches per week	Quick-Table A: #4 ÷ 4
2	Irrigation Frequency (I)	3	number of irrigations per week	Quick-Table B: #7
3	Precipitation Rate (PR)	1.0	inches per hour	Measured with catch devices or by other method
4	Station Runtime (RT)	24	minutes	(#1 x 60) ÷ (#2 x #3)

Determining Precipitation Rate

Definitions

Catch device — a container (commonly referred to as a "catch can")used to measure the amount of water an irrigation system applies.

Coverage area (A) — the landscape area in square feet (ft^2) covered by a single sprinkler head or contained within a station.

gpm — flow rate of water through an irrigation system, expressed in gallons per minute (gpm).

Heads — sprinkler application devices used to apply water to a landscape; the most common such devices are sprays, rotors and impacts.

Station — sprinkler group on a common valve that may be part of an automatic irrigation system and that operates at the same time.

Testing Runtime (RT) — total time that each station is operated during catch can tests.

Throat area (A_t) — surface area in square inches (in^2) of the top of a catch device through which water falls.

A. Catch Can Method

Step 1: **Select Catch Device**

Step 2: **Determine Throat Area (A_t)**

Step 3: **Identify Stations and Locations of Heads**

Step 4: **Lay Out Catch Devices**

Step 5: **Run Each Station**

Step 6: **Record Catch Volumes (V)**

Step 7: **Calculate Precipitation Rate ($(PR)_e$)**

Step 1: **Catch Device** — A catch device "catches" irrigation water during a test and holds it for measurement. Catch devices range from special graduated conical cylinders to tuna cans. Some devices have raised graduation marks which allow volume to be read directly. With other devices, the water caught is poured into a graduated cylinder, then measured. Irrigation depth in straight-sided devices, such as tuna cans, may be estimated using a ruler; however, this method is not always practical since it requires long test-Runtimes in order to collect sufficient depths of water necessary for accurate measurement.

Step 2: **Determine Throat Area (A_t)** — The "throat area" is the size in square inches of the top of the catch device. For round catch devices, the throat area is calculated as follows:

$$A = \frac{\pi d^2}{4}$$

where A = throat area (square inches, in^2), d = diameter (inches, in), and $\pi = 3.14$ (constant).

Step 3: **Identify Stations and Locations of Heads** — Identify the location of each sprinkler head in a station by running each station briefly on the controller. Place colored flags to mark all heads, using different colors for each station (e.g., red flags for station 1, green flags for station 2, etc.).

Step 4: **Lay Out Catch Devices** — Sketch a diagram showing the location of sprinkler heads in each station. Spending a few minutes with the diagram to determine catch device placement can save significant time and confusion in the field.

An effective and efficient pattern used to lay out catch devices is called "at-a-head" and "half-way- between-heads." (Note: "At-a-head" refers to placing cans no closer than about 2 feet from spray heads and about 4 feet from rotor and impact sprinklers.) This simple placement pattern requires the least number of catch devices and provides adequate coverage over the test area. Figure 1 shows a suggested catch device placement for a rectangular sprinkler pattern. <u>It is important to use a grid layout with all cans roughly equally spaced.</u>

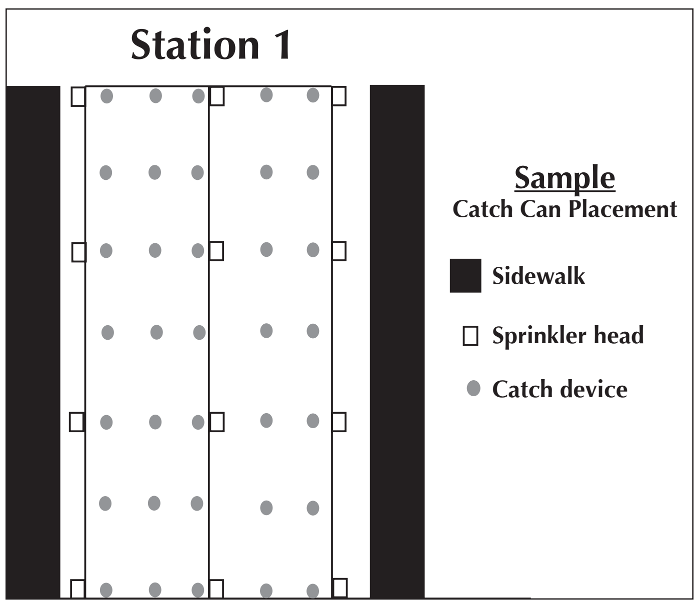


Figure 1. Recommended catch device placement.

Step 5: **Run Each Station** — Conduct catch can tests under a system's normal operating conditions (wind, pressure, etc.). In some locations, pressure will fluctuate during the day with changing water demands. Test-Runtimes for large impact sprinklers normally range from 10 to 30 minutes,with at least three complete revolutions recommended. Spray heads usually have higher precipitation rates and require no more than 5 to 10 minutes of Runtime to provide water sufficient for measurement.

Step 6: **Record Catch Volumes** — Catch volumes are recorded in milliliters (ml). Use a catch device that measures milliliters directly, or pour the water into a graduated cylinder. To simplify data management, prepare a data sheet in advance to record the results. Collect such information as date and time of test, approximate weather conditions, station numbers, test-Runtimes and catch can volumes. Table 4 shows one possible data sheet format. (Blank forms are included in Appendix A.) It also is useful to record individual catch can volumes on the site diagram to identify problem areas.

