Turf and Landscape Irrigation Best Management Practices

December 2010

Prepared by the Water Management Committee of the Irrigation Association.

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Acknowledgements:

The Water Management Committee appreciates the following participants for their help in developing or reviewing the Turf and Landscape Irrigation Best Management Practices: Eugene W. Rochester, the Board of Directors of The Irrigation Association, the Certification Board of the IA, and the IA members and other professionals that supplied insight and comment.

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FORWARD

The IA has developed these best management practices for turf and landscape irrigation (T&L BMPs) for use in a wide range of activities from policy making to the implementation of efficient irrigation practices. This document has identified the relevant stakeholders and their linkages, relationships and common values. The primary stakeholders include water purveyors, system owners, irrigation designers and consultants, contractors and maintenance personnel. Additional stakeholders include state, federal, public agencies and related landscape industries and associations. Each stakeholder group has specific needs and operates with different resources. This document provides the required hierarchies of information that are comprehensive, and specific while allowing for local interpretation.

The landscape and irrigation industry must demonstrate the ability to irrigate efficiently. The landscape industry is the most visible user of water in an urban setting. Landscape water use during the growing season defines the “peak load” that the water delivery infrastructure must accommodate. The failure to demonstrate efficient irrigation could set the stage for serious consequences to the landscape industry. A drought or perceived water shortage could provide all the impetus necessary for onerous mandates determining when and how much to irrigate as well as the type of plants a landscape can have. The ability to irrigate efficiently will help the landscape industry control its destiny.

The broad and comprehensive nature of the T&L BMPs differentiates them from previous “efficiency” initiatives. The BMPs provide tools to create active partnerships between the water purveyor, property owner and the green industry. It elevates the scope of efficient irrigation to encompass the development of appropriate water allowances for a site (and by extension a municipality or region), in the hope of improving decision making with respect to regional water demand. Specific benefits include:

- By enjoining the water purveyor and the Green Industry in water allowance planning and development of local strategies for implementation, both the Green Industry and the water purveyor are accountable for reduced water use in a way that is not detrimental to the landscapes.

- Reduced peak demand mitigates the need for infrastructure improvements, a cost benefit to the water purveyor.

- May reduce energy cost of pumping water at times of high energy demand and peak load water requirements.

- Reduces the need for onerous mandates regarding irrigation and as a consequence allows greater flexibility in the preservation of existing landscapes, with increased community support for the water purveyor as a result.

The T&L BMPs is distributed as a document:

- Turf and Landscape Irrigation Best Management Practices

The Turf and Landscape Irrigation Best Management Practices document includes:

- Definition of a *Turf and Landscape Irrigation Best Management Practice*.
- Five BMPs that address the quality, design, installation, maintenance, and management of irrigation systems.
- Definition of a *Practice Guideline*.
- Five Practice Guidelines (PG) that address ways to implement respective BMPs. Each PG is meant to be a template for facilitating the development of local specifications by persons or authorities that have direct knowledge of the relationships between landscapes, irrigation systems and related water use.
- Appendices that include a system design package and benefits of advanced irrigation control.
- Glossary of terms used in the BMPs and Practice Guidelines.

The tools provided herein are meant to ensure the installation and management of efficient irrigation systems. This in turn enhances the value of landscapes while making responsible use of a precious and finite resource. The metrics defined raise the bar for turf and landscape irrigation systems, while pinpointing specific opportunities for greater efficiency. The T&L BMPs and related Practice Guidelines provide the basis for sensible, informed decision making regarding regional water use and response to drought.

John Ossa
Chairman, Water Management Committee of the Irrigation Association

VERSION HISTORY

New Version	**Prior Version**	**Description of Change**
April 2005	February 2004	Added “plant available water” and additional Irrigation Association certifications to the Glossary.
December 2010	April 2005	Removed reference to *Consumer Bill of Rights*
		Removed reference to *Landscape Irrigation*
		Irrigation Scheduling and Water Management
		Updated Target DU_{LQ} values
		Updated references and definitions in glossary

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1 INTRODUCTION

1.1 Purpose

The purpose of this document is to present Best Management Practices for irrigation of turf and landscapes (T&L BMPs). These T&L BMPs support the design, installation, maintenance and management of turf and landscape irrigation systems in ways that save water and protect water quality. This document also presents Practice Guidelines that facilitate local implementation of the T&L BMPs. The BMPs and Practice Guidelines complement existing turf and landscape cultivation practices.

The goal is to provide landscape irrigation stakeholders with tools to understand, implement, and manage efficient turf and landscape irrigation system. Stakeholders include landscape irrigation designers, irrigation consultants, landscape irrigation contractors, landscape contractors and maintenance personnel, landscape irrigation system owners, and water purveyors.

1.2 Definitions

1.2.1 Turf and Landscape Irrigation Best Management Practice

A *Turf and Landscape Irrigation Best Management Practice* (T&L BMP) is a voluntary irrigation practice that is designed to reduce water usage and protect water quality. A T&L BMP is economical, practical and sustainable, and maintains a healthy, functional landscape without exceeding the water requirements of the landscape.

1.2.2 Practice Guideline

A *Practice Guideline* (PG) is a recommended set of practices that contribute to the related T&L BMP. The PG is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs. It is the responsibility of the framers of such specifications to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

1.3 Stakeholders

The primary stakeholders that benefit from the T&L BMPs and Practice Guidelines include water purveyors and owners of the irrigation system, irrigation designers, irrigation consultants, irrigation contractors, and landscape maintenance personnel. Additional stakeholders include state, federal and public agencies, landscape contractors, nurseries, and related landscape industries and associations. Refer to Appendix A for a list of stakeholders and the issues that each must confront to achieve improved resource conservation.

1.4 Qualified Professionals

The implementation of Best Management Practices and Practice Guidelines requires a commitment from qualified irrigation professionals. The Irrigation Association certifies individuals in design, contracting, and management of irrigation systems. Various certifications include:

Certified Irrigation Designer (CID)
Certified Irrigation Contractor (CIC)
Certified Landscape Irrigation Auditor (CLIA)
Certified Landscape Water Manager (CLWM)
Certified Golf Irrigation Auditor (CGIA)

A listing of certified individuals can be found on The Irrigation Association's web site at http://www.irrigation.org.

2 TURF AND LANDSCAPE IRRIGATION BMPS

2.1 Identification of T&L BMPs

Table 2-1 lists the Turf and Landscape (T&L) Irrigation BMPs for the design, installation, maintenance, and management of irrigation systems that result in the efficient use of water resources.

Table 2-1
Turf and Landscape Irrigation Best Management Practices

T&L BMP No.	Best Management Practice	Affected Stakeholders
1	*Assure Overall Quality* of the Irrigation System	All Stakeholders
2	*Design* the Irrigation System for the Efficient and Uniform Distribution of Water	Water Purveyor General Contractor Irrigation Contractor Irrigation Designer Irrigation Consultant End User or Owner
3	*Install* the Irrigation System to Meet the Design Criteria	Water Purveyor General Contractor Irrigation Contractor Irrigation Designer Irrigation Consultant End User or Owner
4	*Maintain* the Irrigation System for Optimum Performance	Water Purveyor Irrigation Contractor Irrigation Designer Maintenance Contractor End User or Owner
5	*Manage* the Irrigation System to Respond to the Changing Requirement for Water in the Landscape	Water Purveyor Irrigation Contractor Irrigation Designer Maintenance Contractor End User or Owner Irrigation Consultant

Each T&L BMP of Table 2-1, and the Practice Guidelines that support them, were developed to meet the criteria of the following tenets of Best Management Practices. To be effective a T&L BMP must be:

- Broadly applicable to any location, while allowing for local interpretation and implementation through the related Practice Guideline

- Protect water quality and conserve water resources
- Sustainable by allowing for improvement through adoption of new technology and knowledge
- Economically feasible in installation and use

2.2 T&L BMP 1 - Assure Overall Quality of the Irrigation System

The purpose of an irrigation system is to provide supplemental water when rainfall is not sufficient to maintain the turf and landscape for its intended purpose. A quality irrigation system and its proper management are required to distribute supplemental water in a way that adequately maintains plant health while conserving and protecting water resources and the environment. Assuring the overall quality of the system requires attention to system design, installation, maintenance and management, in particular:

- The irrigation system shall be designed to be efficient and to uniformly distribute the water.
- The irrigation system shall be installed according to the irrigation design specifications.
- The irrigation system shall be regularly maintained to preserve the integrity of the design and to sustain efficient operation.
- The irrigation schedule shall be managed to maintain a healthy and functional landscape with the minimum required amount of water.

