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Determining Landscape Plant Water Demands

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0 Foreword

This standard was created to provide science-based guidelines for determination of the minimum plant water demands for mixed species landscapes that maintain adequate aesthetic quality. Plant water demands can be met by any combination of precipitation and irrigation.

The plant factors and other information in this standard are broad in nature and based on available science. Localized climate data, if available, should be used to corroborate or customize as applicable. The plant categories are purposely broad for general applicability. If scientifically-proven reasons for altering the plant factors are available, the numbers may be adjusted accordingly.

An informative annex of information and techniques for application of the plant factors is included. This annex may also be used to aid decisions for potential deficit watering to maintain minimum survival requirements for plants under low water availability.

1 Scope

This methodology will provide an estimate of plant water demands of permanently installed, non-production based, established landscape materials. The standard will provide minimum water demands for acceptable plant appearance and function. This standard does not cover plants for sports fields, golf courses, or food production. This methodology is applicable for planning and design of planted landscape areas as defined in section 3. It is assumed throughout this standard that the soil around the plants in question are wetted uniformly by precipitation or irrigation.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies unless noted. For undated references, the latest approved edition of the referenced document (including any amendments) applies.

ASCE Environmental and Water Resources Institute (EWRI) standardized reference evapotranspiration equation. 2005. Reston, Virginia: American Society of Civil Engineers.

3 Definitions

3.1 acceptable plant appearance: a plant that is maintaining its intended health, coloration, growth and function is considered “acceptable” for purposes of this standard.

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3.2 climate: for purposes of this standard, climate refers to the typical annual precipitation and temperature of geographically delimited regions.

3.3 drought: a period of abnormally dry weather for a climate region sufficiently prolonged to where the amount of water available in the soil no longer meets the demands of the landscape area to meet expectations of acceptable plant appearance.

3.3.1 drought resistance: physiological and phenological mechanisms by which a plant may withstand periods of dry weather.

3.4 evapotranspiration (ET): the loss of water from the earth's surface through the combined processes of evaporation (from soil and plant surfaces) and plant transpiration (i.e., internal evaporation) (ASCE-EWRI, 2005).

3.4.1 reference evapotranspiration (ET_o): the evapotranspiration (ET) from a defined vegetated surface (cool season grass) which serves as an evaporative index by which ET can be predicted for a range of vegetation and surface conditions For purposes of this standard, the ASCE-EWRI Standardized Reference Evapotranspiration Equation (ET_{os}) is used.

3.5 planted landscape area: managed and maintained plantings of turf, woody plants (including trees), desert plants, annual flowers and herbaceous perennials located in or around urban residential premises, public or commercial facilities, parks, workplaces, care facilities, or recreational areas. The landscape area does not include footprints of buildings or structures, sidewalks, driveways, parking lots, decks, patios, gravel or stone walks, other pervious or non-pervious hardscapes, and other areas permanently designated to not be planted or irrigated.

3.6 landscape plant: a plant in a planted landscape area.

3.7 plant factor (PF): the fraction of reference evapotranspiration (ET_o) required for acceptable plant appearance. When multiplied by ET_o, the plant factor estimates the depth of water required by plants. This standard implements PF rather than traditional "crop coefficients" (K values) to acknowledge the variability inherent in empirical water use adjustments for landscapes, rather than the implied precision of a coefficient.

4 Plant Water Demands

4.1 Plant factor table. Table 1 indicates, for various broad categories of plant types used in planted landscape areas, accepted plant factors: fractions of reference evapotranspiration (ET_o) based on the required acceptable appearance of the landscape. Numbers given are intended as guidelines for assisting in calculating landscape plant water demand which can be used for scheduling irrigation frequency and duration and for determining plant water allocation to planted landscape areas. Plant water demand is calculated by multiplying the plant factor for a given plant type from Table 1 by ET_o, with other required adjustment factors also included (see section 5). Table 1 is the plant water demand by fraction of ET_o. It is not irrigation demand, which may include factors to account for system non-uniformity.