Table 4. Sample Data Collection Sheet

Data Collection Sheet

Site Name:	Beaver Park		**Start Time:**	7:00 AM
Date:	4/26/2005		**End Time:**	9:30 AM
Station number	1	2	3	4
Test-Runtime (minutes)	10	5	3	5
Catch can volume (ml)	12, 15, 18, 22, 12, 15, 14, 18, 26, 10, 14, 18	30, 28, 26, 32, 18, -20, 22, 28, 18, 40, 36, 20, 32, 38, 34, 28, 26, 42, 40	12, 10, 8, 14, 20, 8, 8, 14, 16, 12, 15, 18, 13, 15, 17, 21, 10	12, 10, 6, 10, 8, 4, 8, 14, 7, 5, 13, 10, 10, 10, 7, 12, 15, 20
		Temperature	**Wind Spreed/ Direction**	**Relative Humidity**
		81 °F	5-10 mph/South	High ~ 80%

Step 7: **Calculate Precipitation Rate** — Calculate the precipitation rate of each station using the following equation:

$$PR = \frac{\sum V \ x \ 3.6612}{n \ x \ A_t \ x \ T_r} \qquad \text{(Equation 5)}$$

Where:
PR – Precipitation rate (inches per hour)
$\sum V$ – Summation of all catch can volumes (milliliters)
3.6612 – Constant that converts milliliters to cubic inches and minutes to hours
n – Number of catch devices
A_t – Throat area of catch device (square inches)
T_r – Test Runtime (minutes)

<u>Example 5:</u> For Station 1 above.
$\sum V$ = 244 milliliters
n = 10
A_t = 16.61 square inches
T_r = 10 minutes
PR = (244 x 3.6612) / (10 x 16.61 x 10)
PR = 0.54 inches per hour

B. Area/Flow Method

Step 1: Determine the Flow Rate of Each Station

Step 2: Determine Coverage Area

Step 3: Calculate Precipitation Rate

Step 1: **Determine the Flow Rate of Each Station** — Sprinklers are rated in gallons per minute (or gpm) and vary considerably with sprinkler type (rotor, spray, impact), nozzle size, and pressure. Flow rates for sprinkler heads are provided in manufacturers' specifications catalogs. In the area/flow method, the total flow into a station is determined by summing the individual flow rates of each sprinkler head. For example, assume that an irrigation system consists of one station, shown in Figure 2.

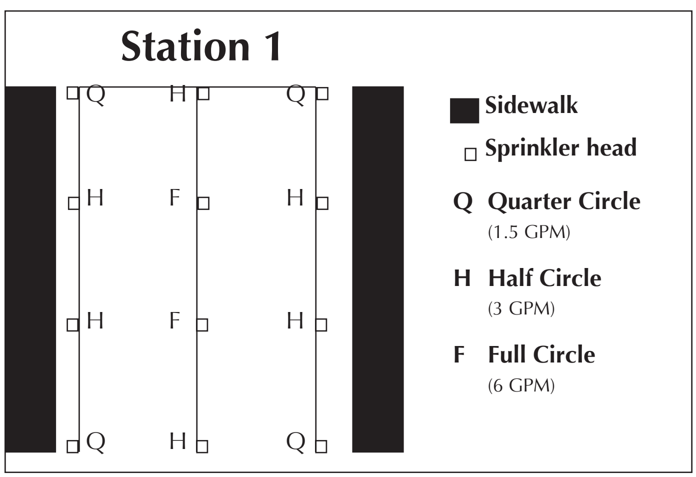


Figure 2. Sprinkler layout and GPM rating.

Station 1 contains four quarter-circle heads, six half-circle heads and two full-circle heads, rated at 1.5 gpm, 3.0 gpm and 6.0 gpm, respectively. The total flow through Station 1 is computed as follows:

Total Flow = (4 x 1.5 gpm) + (6 x 3.0 gpm) + (2 x 6.0 gpm)
Total Flow = 6 gpm + 18 gpm + 12 gpm
Total Flow = 36 gpm

Step 2: **Determine Coverage Area** — The coverage area in square feet (ft^2) is the entire landscape area over which the station applies water. If available, obtain an "as-built" or scaled drawing of the irrigation system to determine dimensions of landscaped area. If maps or drawings are not available, then measure the landscape using a measuring wheel or tape measure. The equations provided in Figure 3 are useful for calculating surface area for common shapes.

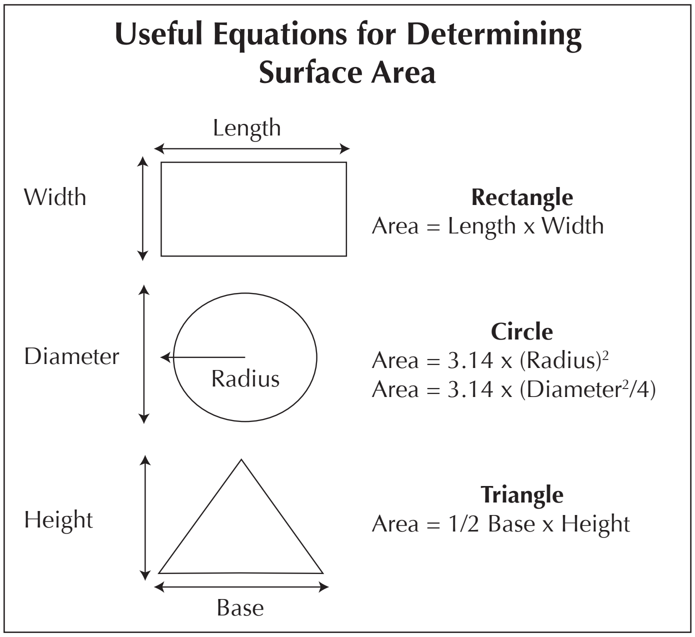


Figure 3. Useful equations for determining surface area.