2.3 T&L BMP 2 - Design the Irrigation System for the Efficient and Uniform Distribution of Water

The irrigation system shall be designed to be efficient and to uniformly distribute the water. Specific criteria that shall be considered in the design include soil type, slope, root depth, plant materials, microclimates, weather conditions and water source (e.g., quantity, quality and pressure). To conserve and protect water resources, the irrigation designer shall select appropriate equipment components that meet state and local codes and site requirements.

2.4 T&L BMP 3 - Install the Irrigation System to Meet the Design Criteria

The irrigation system shall be installed according to the irrigation design specifications. To conserve and protect water resources, the installed components shall meet the irrigation design specifications, manufacturer’s specifications, and state and local code requirements. The installation shall result in an efficient and uniform distribution of the water. The irrigation contractor or installer shall be licensed (and certified where applicable) and insured.

2.5 T&L BMP 4 - Maintain the Irrigation System for Optimum Performance

The irrigation system shall be regularly serviced to maintain the performance of the system as designed. To conserve and protect water resources and the environment, the serviced components shall meet the irrigation design specifications, manufacturer's specifications, and state and local code requirements. The maintenance shall result in sustaining an efficient and uniform distribution of the water. The maintenance contractor, owner, manager, or irrigation contractor shall be licensed (and/or certified where applicable) and insured.

2.6 T&L BMP 5 - Manage the Irrigation System to Respond to the Changing Requirement for Water in the Landscape

To conserve and protect water resources and the environment, the irrigation schedule shall be changed as required to provide supplemental water to maintain a functional and healthy turf and landscape with the minimum required amount of water.

3 PRACTICE GUIDELINES

3.1 Identification of Practice Guidelines

Each T&L BMP is supported by a Practice Guideline that represents a recommended set of practices for implementing the BMP at the local level. **Each Practice Guideline is intended as a template for establishing specifications that address local needs**.

Table 3-1
Practice Guidelines

PG No.	Related T&L BMP	Practice Guideline
1	1	Practice Guideline for Assuring Quality of an Irrigation System
2	2	Practice Guideline for Designing an Irrigation System
3	3	Practice Guideline for Installing an Irrigation System
4	4	Practice Guideline for Maintaining an Irrigation System
5	5	Practice Guideline for Managing the Use of Irrigation Water

3.2 PG 1 - Practice Guideline for Assuring Quality of an Irrigation System

Practice Guideline 1 (PG 1) meets the requirements of T&L BMP 1. PG 1 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs to assure quality of the irrigation system. It is the responsibility of the framers of such specifications to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To assure that a high-quality irrigation system is designed, installed, maintained, and managed:

1. A qualified irrigation designer or irrigation consultant shall design the system for the efficient and uniform distribution of water based on the requirements of PG 2. "Qualified" means certified, formally trained, licensed or other similar qualification that meets state and local requirements.

2. A qualified irrigation contractor shall be selected to install the irrigation system based on the requirements of PG 3. The irrigation contractor shall test the completed system to verify that the system operates according to the design criteria.

3. The landscape architect, irrigation designer, irrigation consultant, or local water district representative shall perform one or more site observations during system installation to check for adherence to the design. The observation should inspect the

installation of the backflow prevention assembly, main line, laterals, valves, sprinkler heads, drip/micro-irrigation equipment, control wire, controller, and water conserving devices and should assure that the intent of the irrigation designer or consultant has been preserved.

4. The irrigation system shall be maintained for ongoing efficient performance based on the requirements of PG 4.

5. The controller programming (scheduling) shall be managed to respond to the changing need for water in the landscape (see PG 5).

6. Following installation of a new system, a field performance audit shall be conducted using an accepted procedure such as the Irrigation Association's Certified Landscape Irrigation Audit Program (or equivalent). The audit shall be scheduled within a reasonable time period following completion of the installation and as established by the local water purveyor or other governing authority. The audit shall check the performance of the system for conformance with state and local requirements including meeting standards for the minimum precipitation rate and lower quarter distribution uniformity (DU_{LQ}) (and, where possible, emission uniformity for drip/micro-irrigation systems). In addition, the audit shall also verify the installation of specified water management devices such as a rain shutoff device and/or soil moisture sensors. Finally, the irrigation schedule shall be evaluated to assure that the irrigation system meets the supplemental water needs of the plants without wasting water.

   Those systems that are not in compliance with the audit within a reasonable amount of time (as specified by the local governing authority) may be assessed a financial penalty.

   For geographical areas where a landscape water allowance applies, financial incentives should be established for property owners. The incentive should be based on the amount of water applied to the landscape in excess of the established landscape water allowance. The water purveyor or other governing authority shall coordinate the water rate incentives.

3.3 PG 2 - Practice Guideline for Designing an Irrigation System

PG 2 meets the requirements of T&L BMP 2. PG 2 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs for proper design of an irrigation system. It is the responsibility of the framers of such specifications to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To ensure that the irrigation system is designed to efficiently and uniformly distribute the water, and to conserve and protect water resources, the irrigation designer shall:

1. Obtain direct knowledge of site conditions and not rely solely on plot plans to generate a design.

2. Meet all applicable state and local codes including plumbing and electrical codes.

3. Specify manufacturer, model, type, and size of all components to eliminate ambiguity at construction and to facilitate management of the system. The selection of pipe, electrical wire and other materials shall be based on design parameters, environmental conditions and code requirements.

4. Design the irrigation system to minimize installation and maintenance difficulties. The selection and placement of sprinkler and drip/micro-irrigation components should be guided by the expected size of larger specimen plants through a minimum three-year establishment period for shrubs and ten years for trees.

5. Provide a complete irrigation design package to the owner of the system. Refer to Appendix B for a list of recommended items to include in the design package.

6. Apply the following rules of maximum safe flow rate for municipal water suppliers with the lowest safe flow rate prevailing as the design guideline:

   a. The maximum allowable pressure loss through the meter should be less than 10% of the static pressure at the meter.

   b. The maximum flow rate through the meter should not exceed 75% of the maximum safe flow rate through the meter.

   c. The velocity of water through the service line supplying the meter should not exceed 7.5 feet per second (fps).

   d. Select main and lateral pipe sizes so that the velocity of water moving through the irrigation pipe does not exceed state and local requirements, or the industry standard of 5 fps.

7. Where applicable, specify a water source that meets peak demands for landscape water with an irrigation duration of no more than 10 hours per day. This guideline helps determine the correct size of the supply meter. Also consider local statutes, anticipated irrigation intervals, or site uses that may dictate different irrigation durations (for example, golf courses). This guideline is intended to match the system requirements to the particular site, not dictate the actual hours of operation on any given day.

8. Specify protection of the water source in accordance with state and local requirements. Where no requirements exist, assess the degree of hazard and specify the appropriate backflow prevention device. To assist in device selection for protection of potable water supplies, see the references listed below.[1,]

9. For commercial installations, specify a metering device that measures the total landscape water use separate from other use. For residential installations, a separate metering device is recommended.

10. For systems on a municipal supply, allow for a reduction in static pressure of up to10 psi to accommodate possible expansion in the supply network.

11. Specify pressure regulation where variable or excessive static pressure exists.

12. Specify the recommended operating (working) pressure at the maximum design flow rate of the system.

13. For zones with drip/micro-irrigation:

    a. Specify filtration at the control valve to remove particulate matter.

    b. Separate drip/micro-irrigation zones from overhead irrigated zones since drip/micro-irrigation systems are not as susceptible to water losses due to evaporation, wind, or surface runoff. Separate zoning allows the irrigator to adjust water requirements given these differing conditions.

    c. Consider differing plant water requirements and root zone depths and use separate drip/micro-irrigation zones where practical.

    d. Specify pressure-compensated devices to improve overall uniformity.

    e. Specify pressure regulation upstream from the drip/micro-irrigation components. Typically, the pressure of city water sources may be increased periodically by the city for flushing or other purposes, and can potentially damage a drip/micro-irrigation system that has no pressure regulator on the zone controls. Pressure-compensated emitters do not serve this function. Pressure regulating devices can be omitted only when the absolute maximum possible pressure is known to be lower than the maximum allowable pressure for all drip/micro-irrigation components.

    f. Connect (loop) the ends of individual laterals to improve system uniformity and limit possible contamination if drip tubing is damaged. This helps to equalize system pressure and can increase uniformity, and also allows water to flow from

[1] Manual of Cross-Connection Control, Tenth Edition, 2009, Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California.

both sides of damaged drip tubing, thus flushing out any debris.

g. Use air release valves to minimize ingestion of dirt or other contaminants into the emitters.

h. Use flush valves to flush the laterals after completion of the irrigation cycle.