The numbers in Table 1 are plant factors (see Section 4.2) for the average water demands during the portion of the year where the plant is actively transpiring. These numbers are based on available science. Applying these numbers to water allocation, irrigation design, and scheduling may require the end user to make adjustments up or down to supply the appropriate amount of water to meet plant water demand. Plants that are not fully or near fully established will typically require more frequent water but will typically not require a greater fraction of ET_o. During the transition period from dormancy to active growth or vice versa, the plant may not require the full fraction of ET_o, but that change in amount is not sufficiently documented for inclusion in this standard.

As described in the sections below, areas with ≥20 in. of annual precipitation, especially if it occurs during the growing season, should be considered "wet" in regards to Table 1. Areas with lower growing season precipitation should be considered "dry" or may even require desert plants for survival without supplemental irrigation. Cool-season and warm-season turfgrasses are described in sections 4.1.1.2 and 4.1.1.3.

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Table 1 – Annual average fraction of ET_o for acceptable appearance of established landscape plants

Plant Type	Recommended Plant Factor
Turf, cool season	0.8
Turf, warm season	0.6
Annual flowers	0.8
Woody plants and herbaceous perennials, wet [1)]	0.7
Woody plants and herbaceous perennials, dry	0.5
Desert plants	0.3

[1)] Tropical plants: for tropical plants with precipitation the majority of months, a plant factor of 0.7 applies. Where monsoonal climates are present, 0.7 applies for the wet season, and 0.5 during the dry season.

4.1.1 Plant categories

4.1.1.1 turfgrass: grasses managed and maintained as a monoculture (a.k.a. "lawns"), rather than ornamental grasses or sedges.

4.1.1.2 turf, cool season: cool-season grasses, which do better in the cooler times of the year and thrive in temperatures from 65° to 75° F. Examples include, but are not limited to, bluegrass, tall fescue, perennial ryegrass, and fine fescues.

4.1.1.3 turf, warm season: warm-season grasses, which are best adapted to temperatures between 80° and 95° F. Examples include, but are not limited to, bermudagrass, zoysia, St. Augustine, seashore paspalum and buffalograss.

4.1.1.4 annual flowers: annual plants grown in a usually formal, high-visibility area for seasonal display of colorful flowers or attractive foliage; often referred to as bedding plants.

4.1.1.5 woody plants and herbaceous perennials, wet: trees, shrubs, vines, ground cover, and herbaceous perennials adapted to grow in a wet environment (≥20 in. of average annual precipitation) where soil water deficits and dry air (low humidity) do not restrict transpiration. This includes plants from habitats and climates where both soil and atmospheric water deficits are infrequent and irregular. This includes species growing in high summer rainfall regions (adapted to infrequent atmospheric and soil water deficits). These environments typically support a permanent forest cover.

4.1.1.6 woody plants and herbaceous perennials, dry: trees, shrubs, vines, ground cover, and herbaceous perennial species adapted to grow in non-desert climates or habitats being grown in sufficiently dry climates (>10 ≤20 in. of average annual precipitation) where atmospheric water deficits (low humidity) can restrict transpiration.

4.1.1.7 desert plants: plants that can survive a very dry (<10 in. of annual precipitation) environment.

4.2 plant factor (PF): Water demands of landscape plants are effectively defined as the fraction of reference evapotranspiration (ET_o) (ASCE-EWRI, 2005) required to maintain their acceptable appearance and intended landscape function (Pittenger et al., 2001; Shaw and Pittenger, 2004). The ET_o calculation assumes the following standard conditions for a hypothetical cool-season turfgrass surface: a uniform plant canopy that governs how foliage connects to the atmosphere, uniformly adequate soil water, and plant water use that is tightly synchronized and linearly related with changes in ET_o (ASCE-EWRI, 2005). The ET_o algorithm was developed for agriculture; the product of ET_o multiplied by a species-specific fraction that estimates the depth of water a specific crop requires. The species-specific fraction assumes uniform crop canopies tightly synchronized to ET_o.