Figure 4 shows the dimensions for a landscape. The area of coverage for Station 1 can be calculated as follows, using the equation for a rectangular area:

Area = Length x Width

Area = 40 feet x 60 feet

Area = 2400 square feet

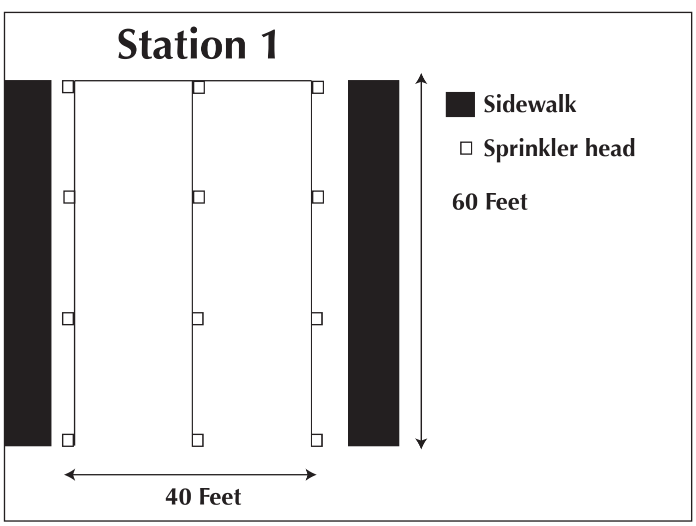


Figure 4. Landscape dimensions for Station 1.

Step 3: **Calculate Precipitation Rate** – If you know the total flow through the station and area of coverage, you can calculate the precipitation rate for Station 1 as follows:

$$PR = \frac{96.25 \times GPM}{A} \qquad \text{(Equation 6)}$$

Where: PR – Station precipitation rate (inches per hour)
96.25 – A constant that coverts gallons per minute to inches per hour
[It is derived from: (60 min per hr x 12 in per ft)) 7.48 gal per min.]
gpm – Total rated flow through the station (gallons per minute)
A – Area of coverage (square feet, ft^2)

<u>Example 6:</u> For Station 1 above:
gpm = 36 gallons per minute
A = 2400 square feet
PR = (96.25 x 36) / 2400
PR = 1.44 inches per hour

Example 6: Quick-Table E. Calculating Precipitation Rate Using the Area/Flow Method

#	Variable	Value	Unit	Data Source
1	Flow rate (FR)	36	Gallons per minute	Manufacturer's performance catalogs
2	Irrigation coverage area (A)	2400	Square feet	Measured or calculated
3	Precipitation rate (PR)	1.44	inches per hour	[#1 x 96.25] ÷ #2

C. Meter Method

Step 1: Determine Coverage Area
Step 2: Record Initial Meter Reading
Step 3: Run Station
Step 4: Record Final Meter Reading
Step 5: Calculate Precipitation Rate

The precipitation rate of irrigation systems can be estimated from water meter readings. This is particularly easy if the irrigation system is equipped with a separate meter. Unfortunately, many sites, such as residential properties, have only one meter that measures both household and outdoor water use. For these situations, landscape water use can be estimated by (1) determining the average monthly water use in winter months (December, January and February) when irrigation systems are typically turned off and (2) subtracting this winter water-use figure from monthly water use during the irrigation season.

Water meters measure the total amount of water flowing through a pipeline system. Such measurements do not take into account water loss due to leaks in pipelines and sprinkler heads and due to wind drift. Thus, meter readings can represent a significantly higher volume of water than that actually applied to the landscape.

Step 1: **Determine Coverage Area (A)** — Determine the landscape area in square feet (ft^2) for each station on the system. Landscape area can be computed from a detailed design drawing, or estimated using equations for calculating area as shown in Figure 3.

Step 2: **Record Initial Meter Reading (I)** — Record the initial meter reading on a data collection sheet, such as the one provided in Table 5.

Table 5. Sample Data Collection Sheet – Meter Method			
Site Name: Clark Field	**Date: 8/9/97**		
Station number	1	2	3
Test Runtime (minutes)	15	15	20
Initial reading (1000 gallons)	05015	05016	05018
Final reading (1000 gallons)	05016	05018	05019
Landscape Area (square feet)	5,200	8,000	5,200

Step 3: **Run Station** — Turn on each station and operate it for at least 10 to 15 minutes. It is a good idea to use a stop watch to keep track of the test-Runtime. After the test has ended, record the total Runtime on the data sheet.

Step 4: **Record Final Meter Reading** — Take a meter reading at the conclusion of each test and before initiating the next station. This final reading then becomes the initial meter reading for the next station. Continue until each station has been tested, and record all information on the data sheet as shown in Table 4. Be sure to check the units of the water meter. While most read in terms of 1000 gallons, some read in cubic feet and other gallon units.

Step 5: **Calculate Precipitation Rate** — Using the meter readings, test-Runtime and area of coverage, calculate precipitation rate using the following equation:

$$PR = \frac{96.25 \times gpm}{A} \quad \text{(Equation 7)}$$

Where:
- A – Area of coverage (square feet)
- 96.25 – Constant
- gpm = (FR-IR)/RT
- FR – Final meter reading (gallons or 1000 gallons)
- IR – Initial meter reading (gallons or 1000 gallons)
- RT – Test Runtime (minutes)

Example 7: For Station 1 above:
- A = 5200 square feet
- FR = 5,016,000 gallons
- IR = 5,015,000 gallons
- RT = 25 minutes
- gpm = (5016000 -5015000)/25 = 1000/25
- gpm = 40
- PR = 0.74 inches per hour
- RR = (96.25 x 40)/5200

Example 7: Calculating Precipitation Rate (inches per hour) - Meter Method			
Site Name: Park Place	**Date: 10/20/98**		
Station number	1	2	3
Test Runtime (minutes)	15	15	20
Initial reading (1000 gallons)	0525	0527	0529
Final reading (1000 gallons)	0527	0529	0531
Landscape Area (square feet)	18,000	8,500	10,000

Additional Example Problems

Example 1: Calculating Turf Water Requirement (WR)

A bermudagrass turf growing in Brownsville has a crop coefficient of 0.6 and an adjustment factor of 0.8. What is the monthly water requirement for this turf in July?

$$WR = ET_o \times T_c \times A_f$$ (Equation 1)

ET_o = 7.59 in per month (from Appendix A)
K_c = 0.6
A_f = 0.8

$$WR = 7.59 \times 0.6 \times 0.8$$

WR = 3.64 inches for the month of July

Example 2: Calculating Plant Available Water (PAW)