14. Select components and design zones to achieve a minimum *operational* lower quarter distribution uniformity (DU) or emission uniformity (EU) according to the following table:

Table 3-2
Minimum Operational Uniformity

Type of Zone	Type of Uniformity	Target Uniformity*
Spray	Lower Quarter DU	0.55-0.65
Rotor	Lower Quarter DU	0.65-0.75
Drip/micro-irrigation	Emission Uniformity	0.80-0.90

* Target Uniformity is dependent on the configuration of the area being irrigated. Lower expectations for free-form and curvilinear shaped areas compared to large areas that will accommodate regular and consistent spacing of sprinklers.

15. Design the layout of heads and other emission devices for zero overspray across or onto a street, public driveway or sidewalk, parking area, building, fence, or adjoining property. Overspray may occur during operation of the irrigation system due to actual wind conditions that differ from the design criteria.

16. Specify any required equipment changes in a way that meets or exceeds the minimum DU_{LQ}, EU, and overspray criteria.

17. Design sprinkler head spacing with a minimum of "head-to-head" coverage (minimum 50% of diameter) unless the coverage is designed for wind de-rating. Wind derating should be based on wind criteria for the time period that the system is normally run, typically nighttime.

18. Use separate station/zones (hydrozones) for areas with dissimilar water or scheduling requirements.

19. When selecting system components, place a high priority on avoiding surface runoff. Select components to keep the sprinkler precipitation rate below the infiltration rate of the soil and/or use repeat cycles to allow the water to soak into the root zone. Separate station/zones for sprinklers at the top and toe of sloped areas.

20. Locate sprinkler heads based on a thorough evaluation of physical, environmental, and hydraulic site conditions, including typical wind conditions during the normal irrigation period.

21. Use drip/micro-irrigation where appropriate to reduce evaporation losses and surface runoff, and to avoid applying water on hardscapes.

22. Provide a monthly irrigation water budget. Refer to PG 5.

23. In regions where a landscape water allowance applies, include an estimate of the future monthly landscape water allowance, based on historical reference ET, landscape area, and the landscape water adjustment factor provided by the purveyor or water provider.

24. Provide monthly base irrigation schedules where the frequency of irrigation (*when to irrigate*) depends on replenishing allowable depletion (*how much to irrigate*) of the soil moisture between irrigations based on monthly reference historical evapotranspiration data. For each station/zone (or hydrozone as applicable), the designer shall specify the plant type, soil type, average root zone depth, precipitation rate, lower quarter distribution uniformity, area square footage, target gallons per minute flow rate, recommended operating pressure range, and maximum recommended cycle run time without runoff. The designer shall recommend a site-specific rainfall factor to convert historical rainfall to effective rainfall (see reference 5). This is useful for budgeting purposes and for schedule compensation when a rain shutoff device is not installed. Refer to PG 5 for additional scheduling requirements.

25. Recommend the following water-conserving concepts and equipment where appropriate and economically justified:

    a. Use an alternative (non-potable) water source (such as reclaimed water) where practical and allowed by law. Special management practices and components may be required when using alternative water sources.

    b. To mitigate the effects of wind, use low-trajectory sprinkler nozzles along with the appropriate modified head spacing. Select components that do not mist when manufacturer's pressure specifications are met.

    c. Install water-conserving devices such as:

        - Check valves to minimize low-head drainage

        - Pressure regulators or pressure compensating screens, stems or nozzles to control high pressure

        - Rain, freeze, and/or wind sensors to suspend irrigation during weather conditions that are unfavorable for irrigation.

        - Environmental sensors that can actively measure weather conditions to determine daily plant water need.

- Soil moisture sensors to monitor soil moisture and suspend irrigation if the moisture reserve in the root zone is significantly above the allowable depletion limit.

d. To simplify manual reading of the total landscape irrigation water use, a water meter with an electronic output signal that supports a remote display mounted at the controller.

e. For automated management of the landscape irrigation water use, a landscape irrigation meter with an electronic flow rate output signal that is compatible with the controller. This allows the controller to measure and control the amount of water use, as well as to indicate leaks (e.g., broken pipes or sprinklers).

f. A controller that has multi-program capability with at least four start times (for multiple repeat soak cycles) and run time adjustments in one-minute increments.

g. For larger sites where a significant potential water savings may result, a controller that allows for flexible irrigation scheduling and advanced water management features. These features may include incorporating current (real time or daily) evapotranspiration (ET) data, water budgeting, and soil moisture monitoring. Refer to PG 5 and Appendix C (Benefits of Advanced Control Systems) for further details.

h. A separate common wire from the controller to each hydrozone station valve to allow for sensor-based control of each hydrozone.

3.4 PG 3 - Practice Guideline for Installing an Irrigation System

PG 3 meets the requirements of T&L BMP 3. PG 3 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs for proper installation of an irrigation system. It is the responsibility of the framers of such specifications to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To ensure that the irrigation system is installed to efficiently and uniformly distribute the water, and to conserve and protect water resources, the irrigation contractor or installer shall:

1. Contact all appropriate utility companies prior to beginning installation, to locate underground utilities including gas lines, electrical, telephone, cable, and so forth. State laws (and some Federal laws) require anyone who digs to notify utility companies before starting. Installation shall not be started until all underground utilities are located and marked.

   The contractor/installer shall coordinate with the property owner to locate, identify, and mark all privately-owned underground utilities. Installation shall not be started until all private utilities are located and marked.

For more information, check your local phone directory to directly contact utility companies in your area. The following free notification services are also located on the internet:

- http://www.digsafely.com
- http://www.digsafe.com
- http://www.underspace.com/refs/ocdir.htm.

2. Prior to beginning installation, verify that the point of connection, flow rate, and static and dynamic pressures meet design criteria.

3. Install the irrigation system according to the design specifications and manufacturer's published performance standards. The design shall reflect the practices defined in PG 2. If a design does not exist, then *encourage the property owner to have a qualified irrigation designer or consultant develop a design*.

4. Review planting plans prior to installation to minimize conflicts between larger plants and irrigation heads. Also review construction plans for conflicts between hardscape and sprinkler head placement.

5. Inform the property owner and irrigation designer of unusual or abnormal soil conditions which may impact the design and management of the irrigation system.

6. Where deviations from the design are required (for example, running pipe around a tree or other structure), redline the plan drawing to note the deviation. Always consult with the designer prior to making the change to ensure that the change is within design performance specifications.

7. Furnish a "red-line" record set of drawings to the owner of the system. Within the record set of drawings, describe the system layout and components including all changes from the original design.

8. Test the irrigation system to verify that it meets the design criteria.

9. Perform an irrigation audit using an accepted procedure. Provide the end user (or owner) with system specifications and a performance summary report by station/zone that includes the plant type, soil type, average root zone depth, precipitation rate, lower quarter distribution uniformity (DU_{LQ}), area square footage, target gallons per minute flow rate, recommend operating pressure range, and maximum recommended cycle run time without runoff. Retain a reference of each station/zone's $DU_{LQ,}$ precipitation rate, operating pressure, and flow rate at the controller. (Also see item 5 of PG 2.)

10. Review the irrigation schedule that should accompany the design. If no such schedule exists, then create an irrigation schedule (see PG 5). Review the irrigation schedule, specifically the rationale and methods for determining irrigation days, station/zone run times and start times. Operate the system. Add repeat cycles and adjust cycle run time to eliminate runoff.

11. Explain to the end user (or owner) the location and operation of the controller, valves, sensors, pressure regulators, backflow device, sprinkler heads, and drip/micro-irrigation devices. Review advanced programming features such as multi-cycle irrigation to prevent run-off and the use of the percentage water increase/decrease function. Educate the owner on features and capabilities of the system including the maintenance requirements of PG 4.

12. Provide the end user (or owner) with recommendations for landscape water conservation. Emphasize the following topics:

    a. Maintaining proper operation of system components.

    b. Landscape irrigation is meant to supply water to supplement rainfall.

    c. Plant water requirements may change from day-to-day.

    d. Importance of hydrozoning according to plant water requirements.

    e. Benefits of using drip/micro-irrigation components.

    f. Benefits of applying water-conserving landscaping practices such as the use of mulch and soil amendments.

    g. Benefit of assigning someone to be held accountable for water use in the landscape.

13. Provide the end user (or owner) with product warranties and operating instructions for all equipment.

Note: Irrigation system owners have an important, if not *the* main role in managing and maintaining irrigation systems for optimum performance. It is also crucial that owners request that irrigation systems be designed and installed for efficient and uniform distribution of water. Owners are key stakeholders for promoting and implementing these turf and landscape irrigation BMPs.

Irrigation system owners should strongly consider the following practices. While these practices work to conserve and protect water resources, they also protect the owner's interests:

1. Ensure that the irrigation contractor and maintenance contractor are currently licensed, certified (where applicable), insured and legally authorized to install irrigation systems in your area.

2. Ask all contractors for references of previous work and contact those references to seek information on the contractor's quality of service and timeliness in performing the job.