However, the ET_o multiplied by a species-specific fraction algorithm has limited accuracy in estimating water demands of urban landscapes. The algorithm is not robust enough to account for the spatially and biologically complex mixes of turfgrass, woody, and herbaceous plant types (St. Hilaire et al., 2008) in urban landscapes. These plant types differ in canopy architecture, plant structure and leaf size in ways that do not conform to the standard conditions under which ET_o is defined. Water demands of many non-turf landscape plant species are not tightly synchronized to ET_o and may respond non-linearly to weather factors used to estimate ET_o (Choudhury and Montieth, 1986). Also, unlike agricultural crops, urban landscape plants are grown for their aesthetic

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appearance and functional value achieved over a range of water applications, rather than optimum growth and yield based on precise water application targets.

Nevertheless, this standard's approach to estimating landscape plants' water demands as a fraction of ET_o using an adjustment factor (plant factor, PF) value is rational, reasonable, scientific, and climate-based. This approach is sufficiently accurate and effective in estimating water demands for a landscape design grouping species with similar plant factors (Kjelgren et al., 2000; Eching and Snyder, 2006). Understanding the limitations of $ET_o \times PF$ is crucial to success in applying the standard to manage landscape water for the range of different landscape plant types.

4.2.1 turf: Estimating water demands of turfgrass as $ET_o \times PF$ is an effective tool in estimating water demands and managing irrigation because turfgrass closely mimics the standard conditions of ET_o estimation (Richardson et al., 2012; Devitt et al., 1992; Gibeault et al., 1985). A similar approach has been shown experimentally to be an appropriate means of estimating water demands for landscape groundcovers and shrubs (Beeson, 2012; Pittenger et al., 2001; Pittenger et al., 2002; Pittenger et al., 2009; Shaw and Pittenger, 2004; Staats and Klett, 1995; Sun et al., 2012).

However, providing a single plant factor value for all turfgrass is difficult due to the variation among grass species and climates, as well as the intended usage and maintenance regime of the turfgrass area. The recommended average plant factors for warm-season and cool-season grasses are 0.6 and 0.8, respectively. These plant factors are based on a review of scientific literature published on actual evapotranspiration rates (ET_a) and crop coefficient (K_c) for turfgrasses tested in greenhouse or field experiments.

Early research provided ET_a comparisons for turfgrass under non-limiting soil moisture conditions (Beard, 1989). Under peak evaporative demand, the ET_a rates for cool-season grasses range from 7.0 to 12 mm d^{-1} (Beard, 1989). Generally, the fine-leafed fescues rank medium, while Kentucky bluegrass, annual bluegrass, and creeping bentgrass have very high ET_a rates (Table 2). Among the warm-season turfgrasses, the ET_a rates generally range from 4.5 to 8.5 mm d^{-1} under peak evaporative demand. Buffalograss, bermudagrass, and centipedegrass rank very low in terms of their ET_a rates, while St. Augustinegrass and seashore paspalum are intermediate (Table 2). It is important to realize that there is a great deal of variation for ET_a among cultivars within a turfgrass species.

Table 2 – Relative ranking of evapotranspiration rates for the most commonly used cultivars of the major cool- and warm-season turfgrasses [1)]

Relative Ranking	Cool-Season	Warm-Season
Very low		Buffalograss
Low		Bermudagrass hybrids
		Centipedegrass
		Bermudagrass
		Zoysiagrass
		Blue Grama
Medium	Hard fescue	Bahiagrass
	Chewings fescue	Seashore paspalum
	Red fescue	St. Augustinegrass
		Zoysiagrass
High	Perennial ryegrass	
Very high	Tall fescue	
	Creeping bentgrass	
	Annual bluegrass	
	Kentucky bluegrass	
	Annual ryegrass	

NOTE: Table 2 is adapted from Beard et al., 1989. USGA Green Section Record.
[1)] Grown in their respective climatic regions of adaptation and optimum culture regime. Cultural or environmental factors that cause a drastic change in leaf area or shoot density of a given species may result in a significant shift in its relative ranking compared to the other species.

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