A bermudagrass turf has an effective root zone depth of 4 inches and is growing in a loam soil. If the managed allowable depletion (MAD) is 50%, how much available water is stored in the root zone?

$$PAW = D \times SWHC \times MAD$$ (Equation 2)

D = 0.33 feet, (4 inches ÷ 12 inches per foot)
SWHC = 1.7 inches per foot (from Table 2, page 9)
MAD = 0.50

$$PAW - 0.33 \times 1.7 \times 0.5$$

PAW = 0.28 inches

Example 3: Calculating Irrigation Frequency (I)

The weekly water requirement for a St. Augustinegrass
is 1 inch per week. If the plant available water is 0.25 inches, how many irrigations per week are recom-mended?

$$I = \frac{WR}{PAW}$$ (Equation 3)

WR = 1 inch per week
PAW = 0.25 inches

$$I = 1/0.25$$

I = 4 Irrigations per week

Example 4: Calculating Station Runtime (minutes)

The weekly water requirement for a baseball field is 1 inch per week. The field is irrigated 3 days per week. If Station 1 on the irrigation system has a precipitation rate of 0.5 inches per hour, how long (in minutes) must the station run per irrigation?

$$RT = \frac{WR}{I \times PR} \times 60 \qquad \text{(Equation 4)}$$

WR = 1 inch per week
I = 3 times per week
PR = 0.5 inches per hour

$$RT = (1/(3 \times 0.5) \times 60$$

RT = 40 minutes

Example 5: Calculating Precipitation Rate (inches per hour) - Catch Can Method

A catch can test was conducted at Beaver Park on three stations of the irrigation system. Calculate the precipitation rate for Station 1 using the data recorded in the table below. The throat area of the catch device is 15 square inches.

$$PR = \frac{\sum V \times 3.6612}{n \times A_t \times T_r} \qquad \text{(Equation 5)}$$

$$\Sigma V = 24 + 20 + 21 + 30 + 22 + 22 + 32 + 25 + 28 + 20$$

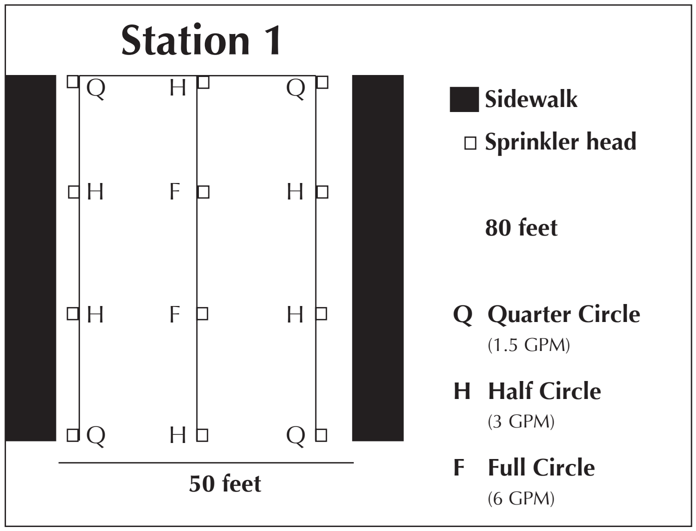
ΣV = 244 milliliters
n = 10
A_t = 15 square inches
T_r = 10 minutes

$$PR = (244 \times 3.6612)/(10 \times 15 \times 10)$$

PR = 0.58 inches per hour

Examples – Data Sheet	
Site Name	Beaver Creek
Date	4/26/05
Station Number	1
Test Runtime (minutes)	10
Catch Volume (ml)	24, 20, 21, 30, 22, 22, 32, 25, 28, 20

Example 6: Calculating Precipitation Rate (inches per hour) - Area/Flow Method



Calculate the precipitation rate for Station 1 using the Area/Flow method.

$$PR = \frac{96.25 \times GPM}{A} \qquad \text{(Equation 6)}$$

$$GPM = (4 \times 1.5) + (6 \times 3.0) + (2 \times 6.0)$$

gpm = 36 gallons per minute

$$A = 80\ ft \times 50\ ft$$

A = 4000 square feet

$$PR = \frac{96.25 \times 36\ GPM}{4000\ ft^2}$$

PR = 0.87 inches per hour

Example 7: Calculating Precipitation Rate (inches per hour) - Meter Method

Calculate the precipitation rate for Station 1 using data collected below.

$$PR = (96.25\ gpm)/A \qquad \text{(Equation 7)}$$

gpm = (FR – IR)/RT
FR = 527,000 gallons (527 x 1000)
IR = 525,000 gallons (525 x 1000)
RT = 15 minutes
A = 18,000 square feet
gpm = (527000 – 525000)/.15 = 2000/15 = 133

$$PR = (96.25 \times 133)/18000$$

PR = 0.71 inches per hour

Taking Soil Samples

Step 1: **Gather Equipment and Supplies**

Step 2: **Sample Representative Areas**

Step 3: **Submit Samples for Analysis**

Landscape managers test soils primarily to determine existing soil nutrient levels. This information serves as a baseline for applying supplemental nutrients required for optimal plant growth. The following sampling technique ensures accurate and reliable soil-test results.

Step 1: **Gather Equipment and Supplies** — For medium- to light-textured soils, a sampling tube, commonly called a soil probe, will work well. Force the probe into the ground to retrieve an undisturbed core of soil. In heavy clay soils, it often is difficult to push a soil probe into the ground, and a soil auger may be needed.

A large, clean bag, such as a paper grocery sack, or plastic bucket will be needed for collecting and mixing the soil samples. A smaller, clean bag or box (about 1 pint in size) is needed for transmitting the sample to the laboratory. Most laboratories have special sample bags available upon request and may require a form to be submitted with the sample. Forms and sample bags for the Texas A&M Soil and Water Testing Lab are available from your local county Extension office.