3. Obtain a written contract. The contract should, at minimum, include the scope of work, prices, permits required, warranties, necessary exclusions, and payment terms. The scope of work should clarify the extent of contractor liability should damage to site utilities occur. Similarly, the scope of work should clarify the extent of property owner liability should damage to unmarked private utilities occur. Also ask the contractor for written warranties on materials and labor.

4. Insist in the contract that the irrigation contractor, designer or consultant provide design documents at the beginning of the project (see the Irrigation Design Package in Appendix B). Also insist that an "as built" record set of drawings be provided at the completion of the project. You may need the drawings to locate system components that wear or break as the system ages, or for additions and/or modifications to the landscape.

5. Consider the possible impact of the irrigation system installation on plants and the landscape. For instance, preferably any trenches should be dug outside the drip line of existing trees. Otherwise tree roots may be cut. Determine whether landscape restoration should be part of the scope of work.

6. Determine the permits that are required prior to installation of the irrigation system. Find out which parts of the system will be subject to third party observations, reviews, or inspections.

7. Ensure that the backflow prevention device and other components meet all applicable state and local code requirements.

8. Ensure that the system meets precipitation rate requirements prescribed by state or local codes (the precipitation rate in every hydrozone must be in compliance).

9. Insist upon design features that promote efficient use and uniform distribution of water, including the following:

   a. A water meter dedicated to measuring only landscape water use. A meter with a flow rate output signal for interfacing to the controller is recommended because it can help detect leaks and manage water use.

   b. Commercial quality irrigation system components. Ask the contractor which manufacturer will be used for the valves, sprinkler heads, drip/micro-irrigation components, the controller and other parts of the system. Ask the contractor to show you samples.

   c. A design that results in uniform and efficient coverage. Sprinkler head spacing should be a minimum of "head-to-head" (minimum 50% of diameter) unless the coverage is designed for wind de-rating. Wind de-rating should be based on average nighttime wind speed. Design to avoid overspray onto hardscapes, fences, buildings and adjoining property.

   d. Design with drip/micro-irrigation components for lower evaporation and runoff.

   e. Specify separate station/zones for sprinklers at the top and toe of sloped areas. If not separated, determine how the sprinkler heads on sloped terrain will be installed to ensure that the sloped area gets adequate water, without flooding other areas.

   f. Use separate station/zones (hydrozones) for areas with dissimilar water or scheduling requirements.

   g. Specify features or components that keep water off the paved areas, fences, the sides of buildings, and adjoining property.

   h. Specify the recommended operating (working) pressure and range. The operating pressure of the water supply should be determined at the maximum design flow rate of the system. This is a factor in the layout and design of station/zones and in the selection of sprinklers.

   i. Specify water conservation features such as (1) a rain shutoff device to suspend irrigation during and following significant rain events and (2) soil moisture sensors to avoid over irrigating hydrozones.

10. Understand the expected monthly irrigation water usage (budget) and cost.

11. Learn how the system will operate. For example: how long will it run per week, normally and in the peak summer months; what is the expected maximum run time on a day of the warmest month; whether the system will run only at night; how much

water will the system use in the peak summer months; and whether you should expect dry spots in your turf during the warmest month of the year.

12. Allow soil moisture in the root zone to deplete to a predefined allowable depletion limit. Then base irrigation schedules on replenishing the soil moisture back to field capacity.

13. Ensure that system can be managed to promote efficient use of water. The system should be designed and managed to accommodate a cycle-and-soak irrigation principle that allows the water to infiltrate instead of running off. Learn how to schedule irrigation cycles to incorporate this principle.

3.5 PG 4 - Practice Guideline for Maintaining an Irrigation System

PG 4 meets the requirements of T&L BMP 4. PG 4 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs for proper maintenance of an irrigation system. It is the responsibility of the framers of such specifications to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To ensure that the irrigation system continues to efficiently and uniformly distribute the water, and continues to conserve and protect water resources, the maintenance contractor, owner, manager, or irrigation contractor shall:

1. Establish a periodic maintenance schedule for inspection and reporting performance conditions to the end-user (or owner) of the irrigation system. Report any deviations from the original design. Create a station/zone map for ease of system inspection and controller programming.

2. Periodically review the system components to verify that the components meet the original design criteria for efficient operation and uniform distribution of water:

    a. Verify that the backflow prevention device is working correctly.

    b. Verify that the water supply and pressure are as stated in the design.

    c. Verify that pressure regulators are adjusted for desired operating pressure.

    d. Examine filters and clean filtration elements as required.

    e. Verify proper operation of the controller. Confirm correct date/time input and functional back-up battery.

f. Verify that sensors used in the irrigation system are working properly and are within their calibration specifications.

g. Adjust valves for proper flow and operation. Adjust valve flow regulators for desired closing speed.

h. Verify that heads are properly adjusted – nozzle size, arc, radius, level and attitude with respect to slope.

i. Repair or replace broken hardware and pipe; restore the system to its design specifications.

j. Complete repairs in a timely manner to support the integrity of the irrigation design and to minimize the waste of water.

k. Notify the end-user (or owner) of any deviations from the original design.

l. Test all repairs.

3. Ensure that the replacement hardware used for system repairs matches the existing hardware, and is in accordance with the design. Aftermarket replacement nozzles may not match original parts well enough to preserve distribution uniformity and the precipitation rate. Conduct a performance audit every three to five years to assure that the system is working efficiently and with the desired DU_{LQ} and precipitation rate specifications.

4. As plant material matures, trim or remove vegetation as required to preserve system performance. Add additional sprinklers or other hardware as required to compensate for blocked spray patterns or changes in the irrigation needs of the landscape. Ensure that system modifications are in keeping with design specifications and do not cause landscape water demand to exceed the hydraulic capacity of the system.

5. Establish a "winterization" protocol (if required) and a corresponding process for system activation in the spring.

Additional point for an owner to consider is:

1. Ensure that the maintenance contractor is licensed and/or certified (where applicable), is insured, experienced and reputable, and is legally authorized to maintain irrigation systems in your area. Ask the contractor for references of previous work and contact those references to seek information on the contractor's quality of service and timeliness in performing the job.

3.6 PG 5 - Practice Guideline for Managing the Use of Irrigation Water

PG 5 meets the requirements of T&L BMP 5. PG 5 is meant to be a guide to facilitate the development of specifications that address local landscape irrigation needs for proper management of the use of irrigation water. It is the responsibility of the framers of such specifications to adopt only those guidelines that apply to their local needs and in such a way as to be economical, practical and sustainable for maintaining a healthy and functional landscape without exceeding the water requirements of the landscape.

To conserve and protect water resources and the environment, the irrigation schedule shall be changed as required to provide supplemental water to maintain a functional and healthy turf and landscape with the minimum required amount of water.

Figure 3-1 gives an overview of the irrigation scheduling process.

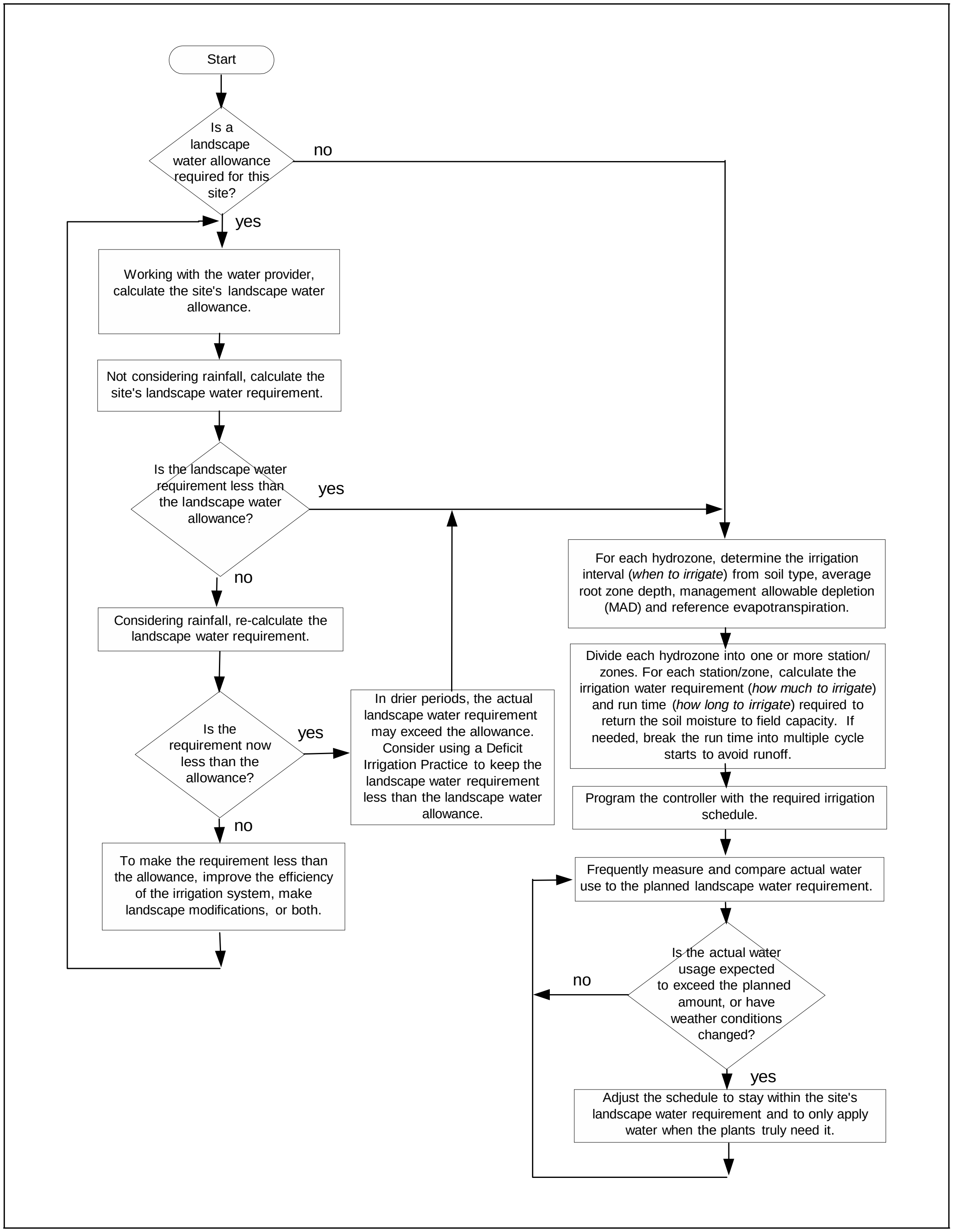
- Landscape irrigation basic concepts,
- Scheduling and water management,
- Establishing quality ratings for irrigation systems,
- Landscape water allowances, and
- Deficit irrigation and drought planning.