Step 2**: Sample Representative Areas** – Soil samples should be taken down to the bottom of the root zone. Avoid pushing the probe deeper than the root zone. Shallow root zones are common in Texas, so it is not unusual to have root zones less than 3 to 4 inches deep. Avoid collecting samples in depressions where water often puddles.

It is important to obtain samples representative of the entire area. When taking soil samples, follow a random pattern and obtain at least 20 to 25 individual samples. Put the samples into your sack or bucket, and mix the soil to form a single composite sample. Withdraw at least one pint of the composite sample for analysis.

Step 3: **Submit Samples for Analysis** – Prior to shipping samples to the laboratory, record the sample date, sample location, sample identification number and plant type on the form and on the sample bag, in case the sample gets separated from the form. Samples should be submitted immediately after collection. For more on soil testing procedures or to obtain copies of submission forms and containers, contact your local county Extension office or:

Texas A&M Soil and Water Testing Lab
Soil and Crop Sciences Department,
Texas A& M University
College Station, TX 77843-2474
Phone: (979) 845-4816

Determining Chemical and Fertilizer Requirements

Step 1: Examine Soil Test Results

Step 2: Classify Soil

Step 3: Recognize Plant Nutrient Deficiency

Step 4: Determine Fertilizer Requirements

Definitions

SAR — sodium adsorption ratio; the ratio of sodium to calcium and magnesium in the soil

Soil pH — degree of acidity or alkalinity of a soil, measured on a scale of 1 to 14. A soil with a pH of 7 is termed neutral. A pH of 6 is ten times as acidic as one having a pH of 7.

Detailed Instructions for Determining Chemical and Fertilizer Requirements

Step 1: Examine Soil Test Results — A routine soil analysis report will contain information about the following parameters:

- Soil pH
- Primary nutrients: Nitrogen, phosphorus, and potassium
- Secondary nutrients: Calcium, magnesium and sulfur
- Potential salinity

Most substances are measured in ppm (parts per million) or mg per l (milligrams per liter); these measurements are equivalent. Soil pH is reported on a scale of 1 to 14, as discussed below. Salinity information is reported in a number of ways. Most important are total salinity (usually reported as electric conductivity in units of mmhos per cm) and SAR (sodium adsorption ratio), which is reported as a number. For more information on salinity, methods of reporting, and interpretation of results, see Extension publication ***B-1667: Irrigation Water Quality Standards and Salinity Management Strategies*** (view and order online at **http://tcebookstore.org**).

Essential Nutrients — Soil tests measure nutrients available within the soil and are used in conjunction with other information to determine which nutrients are plentiful or deficient. For example, a soil report may state that available phosphorus is very high, 480 ppm, but available nitrogen (nitrates) is very low, 5 ppm. Given the relationship

ppm x 2 = pounds per acre, 6 inches deep

the available phosphorus would be 960 pounds for every acre 6 inches deep, while the nitrogen level would be only 10 pounds for every acre 6 inches deep.

Step 2: Classify Soil — Soils are classified by salinity and pH in order to determine treatment strategies for correcting problems:

- ***Acidic soils*** (soil pH less than 5.5) result in decreased root growth, decline in earthworm populations and reduced nutrient release rates. pH less than 5.0 can lead to plant death. Soils with a pH between 5.5 and 6.0 require liming to raise the pH to its optimum range. Liming considerations include rate of action or reaction, fineness of grade, magnesium content, caustic nature and cost. Application rates are based on soil test results, turfgrass species, and fineness of the lime. **On established turf, apply no more than 50-lbs per 1000 ft^2 of fine limestone and no more than 25-lbs per 1000 ft^2 of oxides and hydroxides.**
- ***Alkaline soils*** (pH between 7.2 and 8.4) can result in a decline of turfgrass vigor, growth and density. Also, micro nutrients such as Fe, Mn, Cu, Zn and B may become deficient. Lowering alkaline soil pH is very difficult in Texas soils high in free carbonates. Use

acidifying fertilizers where possible; it may be necessary to apply higher rates of micronutrients to compensate for alkaline soil pH.

- ***Saline soils*** (pH between 7.2 and 8.4, conductivity greater than 4 mmhos per cm, SAR less than 13) have low sodium content and therefore do not require chemical treatment. **If water quality is good, then occasional leaching of soils should correct the problem. If water quality is poor, water application rates should continually exceed evapotranspiration rates.**
- ***Sodic soils*** (pH greater than 8.5, SAR greater than 13) cause clays in the soil to flocculate, resulting in loss of soil structure, which causes poor aeration and infiltration, restricts root growth, and results in a decline in shoot growth. Gypsum ($CaSO_4$) will correct some sodic soils if leaching is possible. The calcium in gypsum replaces sodium on the cation exchange sites, making the sodium available for leaching. Elemental sulfur should also be applied in conjunction with gypsum to help correct high pH problems. **Recommended limits for sulfur and gypsum on turfgrasses are 10-lbs per 1000 ft^2 for sulfur and 50-lbs per 1000 ft^2 gypsum.** Note: Sulfur will have minimal effect in lowering soil pH in calcareous soils.
- ***Saline-sodic soils*** exhibit high pH, conductivity greater than 4 mmhos per cm, and SAR greater than 13.

For most turfgrasses, optimum soil pH is between 6.0 and 7.0, which promotes microorganism activity and root growth, increased nutrient uptake efficiency, thatch decomposition, and reduced solubility of toxic elements such as aluminum. Nutrient availability of P, Ca, Mg and N (Table 6) is at its optimum range when pH is near 6.5. Soils that are either acidic (below 6.0) or alkaline (above 7.2) require corrective action.

Table 6. Essential Elements for Plant Growth

Element	Available Forms	Optimum pH
Nitrogen (N)	No_3, NH_4	5.5 - 7.5
Phosphorus (P)	H_2 PO_4, HPO_4	5.5 - 7.0
Potassium (K)	K	6.0 - 7.0
Calcium (Ca)	Ca_2	>6.5
Magnesium (Mg)	Mg_2	5.5 - 7.5
Sulfur (S)	SO_4	5.5 - 7.5
Zinc (Zn)	Zn_2	<5.5
Copper (Cu)	Cu, Cu_2	5.5 - 7.5
Iron (Fe)	Fe_3, Fe_2	<6.5
Manganese (Mn)	Mn_2	<5.5
Boron (B)	H_3BO_3	5.5 - 7.5
Chlorine (Cl)	Cl	>6.0
Molybdenum (Mo)	MoO_4	>7.5

Step 3: Recognize Plant Nutrient Deficiency — Common signs of nutrient deficiency for primary, secondary and minor nutrients are discussed below.

Primary Nutrients

Nitrogen has the most effect on turfgrass and is required in the largest quantities. Plants utilize nitrogen in two forms: nitrate nitrogen and ammonium. Nitrogen is readily lost from the soil by leaching and runoff. Signs of nitrogen deficiency include reduced rate of shoot growth, leaf-tip color changes in older leaves from green to pale green to yellow, decreased shoot density and poor stem structure.

Phosphorus is required in much smaller amounts than nitrogen and potassium, except during turfgrass establishment, when it is used at much higher rates. A newly seeded bermudagrass such as NuMex Sahara requires nearly as much phosphorus as nitrogen during establishment. Symptoms of phosphorus deficiency rarely are seen on an established turfgrass, but often are detected during the establishment phase, when new seedlings may show purple discoloration along leaf blade margins.

Potassium is second only to nitrogen in quantity required. It is absorbed by turfgrasses as the K^+ and may be lost from the soil by leaching. Potassium is important in stimulating opening and closing of stomates and often will evidence deficiency through water stress. Other signs of potassium deficiency include stunted plants with brown leaf margins.

Secondary Nutrients

Iron is not needed in large quantities, but it is often deficient due to its conversion to insoluble, unavailable forms. Alkaline soils, high soil phosphates, zinc, manganese and high organic matter often cause iron to become unavailable in the soil. Iron deficiency symptoms are common and include yellowing of the youngest actively growing leaves, eventually spreading to older leaves. A foliar application of iron can correct deficiency in a matter of hours.

Sulfur deficiency results from leaching and lack of availability when soil pH falls below 6. Deficiency symptoms include initial yellowing of lower older leaves with a faint scorching at the tip.

Calcium is rarely deficient except in sandy soils with leaching prevalent or pH below 6. Calcium deficiency symptoms include cupping of leave blades and extensive blackening of young leaves.

Magnesium deficiency results from leaching and lack of availability due to high calcium content. Symptoms of magnesium deficiency include interveinal chlorosis, beginning in older leaves, which appear mottled.

Minor Nutrients

Minor nutrients are essential to plants and are used as catalysts in enzymatic reactions. Their deficiencies are rare except in extreme conditions such as very acidic or alkaline soils. An alkaline soil can lead to deficiencies in ***boron***, ***copper***, ***zinc***, and ***manganese***, while ***molybdenum*** and ***chloride*** deficiencies are more likely to occur in acidic soils. Other conditions such as high phosphate levels, high concentrations of soil organic matter, excessive thatch accumulation and poor drainage may result in deficiencies of minor nutrients.

Additional tests for micronutrients may have to be conducted.

Step 4: Determine Fertilizer Requirements — The fertilization of turfgrass is a practice whereby essential nutrients are applied to supplement nutrients already present in the soil or to supplement the soil to establish a turfgrass. A plant will have different nutrient requirements depending on its stage of growth. Soil test results, plant tissue analysis, cultural intensity nutrient demands and budget restraints all determine the overall fertilizer management plan.

Table 7 shows the results of a plant tissue analysis conducted on Tifdwarf bermudagrass. This analysis shows that nitrogen, phosphorus and potassium comprise 5.19, 0.60 and 3.18 percent, respectively, of the total weight of upper plant growth. Since this is the plant growth removed during mowing, the ratio of N-P-K (5-0.6-3) should come from this test. The amount of nutrients a turfgrass needs throughout the year is difficult to predict, since there are no yields to be totaled at year end.

Landscape mowing practices often dictate fertilizer applications. Mowing height and whether clippings are returned to the soil will often raise or lower nutrient demands by 50 percent. An intensively managed turfgrass, such as a golf green, requires more fertilizer than an area that is not so intensively managed. The combination of soil tests and plant tissue tests and cultural management requirements should be considered when formulating a management plan.

Table 7. Tissue Analysis Results of Tifdwarf Bermudagrass		
Nutrient	**100% Dry Matter Corrected (Lab Analysis Results)**	**Target Values for Turfgrass Maintenance**
Nitrogen, %	5.19	4.50 - 5.25
Phosphorus, %	0.60	0.45 - 0.65
Potassium, %	3.18	2.5 - 4.0
Calcium, %	0.68	0.5 - .75
Magnesium, % (Mg)	0.21	0.25 - 0.35
Sulfur, %	0.41	0.25 - 0.50
Zinc, ppm	57.18	50 - 75
Copper, ppm	24.14	10 - 30
Iron, ppm	403.78	200 - 400
Manganese, ppm	81.50	80 -150
Boron, ppm	12.05	10 - 20
Sodium, %	0.12	0.01 - 0.04

Fertilization requirements should be broken down into two categories, establishment and maintenance. High amounts of nitrogen, potassium and phosphorus are required to promote turfgrass root establishment and to enable young shoots to overcome the early adverse conditions they must endure.

The amount of nutrients required depends primarily upon requirements of the particular turfgrass and on nutrient levels already present in the soil; however, other factors, such as environmental conditions, the level of turfgrass quality needed and budget constraints, also are important considerations.

The following are nutrient recommendations for high, medium and low intensity landscapes, based on expected turf quality and normal cultural practices.