To facilitate managing irrigation water use, the irrigation manager, consultant, end-user, owner, maintenance personnel, or contractor shall:

1. Create a site map showing, at a minimum, the location of each point of connection water meter, backflow prevention device, controller, station/zone valves, and landscape area served by each valve.

2. Ensure that a dedicated irrigation water meter has been installed for measuring both the irrigation water flow rate and the volume applied to the landscape. To facilitate managing irrigation water use, the water meter should have an electronic flow rate output signal for interfacing with a remote display or to controllers that can perform leak detection and water management.

Figure 3-1
Landscape Irrigation Scheduling



3. If necessary, perform an irrigation audit to obtain data for creating a base irrigation schedule:

   a. For each hydrozone, identify plant type and microclimate factors. From soil cores, identify the soil texture and soil infiltration rate for the purpose of estimating the available water holding capacity of the soil.[4,5] Determine the average effective root zone depth of the hydrozone.

   b. For each station/zone, measure the actual sprinkler performance including operating pressure, precipitation rate, lower-quarter distribution uniformity and average flow rate.

   c. For each station/zone, recommend a normal operating pressure range. Accurately measure the landscaped area.

   d. For each station/zone, if the soil infiltration rate is less than the precipitation rate then activate the zone valve and record the run time until you first see runoff. Recommend the number of cycle starts and soak time between cycles to avoid runoff.

4. Using data collected from the audit, provide a monthly base irrigation schedule where the frequency of irrigation (*when to irrigate*) is based on replenishing the allowable depletion (*how much to irrigate*) of the soil moisture between irrigations. Base the monthly schedules on the plant type, root zone depth, soil type, infiltration rate, and monthly historical reference evapotranspiration data. Also account for site topography such as slope. Where there is a potential for surface runoff, use multiple repeat cycle start times to allow the water to infiltrate into the soil. If a rain shutoff device or soil moisture sensors are not installed, then also factor in an estimate of effective rainfall.

   Information on scheduling is available from the Irrigation Association.[6,]

5. After the system has been placed into service, evaluate the effectiveness of system water management by monitoring and comparing actual landscape water usage to a target design irrigation water budget:

   a. <u>Calculate the design irrigation water budget for normal weather conditions.</u> The design irrigation water budget should be provided by the landscape irrigation designer as one component of the Irrigation Design Package (Appendix B) and based on local historical weather conditions and expected plant water requirements under normal (e.g., non-drought) weather conditions. Base the design irrigation water budget on monthly historical reference

[4] USDA - NRCS Irrigation Guide, Sept. 1997, Pages 2-17 through 2-25.
[5] Miller, Raymond W., <u>Soils in Our Environment</u>, Seventh Edition, Chapters 4-6, 1995, Prentice Hall
[6] The Irrigation Association, <u>Sprinkler System Scheduling</u>, March 2002

evapotranspiration (historical ET_o) data, monthly effective rainfall estimate from monthly historical rainfall, plant landscape coefficient factors, and site factors.

b. Calculate the design deficit irrigation water budget for drought weather conditions. For drought conditions, the irrigation goal is to conserve water while still sustaining the integrity of a majority of the landscape. The normal-weather method for establishing the design irrigation water budget is generally applicable but is modified. The objective is to assign the water reduction required during the drought, rather than meet normal-weather plant water requirements. Focus on water saving techniques for reducing plant water demand including reducing or eliminating fertilizers, changing mowing height, adding or improving mulch, and so forth.

c. Manage the water use of the site. At a minimum, at the beginning and mid-point of each month, monitor water usage by reading the system water meter or flow totalizer. Compare actual water usage to the budgeted amount of water for the month. At mid-month, if water usage exceeds 50% of the current month’s irrigation water budget, then modify the schedule to stay within the monthly budget. Frequently adjust the irrigation schedule to meet changing weather conditions.

d. Evaluate System Performance. Periodically, and at the end of each irrigation season (or annually), evaluate water management efficiency and overall irrigation system efficiency. The evaluation can highlight strengths and weaknesses in the performance of the irrigation system and how it is being maintained and managed.

6. Periodically, verify that sensors and other components in the irrigation system are working properly. Inspect the irrigation system during operation.

7. Periodically, visually verify that the plant material is healthy and that soil moisture is adequate. Use a soil probe to evaluate root depth, soil structure and moisture.

8. To further conserve water, the irrigation manager should:

a. Understand how to use various sensors such as soil moisture and weather sensors to aid in irrigation management.

b. Install a rain shutoff device to stop irrigation during and directly following a significant rain event.

c. Install soil moisture sensors to override the controller's schedule when the root zone is adequately moist. Monitoring soil moisture regularly also helps to reduce the guesswork in establishing proper irrigation intervals for each hydrozone.

d. Install a master valve to stop unscheduled flow of irrigation water.

e. Refer to Appendix C on the benefits of advanced control systems.

f. Use drip/micro-irrigation components for higher distribution uniformity and lower evaporation and runoff.

9. When water supplies are limited, manage the irrigation based on a site-specific Drought Response Plan. The plan should have two primary components, one dealing with landscape cultural practices and the other with deficit irrigation practices:

   a. Landscape Cultural Practices

      There are many cultural practices that can help a landscape irrigation system operator cope with a water shortage, including adjusting mowing height, fertilization practices, use of mulch in planter beds, and amending the soil. The owner should determine the overall priorities of the site and evaluate those areas that deserve the greatest attention. Consult a licensed/certified (where applicable) landscape contractor, extension agent or certified nurseryman for information regarding appropriate cultural practices.

   b. Deficit Irrigation Practice

      Deficit irrigation may be used at the discretion of the irrigation manager. It is most commonly used in response to a drought (or other water shortage). The goal of deficit irrigation management is to apply a reduced amount of water while keeping the plant material alive, but potentially placing the plants in a water-stressed condition.

      It is important to understand that managing plants in a deficit irrigation mode puts them at risk to other environmental and/or biological factors. Careful and frequent observation of the landscape is essential to such an irrigation strategy.

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5. Irrigation Association, Sprinkler System Scheduling. March 2002.

6. Manual of Cross-Connection Control, Tenth Edition, 2009. Foundation for Cross-Connection Control and Hydraulic Research, University of Southern California.

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8. USDA - NRCS Irrigation Guide, Sept. 1997, Pages 2-17 through 2-25.