High Intensity Bermudagrass putting green (mowed daily, at a height of 0.13 to 0.19 inches with clippings removed)

Fertilization Nitrogen — apply 1.0 to 2.0 lbs of actual N per 1,000 ft^2 per growing month. Use 0.2 to 0.5 lb per 1000 ft^2 every 15 growing days for water-soluble carrier or 0.5 to 1.2 lbs per 1000 ft^2 every 20 to 30 growing days for slow-release carrier

Phosphorus — apply in spring or fall as dictated by soil test report; usually part of complete analysis

Potassium — apply as dictated by soil-test report; generally, a 1:1 ratio to nitrogen (higher on sand-based greens) recommended.

Iron — apply 2 to 4 oz. iron carrier per 1000 ft^2 as needed to correct developing iron-chlorosis symptoms, which commonly occur following spring green-up

Medium intensity Bermudagrass fairway (mowed 2 to 3 times per week, if irrigated, and once a week if not irrigated, at a height of 0.5 to 1.0 inch with clippings left on the ground)

Fertilization Nitrogen — apply 175 to 261 lbs per acre per growing season

Phosphorus — apply as dictated by soil-test report, usually once per year

Potassium — apply as dictated by soil-test report, usually at 50 to 100 percent of nitrogen

Low intensity	Bermuda grass rough (mowed every 7 to 14 days if irrigated or every 14 days if not irrigated, at a height of 1.0 to 2.0 inches with clippings left on the ground)
Fertilization	Nitrogen — apply 45-85 lbs per acre annually.
	Phosphorus — apply as dictated by soil-test report, usually once a year or every two years
	Potassium — apply as dictated by soil-test report; apply when nitrogen is applied

Applying Fertilizers

Step 1: **Select Appropriate Form of Fertilizer**

Step 2: **Calibrate Application Equipment**

Step 3: **Apply Fertilizer**

Step 1: **Select Appropriate Form of Fertilizer** — Three forms of fertilizers may be used for landscape areas: soluble (quick release), slow release and organic.

Quick release fertilizers are used when plants need an immediate boost of nitrogen. Since they make nitrogen readily available to the plant, soluble fertilizers should be applied in small quantities to prevent leaching or excess volatilization.

Slow release fertilizers release nitrogen gradually over a longer period of time. Factors such as temperature, moisture and microbial activity affect how fast these materials release their nitrogen content. Some slow-release fertilizers will have released all their nitrogen by six months after application, while other sources may release nitrogen for as long as two years. Generally, it is recommended that landscape fertilizers contain some soluble nitrogen and some slow-release nitrogen.

Organic (natural) fertilizers are derived from by-products of plants and animals. These products can serve as good fertilizers for most turfgrass. However, organic fertilizers cost more, and some of them give off an odor. Generally, organic fertilizers are intermediate between quick-release and slow-release products in their rates of nitrogen release.

Fertilizer labels list three numbers, representing the amounts of nitrogen (N), available phosphorus (P_2O_5), and soluble potash (K_20) present. Fertilizer recommendations are given in terms of pounds of N, P and K. Thus, before determining how much fertilizer should be applied, formulation ratios must be converted to percent N-P-K. Table 8 gives percent N-P-K of nitrogen, available phosphorus and soluble potash 100, 44 and 83 percent by weight, respectively.

Table 8. Percent N-P-K Based on Weight

	Chemical Symbol	%N	%P	%K
Nitrogen	N	100	-	-
Available Phosphorus	P_20_5	-	44	-
Soluble Potash	K_20	-	-	83

Table 9 illustrates a sample fertilizer ratio of 18-5-9, indicating that on a dry-weight basis, this fertilizer contains 18% N, 5% P_20_5, and 9% K_20. Multiply these formulation ratio values by the figures in Table 8 to calculate the percent of N, P and K contained in the fertilizer. In this case, N, P, and K are 18, 2.2 and 7.5 percent, respectively. In order to obtain, for instance, 0.5 pounds of available phosphorus per 1,000 ft^2 of turf, you would need to apply 22.7 pounds of fertilizer per 1,000 ft^2 area (0.5 pounds P divided by 2.2% P).

Table 9. Nutrient Formulation—% Based on Weight					
	Formulation Ration[1]	**%N**	**%P**	**%K**	**Source**
Nitrogen	18	18	-	-	Table 7 (%N x 18)
Available Phosphorus	5	-	2.2	-	Table 7 (%P x 5)
Soluble Potash	9	-	-	7.5	Table 7 (%K x 9)

Formulations given on a dry-weight basis.

Timing and frequency of fertilization depend upon expected levels of turfgrass quality. As frequency of applications increase, nutrient efficiency also should increase. The first application of fertilizer should be a complete nutrient package that matches deficiencies indicated by soil and tissue tests. Subsequent applications of nitrogen, potassium and other detected deficient nutrients should follow on an as-needed basis. Keep in mind that other practices such as frequent mowing and clipping removal will increase the need for additional nitrogen applications.

The timing of fertilization is important for both environmental and biological reasons. If turfgrass is not irrigated,nitrogen should not be applied during heat stress or just prior to extended drought periods. Discontinue nitrogen applications 30 to 40 days before warm-season turfgrasses go into winter dormancy, and avoid fertilizing when conditions are favorable for weed growth. Also, avoid applying nitrogen directly after vertical mowing, coring or any practice that temporarily disturbs turf density. Potassium applications may be required every 3 to 4 weeks during mid-summer. Avoid applying potassium to turfgrass immediately after serious disease, insect, or nematode attacks; wait until temperature and moisture conditions are favorable.

Step 2: Calibrate Application Equipment — Sprayers are used to apply soluble fertilizers and pesticides dissolved in water. The objective is to determine the correct dilution of the material in water and to measure and control the rate at which this water is applied to a known area. The spray volume can be measure either by calculating the water loss from the spray tank or by measuring the amount of water discharged from the sprayer during operation.