APPENDIX A – STAKEHOLDERS AND ISSUES RELATED TO WATER

Table A-1
Stakeholders

STAKEHOLDERS	RESPONSIBILITIES RELATED TO WATER CONSERVATION AND MANAGEMENT
Water Purveyor	1. Documenting beneficial and reasonable uses of water 2. Promoting the adoption and use of reclaimed water 3. Pricing water to recognize its limited nature (the pricing mechanism should provide incentives to water users who conserve water and penalties for those who waste it) 4. Establishment of educational programs and materials for users of irrigation systems 5. Establishing incentives to promote efficient irrigation systems 6. Maintaining desired water pressure in mains and submains 7. Using and maintaining water meters 8. Reducing chemical movements 9. Reducing runoff or off-target irrigation
1. Irrigation Designer, Consultant, or Engineer 2. Irrigation Contractor or Installer 3. Maintenance Contractor 4. Owner or End-user of Irrigation System 5. Landscape Contractor 6. Water Purveyor	1. Assure overall quality of the irrigation system 2. Design the irrigation system for the efficient and uniform distribution of water 3. Install the irrigation system to meet the design criteria 4. Maintain the irrigation system for optimum performance 5. Manage the irrigation system to respond to the changing need for water in the landscape 6. Maintaining healthy turf and landscape plants during droughts 7. Reducing runoff or off-target irrigation
1. Landscape Contractor 2. Nursery and Landscape Retail/Wholesale Companies	1. Optimum turf and landscape fertilizing 2. Reduction of biomass 3. Informing owners about water efficient landscape practices
Nursery and Landscape Retail/Wholesale Companies	1. Characterizing plants for less water use, native plants and xeriscape plants 2. Identifying turf species that use less water

Table A-2
State, Federal and Public Agencies

AGENCY	RESPONSIBILITIES RELATED TO WATER CONSERVATION AND MANAGEMENT
State, Federal and Public Agencies (General)	1. Policies that allow for the lease, sale or transfer of established water or water rights without jeopardizing established water rights 2. Establishment of an independent entity to institute studies to identify water use and misuse by all segments of the water-using industry and to provide data on which to base decisions regarding equitable water distribution during periods of water shortage 3. Watershed protection (hydrology) 4. Integrating water agency involvement in land use planning 5. Reducing runoff or off-target irrigation 6. Reducing chemical movements 7. Optimizing turf and landscape fertilizing 8. Reducing and managing grass clippings 9. Maintaining healthy turf and landscape plants during droughts
State and Federal Environmental Regulatory Agencies	1. Nonpoint source pollution of water resources 2. Water and water quality information 3. Regulations for using treated effluents 4. Information on reference evapotranspiration
Public Agencies (Parks)	1. Maintaining public irrigation systems 2. Monitoring of irrigation systems and water usage 3. Maintaining irrigation system inventory
Municipal and Rural Water Departments and Companies	1. Collaboration with the green industry to establish appropriate landscape water allowance adjustment factors 2. Insuring adequate water supplies to meet demands 3. Regulating and enforcing local regulations
State Water Use Permitting Agencies	1. Documenting and planning for future water needs 2. Equitably appropriating water rights 3. Registering professional engineers, licensed irrigation designers, consultants, landscape architects, and contractors 4. Coordinating continuing education programs
Higher Education, Universities, Federal Research Agencies	1. Irrigation curricula, agronomic, horticulture, and landscape architecture education/research/extension 2. Irrigation technology, crop varieties, irrigation management, water quality research 3. System modeling and simulation
Federal Conservation Agencies	1. Training, demonstrations, technological expertise 2. Sustaining and protecting natural resources 3. Coordinating local conservation district programs

APPENDIX B - IRRIGATION DESIGN PACKAGE

The irrigation designer or consultant should supply an Irrigation Design Package to the owner of the system. The purpose is to provide the system owner with documented site- and zone-specific information, and values used in design calculations.

The Irrigation Design Package should include:

1. **Site-specific Information:**
   - Site map that includes "north" symbol, topography and/or key elevations
   - Static pressure(s) used in the design; psi
   - Monthly historical grass reference evapotranspiration (ET_o); in./month
   - Monthly historical rainfall (R_h); in.
   - Recommended rainfall factor (RF; %), or supply the method for estimating effective rainfall (R_e) from historical rainfall (R_h).
   - Monthly historical effective rainfall (R_e) (may also be specific to each hydrozone)
   - Landscaped area (A); sq. ft., for each hydrozone.
   - Site's design area-weighted average lower quarter distribution uniformity (DU_{LQ}) for overhead-irrigated hydrozones; %
   - Site’s design area-weighted average emission uniformity (EU) for drip/micro-irrigation hydrozones; %
   - Prevailing wind direction during normal period of sprinkler system use (in degrees from north)
   - Average wind speed (mph) during normal period of sprinkler system use
   - Reference to local information regarding location of subsurface utilities
   - Identify heritage trees or special circumstances
   - Note if special trenching or installation techniques are required

2. **Identification and Location of All Irrigation Components:**
   (To aid in initial installation and in future modifications or additions to the system)
   - Point of connection water meters and their locations
   - Dedicated meters and flow sensors and their locations
   - Backflow prevention device(s) and location
   - Station/zone valves and their locations
   - The site area (location) served by each valve
   - Controller(s) and location(s)
   - Sensor types and their locations
   - Pump(s) and location(s)

- All components (above items plus sprinkler heads, nozzles, drip/micro-irrigation components, wire, pipe type and size, valve size, etc.) by manufacturer, model, type and size

3. **Basic Hydraulics (pressure losses and calculations):**
   - Point of connection water meter(s)
   - Backflow prevention device(s)
   - Static water pressure; psi
   - Recommended system dynamic (working) water pressure; psi
   - Acceptable system dynamic (working) water pressure range (minimum to maximum); psi
   - Valve and pipe sizing criteria

4. **Station/zone and Hydrozone Information (for *each* station/zone or hydrozone):**
   - Landscaped area of the zone (A); sq. ft.
   - Plant materials
   - Design plant species factor (K_s)
   - Design microclimate factor (K_{mc})
   - Design plant density factor (K_d)
   - Design landscape coefficient ($K_L = K_s \times K_{mc} \times K_d$)
   - Monthly plant water requirement (PWR) based on historical ET_o; in.
   - Soil type (clay, loam, sand, etc.) and soil profile if applicable
   - Design soil infiltration rate (intake rate); in./hour
   - Design available water holding capacity (AW) of the soil; in. of water per in. of soil
   - Design average root zone depth (RZ); in.
   - Design management allowable depletion (MAD)
   - Design allowable depletion (AD); in.
   - Design flow rate (Q); gpm
   - Design precipitation (application) rate (PR); in./hour
   - Design lower-quarter distribution uniformity (DU_{LQ}); %
   - Design run time multiplier (RTM)
   - Monthly expected station/zone irrigation water budget (V_{IWR}) gallons or ccf
   - Recommended sprinkler spacing, noting maximum spacing that maintains the design DU_{LQ}; ft.
   - Recommended operating pressure; psi
   - Acceptable operating pressure range (minimum to maximum); psi
   - Recommended allowable stress factors (K_{as}) for deficit irrigation during mild and severe droughts

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5. **Design Monthly Irrigation Water Budget:**
    - For each month, compute the design monthly irrigation water budget (V_{IWR}) for the irrigation system by summing the water budget of individual hydrozones. Use the same units as used by the local water purveyor, typically ccf or gallons
    - Identify the values used (ET_o, K_L coefficient, etc.) in the calculation
    - Monthly permitted water withdrawal amount (only applicable for some states with particular requirements)

6. **Seasonal (or Annual) Irrigation Water Budget:** Compute the design irrigation water budget ($V_{IWR,season}$) for the irrigation season (or for the year) by summing the design station/zone water budgets for all months of the irrigation season; ccf/year or gal/year

7. **Monthly and Seasonal Landscape Water Allowance (only if applicable to the region):**
    - Water allowance adjustment factor (K_{wa}) for the particular type of landscape
    - Site's monthly and seasonal landscape water allowance (LWA); ccf/year or gal/year

8. **Monthly Irrigation Schedule (for *each* station/zone):**
    - Document by month the recommended base irrigation schedule. Base the schedule on historical monthly ET_o data, plant type (K_L coefficient), soil type (for available water holding capacity and soil infiltration rate), root zone depth, allowable depletion, optimum irrigation interval, station/zone precipitation rate, station/zone distribution uniformity, and so forth.
    - Recommended irrigation interval (days between irrigation)
    - Recommended irrigation run time (hours or minutes per irrigation event and time of day)
    - Number of cycle starts (N_{cs}) required for each irrigation event to avoid runoff
    - Maximum cycle start run time (RT_{cycle}) of each hydrozone to avoid runoff (minutes) and recommended soak delay time between cycles (minutes)
    - Identify values used (ET_o, K_L, precipitation rate, etc.) in developing the base irrigation schedule

9. **Source of Local Historical or Current Evapotranspiration (ET_o) Data (if available).** Refer to The ET Connection on the Irrigation Association's web site at http://www.irrigation.org/

10. **Source of Local Historical or Current Rain Data (if available).** Include sources used such as the National Weather Service, local weather channel, local weather station (state location), state cooperative extension service, and so forth.

11. **Recommendation for Frequency of Irrigation System Inspection**

12. Pumps (if required):

- Manufacturer, model, type and size
- Hydraulic and energy calculations
- Electrical requirements and projected operating costs

13. Component Warranty and Product Literature (provide to owner)

14. Recommendations for Water Conserving Devices

- Rain shutoff device
- Soil moisture sensors
- Weather station
- High-wind shutoff device
- Freeze protection device
- Flow meter with totalizer
- Automated control system

APPENDIX C - BENEFITS OF ADVANCED CONTROL SYSTEMS

1. Purpose

The objective of an advanced control system is to provide only the supplemental water needed by the landscape. An advanced system can automatically adjust the irrigation schedule based upon recent rain events, local weather conditions, and soil moisture within the root zone. The benefits are reduced water use concurrent with an overall savings in the labor required to monitor and integrate current (real-time or daily) data into irrigation schedule adjustments.

2. Providing Supplemental Water

Nature is unpredictable in most parts of the country. On a day-to-day basis, the water needed from an irrigation system cannot be accurately predicted. To meet the supplemental water requirements of the plants without wasting water, the controller's schedule must be adjusted often enough to account for weather changes. A low automation system only activates zone valves. It does not integrate the weather or soil moisture into system operation. This adjustment is done manually and usually infrequently. Therefore, it is not very effective in managing water or saving labor.

With a highly automated system (i.e., advanced control technology), this adjustment is made frequently and automatically by the control system. It minimizes the waste of water while saving labor. However, no irrigation control system should be installed on the basis of "set it and forget it." While highly automated systems can save substantial labor and water, the landscapes should still be periodically inspected to ensure that the irrigation system is performing properly.

As shown in Table C-1, the level of automation of the irrigation system affects predictability of the system's operation and the amount of water and labor that can be saved. If the user wishes a high level of predictability in the irrigation schedule (i.e., the zones run on fixed dates at fixed start times for a fixed amount of time), then the required level of automation is low (i.e., conventional clock-based controller) but the water savings is also generally low. Additional water savings can only be attained by frequent manual adjustments to the schedule. This greatly increases the labor required to achieve even a modest increase in water savings. However, if the user doesn't care about schedule predictability but wants the landscape to be adequately irrigated without wasting water, then the required level of automation is high (with a rain sensor, current ET, and/or the use of soil moisture sensors[1]) and the level of water savings attained is generally high.

[1] Some soil moisture sensor based systems reduce or eliminate the need for rain sensors and current ET information by providing direct feedback to the clock-based controller concerning current status of soil moisture following recent rainfall or changes in ET.

Table C-1
Level of Automation Required and Irrigation Schedule Predictability
Versus
Water and Labor Savings Attained

Level of Automation of the Control System	**Predictability of the Irrigation Schedule**	**Water Savings Attained**	**Labor Required to Monitor, Compute, Integrate, Record, and Adjust Programming**
Low	High (manually set)	Low	High
Medium (historical ET, rain sensor)	Medium	Medium	Medium
High (current ET, rain, wind and/or soil moisture sensor measurement)	Low (automatically responds to real-time site conditions)	High	Low

3. <u>Frequency of Schedule Adjustment</u>

Systems with "low" automation require that the user manually configure the base schedule or make other manual adjustments to set the irrigation interval and run time. The schedule should be based on plant water need and changing weather conditions. The number of irrigations per week and/or the run time of each station zone should be based on the plant type (species factor), microclimate, plant density, soil type, slope, microclimate exposure, root zone depth, watering window, and other factors. The frequency of irrigation should be based on allowing the soil moisture to deplete to an allowable depletion limit. Scheduling should supply no more than the amount of water needed to bring the soil moisture back to field capacity.

“Medium” automated systems typically adjust their irrigation schedule at least monthly based on historical monthly reference ET. The user should adjust the schedule manually based on plant water need and changing weather conditions.

Systems with "high" automation can automatically adjust their irrigation schedules daily or weekly based on measurements of station zone flow rate and various combinations of rain, ET, soil moisture, and wind. These systems save the greatest amount of water because they continually balance the changing requirements of the landscape with the changes in the environment. These systems can potentially enable the monitoring and adjusting of controllers over a wide geographic area, thereby saving a considerable amount of labor.

No irrigation control system should be installed on the basis of "set it and forget it." The landscapes should still be periodically inspected to ensure that the irrigation system is performing properly.

A sensible balance of automation with landscape and irrigation management can result in attractive, water conserving landscapes.

GLOSSARY

Note: The cited terms below should not infer original development by the Water Management Committee.

active root zone, effective root zone [RZ] {in.} See **root zone**.

allowable depletion [AD] {in.} The amount of total plant available water (PAW) that is to be depleted from the active plant root zone before irrigation is applied. (Water Mgt Committee 2001)

allowable stress factor [K_{as}]{dimensionless} See **coefficients**.

amount of irrigation water [I] (in.) Amount of irrigation water expressed in inches.

area [A]{sq. ft.} Area of the landscape.

available water holding capacity [AWHC]{in. water per in. soil} Ability of the soil to retain water. Also see **field capacity**, **permanent wilting point**, and **plant available water**.

backflow []{}Any unwanted flow of used or non-potable water or substance from any domestic, industrial or institutional piping system into the pure, potable water distribution system. The direction of flow under these conditions is in the reverse direction from that intended by the system and normally assumed by the owner of the system. (USC, 1998)

backflow prevention device [BPD]{} Safety device which prevents the flow of water from the water distribution system back to the water source (ASAE, 1998)

Best Management Practice [BMP]{} A *Turf and Landscape Irrigation Best Management Practice* is a voluntary irrigation practice that is designed to reduce water usage and protect water quality. The Irrigation Best Management Practice is economical, practical and sustainable, and maintains a healthy, functional landscape without exceeding the water requirements of the landscape. (Water Mgt Committee 2001)

Certified Agricultural Irrigation Specialist [CAIS] {} The Certified Agricultural Irrigation Specialist is involved in the management and operation of on-farm irrigation systems. These systems include surface irrigation methods, as well as pressurized systems like micro-irrigation and sprinklers. Prior to certification examination, specialists are required to take an Irrigation Association approved preparatory course.

Certified Golf Irrigation Auditor [CGIA]{} The Certified Golf Irrigation Auditor is involved in the analysis of turf irrigation water use tailored to the unique conditions found on golf courses. Golf Auditors collect site data, make maintenance recommendations and perform water audits on golf courses. Through their analytical work at the site, these irrigation professionals develop base schedules for greens/tees, fairways and roughs. Prior to certification examination, auditors are required to take an Irrigation Association approved preparatory course.

Certified Irrigation Contractor [CIC]{} The Certified Irrigation Contractor is an irrigation professional, who has met a set of minimum standards specified by The Irrigation Association, whose principle business is the execution of contracts and subcontracts to install, repair and maintain irrigation systems. The CIC must conduct business in such a manner that projects meet the specifications and requirements of the contract.

Certified Irrigation Designer [CID]{} The IA Certified Irrigation Designer is an irrigation professional, who has met a set of minimum standards specified by The Irrigation Association, and who engages in the preparation of professional irrigation designs. The CID evaluates site conditions and determines net irrigation requirements based on the needs of the project. The designer is then responsible for the selection of the most effective irrigation equipment and design methods. The objective of a CID is to establish specifications and design drawings for the construction of an irrigation project.

Certified Landscape Irrigation Auditor [CLIA]{} The Certified Landscape Irrigation Auditor is an irrigation professional, who has met a set of minimum standards specified by The Irrigation Association, and is involved in the analysis of landscape irrigation water use. Auditors collect site data, make maintenance recommendations and perform water audits. Through their analytical work at the site, these irrigation professionals develop monthly irrigation base schedules. Prior to certification examination, auditors are required to take an Irrigation Association approved preparatory course.

Certified Landscape Water Manager [CLWM]{} The Certified Landscape Water Manager is an irrigation professional familiar with all areas of turf irrigation design and construction management. CLWMs must be certified as either as a CLIA or CGIA. Certified Landscape Water Managers have extensive understanding of design, installation and irrigation management as well as auditing of turf irrigation systems.

check valve, spring[]{} A spring loaded valve located in a lateral or at the base of a sprinkler and that prevents water from draining through the sprinkler lowest in elevation after the irrigation cycle is completed. Sometimes called an "anti-drain valve". (Water Mgt Committee 2001)

coefficients:

- **allowable stress factor** [K_{as}]{dimensionless} Coefficient used to modify the irrigation interval under deficit irrigation practices. K_{as} = 1.0 for non-stressed vegetation. (Water Mgt Committee 2001)
- **crop coefficient** [K_c]{dimensionless}A numeric value that relates reference crop ET_o to the actual characteristics of the crop being grown. The crop coefficient

value assumes a healthy crop, actively growing, without stress, and with optimum soil moisture.