To calculate the spray volume by the water-loss method:

1) Fill spray tank with known volume of water.
2) Measure area to be sprayed.
3) Spray over known area and then measure the amount of water left in the spray tank (to reduce measurement error, water contained in the hose and boom assembly should be drained following application and added to the remaining volume of water in the spray tank). The difference between start volume and end volume equals the amount of water sprayed.
4) To obtain gallons per 1,000 ft^2, divide total gallons sprayed by the area sprayed.

The second method of sprayer calibration involves measuring the amount of water discharged from the sprayer during operation:

1) Determine miles per hour (mph) for the spray rig.
2) Fix a collection container onto one nozzle of the sprayer. Measure the output of a single nozzle in gallons per minute and multiply this number by 5,940.
3) Divide product of (2) by (the product of) miles per hour (mph) times the distance between nozzles in inches (width) on the spray boom.

$$\textit{gallons per acre} = \frac{5{,}940 \times GPM}{MPH \times width}$$

Spreaders can be calibrated in the same manner, although weight or discharge volume over a known area also can be used for calibration.

Step 3: Apply Fertilizer — Three methods of fertilization include granule distribution, liquid spraying, and fertigation through an irrigation system. Slow-release fertilizers are applied by granule application, and sprayers can be used to treat nutrient deficiency problems such as iron chlorosis or to apply low rates of fertilizer combined with a pesticide.

Fertigation is more practical on highly maintained areas such as golf greens where clippings are removed daily and nitrogen is required on a regular basis. For information on the types of injection devices, calibration procedures, and other recommendations, see Extension publication ***L-2422: Chemigation Equipment and Safety*** (order online at **http://agpublications.tamu.edu/**).

Always apply fertilizers with safety and accuracy in mind. The following recommendations should be followed routinely as part of your overall fertilizer plan:

- Make sure application equipment is completely clean before application begins.
- Calibrate application equipment for material being applied.
- Wear safety equipment when appropriate.
- Never make an application when wind velocity exceeds 5 mph.
- Maintain a steady speed when applying fertilizer.
- Reduce unnecessary overlap of fertilizer.
- Thoroughly clean equipment after application.
- Immediately water-in fertilizer into the root zone.

Historic Average Potential Evapotranspiration (ET_o) in Inches

Chart A. Historic Average Potential Evapotranspiration (ET_o) in Inches

City	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Abilene	1.20	1.60	3.90	4.70	7.90	8.61	8.75	8.15	7.10	4.90	2.80	1.00	60.61
Amarillo	1.20	1.50	3.80	5.00	8.88	9.72	9.61	8.95	6.80	4.70	2.60	1.20	63.96
Austin	2.00	2.66	4.30	5.27	7.55	8.28	8.12	8.20	6.22	4.93	3.08	2.08	62.69
Brownsville	2.57	3.18	4.53	5.31	6.88	7.31	7.59	7.33	5.98	5.16	3.40	2.42	62.66
College Station	2.00	2.65	4.23	5.22	7.57	8.35	8.20	8.41	6.25	4.91	2.83	2.04	61.17
Corpus Christi	2.42	3.06	4.56	5.31	6.97	7.53	7.89	7.45	5.95	5.12	3.28	2.30	61.84
Dallas/Ft.Worth	1.80	2.45	4.09	5.15	7.41	8.42	8.76	8.13	6.13	4.49	2.62	1.72	61.17
Del Rio	1.30	1.80	4.30	5.20	8.01	8.71	8.26	8.24	7.70	6.00	3.00	1.10	63.62
El Paso	1.30	1.70	4.20	5.60	8.88	9.91	9.24	8.32	7.60	5.20	3.00	1.10	66.05
Galveston	1.65	2.10	3.14	4.04	4.84	5.18	4.97	5.10	5.05	3.99	2.51	1.71	44.28
Houston	2.02	2.71	4.03	5.23	7.48	8.08	7.79	7.78	6.06	4.90	3.06	2.12	61.26
Lubbock	1.20	2.10	4.60	5.40	8.37	9.23	9.06	8.26	6.60	5.00	2.30	1.00	63.12
Midland	1.30	1.70	4.20	5.60	8.60	9.23	9.10	8.35	7.60	5.20	3.00	1.10	64.98
Port Arthur	1.98	2.71	4.09	4.93	7.09	7.66	7.25	7.27	5.82	4.74	2.95	2.00	58.49
San Angelo	1.30	1.80	4.30	5.20	8.01	8.71	8.26	8.24	7.70	6.00	3.00	1.10	63.62
San Antonio	2.07	2.77	4.40	5.33	7.58	8.21	7.96	8.03	6.19	4.95	3.14	2.15	62.78
Victoria	2.13	2.78	4.34	5.18	7.13	7.65	7.94	7.59	6.09	5.02	3.19	2.23	61.27
Waco	1.92	2.57	4.27	5.26	7.55	8.38	8.74	8.27	6.30	4.94	2.74	1.79	62.73
Wichita Falls	1.10	1.50	3.70	4.50	7.89	8.86	9.20	8.50	6.70	5.20	2.10	0.90	60.15

Sample Data Collection Sheet

Client name								Date	
Site name						Start time		End time	
Controller ID						Auditor			
Dominant turfgrass	Warm season turf			Cool season turf			Warm season turf – Overseeded		
Root zone depth (inches)									
Soil type	clay	clay loam	silt loam	loam	sandy loam	sand			
Station number									
Testing runtime (minutes)									
Catch can volume		Between		Between		Between		Between	
Notes									
Linking to other stations									
Sprinkler water pressure (psi)									
Sprinkler spacing (feet)									
Sprinkler type									
Weather conditions	Temperature		Relative humidity (%)		Wind speed		Wind direction		

Produced by Agricultural Communications, The Texas A&M University System
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Issued in furtherance of Cooperative Extension Work in Agriculture and Home Economics, Acts of Congress of May 8, 1914, as amended, and June 30, 1914, in cooperation with the United States Department of Agriculture. Edward G. Smith, Director, Texas Cooperative Extension, The Texas A&M University System.
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