- **density factor** [K_d]{dimensionless} Coefficient used to modify K_s to reflect the water use of a particular plant or group of plants with reference to the density of the plant material. K_d ranges from 0.5 for a sparse planting to 1.3 for very dense plantings and averages 1.0. K_d for turf is typically 1.0. (Landscape, 2000)
- **landscape coefficient** [K_L]{dimensionless} Coefficient used to modify reference ET which includes species factor, density factor and microclimate factor. $K_L = K_{Tor\ P} \times K_d \times K_{mc}$ (Landscape Irrigation Auditor, 2010)
- **microclimate factor** [K_{mc}]{dimensionless} Factor or coefficient used to modify K_s to reflect the microclimate of an area. K_{mc} ranges from 0.5 to 1.4 and averages 1.0. For typical lawn conditions, K_{mc} = 1.0 and for plantings in medium strips within a large parking lot or in an environment having nearby reflective glass, K_{mc} = 1.2 to 1.4. (Landscape, 2000)
- **turf** or **plant factor,** [$K_{T\ or\ P}$]{dimensionless} Factor or coefficient used to adjust reference evapotranspiration to reflect plant needs.

coefficient of uniformity [CU] {%} Christianson's coefficient of uniformity.

coefficient of variation, manufacturer's [C_v]{dimensionless} A measure of the variability of discharge of a random sample of a given make, model and size of micro-irrigation emitter, as produced by the manufacturer and before any field operation or aging has taken place; equal to the ratio of the standard deviation of the discharge of the emitters to the mean discharge of the emitters. (ASAE, 2002)

controller []{} An automatic timing device used to remotely control valves or heads (valve in head) according to a set irrigation schedule. (Water Mgt Committee 2001)

crop coefficient. See **coefficients**.

cycle []{minutes or hours} The operating duration of one or more valves for one irrigation start time. (Water Mgt Committee 2001)

cycle [C_s]{dimensionless} Number of cycles to be applied to the station/zone per irrigation. (Water Mgt Committee 2001)

deficit irrigation practice [DIP]{} Irrigation water management strategy where the plant root zone is not filled to field capacity or the plant water requirement is not fully met. (Water Mgt Committee 2001)

deficit irrigation water budget [V_{DIWR}]{ccf, gallon} Reduced volume of irrigation water that results in allowable stress to the plants during periods of drought or reduced water availability. This volume of irrigation water is equivalent to the base deficit irrigation water requirement. (Water Mgt Committee 2003)

deficit irrigation water requirement, base [$DIWR_{base}$]{in./period} The irrigation water requirement (in inches) that provides a reduced amount of irrigation water to the landscape during periods of drought or reduced water availability. The irrigation water requirement includes the plant water requirement with allowable stress plus an additional amount to compensate for distribution non-uniformity. (Water Mgt Committee 2003)

density factor. See **coefficients**.

distribution uniformity[DU]{decimal} The measure of the uniformity of applied irrigation water over an area. (ASAE, 1998). (Water Mgt Committee 2001)

distribution uniformity, lower-half [DU_{LH}]{decimal} A measure of the uniformity of applied irrigation water over an area. The average of the lowest fifty percent of measurements to the overall average measurement, gathered through the use of catch cans, commonly used to evaluate the coverage of one or more sprinklers. It is recommended that this value be calculated from DU_{LQ} values. (Water Mgt Committee 2001)

distribution uniformity, lower-quarter [DU_{LQ}]{decimal} The average of the lowest twenty- five percent of measurements to the overall average measurement, gathered through the use of catch cans, commonly used to evaluate the coverage of one or more sprinklers or drip systems. (Water Mgt Committee 2001)

drought []{}A period of dryness, especially when prolonged, that causes extensive damage to crops or prevents their successful growth. (Webster, 1981)

drought response plan []{} A pre-determined strategy to allow landscape plantings to survive periods of water shortage through a combination of steps that may include deficit irrigation, dormancy, modification of irrigation systems and changes in non-irrigation cultural practices. (Water Mgt Committee 2001)

dynamic pressure []{psi} See pressure, dynamic

effective rainfall [R_e]{in.} The amount of total rain that is actually stored in the root zone. Some rainwater does not reach the soil profile because it is held in mulch or turf thatch or because it runs off. Some water may percolate below the root zone and be lost, depending upon the intensity and duration of the rain event and the water content of the soil prior to the rain event.

efficiency, irrigation system [E_s]{%} The percent of irrigation water that is beneficially used for plant growth.

efficiency, water management [E_{wm}]{%} quantifies how well the irrigation water is being managed; that is, how well the manager *minimizes* the additional amount of water needed by the landscape after accounting for non-uniformity and weather.

emission uniformity [EU]{%} An index of the uniformity of emitter discharge rates throughout a micro-irrigation system. EU takes into account of variations in a group of like emitters and variations in the pressure under which they operate. (Soil and Water Terminology, ASAE 2000; Water Mgt Committee 2003)

evapotranspiration [ET] {in./ time period} Combination of water transpired from vegetation and evaporated from the soil and plant surfaces. (ASAE, 1998)

current evapotranspiration []{in. for the time period} Actual measured or calculated reference evapotranspiration for a period of time.

historical evapotranspiration [Historical ET_o]
A multiple-year average of recorded historical reference ET_o data from a weather station or evaporative pan in a given geographic location. This value is typically a monthly average of the specific month in a given multi-year time frame. This value, when corrected for plant species characteristics, can be used as a baseline to evaluate the expected water needs of a landscape planting in that geographic area.

reference evapotranspiration

- Reference ET is expressed using one of two reference types: ET_o representing grass or ET_r representing tall vegetation similar to alfalfa.
- [ET_o] Rate of evapotranspiration from an extensive surface of cool-season grass cover of uniform height of 12 cm, actively growing, completely shading the ground, and not short of water. (FAO 1998; .ASCE, 1990)
- [ET_r] Rate of evapotranspiration from an extensive surface of alfalfa or very similar agricultural crop of uniform height of approximately 50 cm, actively growing, completely shading the ground, and not short of water. (Wright, 1982; Allen et al., 1989; Walter et al., 2000; ASCE, 1990). Typically ET_r is 10 to 30% greater than ET_o.

field capacity [FC]{in./in.}Depth of water retained in the soil after ample irrigation or heavy rain when the rate of downward movement due to gravity has substantially decreased (usually one to three days after irrigation or rain). (Doorenbos & Pruitt, 1977) Also see **permanent wilting point** and **plant available water**.

flow rate [Q]{gal/min, gpm, gph} Volume of flow per unit time, such as discharge from an irrigation sprinkler or emitter; or flow into a zone.

flow sensor []{} A device that measures the rate of liquid flow or the total accumulated flow. (Water Mgt Committee 2001)

hardscape []{}Impervious surfaces within the landscape, such as concrete walkways or brick paving. (Water Mgt Committee 2001)

historical ET. See **evapotranspiration.**

historical rainfall [R_h]{in.} See rainfall, historical

hydrozone []{}Grouping of plants with similar water (and environmental) requirements for irrigating with one or more common station/zone valves (Weinberg and Roberts, 1988; Water Mgt Committee 2001). Also see **microclimate**.

infiltration rate (intake rate) []{in./h} The dynamic rate at which irrigation water applied to the surface can move into the soil profile. The rate typically declines rapidly after an initial period of surface hydration. This value depends to a great extent on the texture of the soil and whether the soil is overly compacted. (Water Mgt Committee 2001)

intake rate. See **infiltration rate**.

irrigation []{}The intentional application of water for purposes of sustained plant growth. (Water Mgt Committee 2001)

Irrigation Association® [IA]{}A non-profit organization formed to improve the products and practices used to manage water resources and to help shape the worldwide business environment of the irrigation industry. The association's interest in water resources encompasses the application, conservation, drainage, improvement and recovery of water for economic and environmental enhancement in agriculture, turfgrass, landscape and forestry. The IA interacts with private and governmental organizations and other associations in the development of legislation and regulations to properly and appropriately ensure the availability, quality and accessibility of water supplies for, or affected by, irrigation and the efficacy of trade policies. The IA establishes and conducts authoritative educational programs to broaden and focus public awareness of issues related to water management, to provide professional certification of practitioners of irrigation-related disciplines and to ensure the accessibility of research information pertinent to industry practices and products. The IA positions itself as an effective catalyst and umbrella organization for outreach, communication and coordination among the diverse parties and interests involved in irrigation. The IA contributes to the establishment of recognized standards and guidelines dealing with irrigation-related products, engineering applications and practices worldwide.

irrigation audit []{} Procedure to collect and present information concerning the uniformity of application, precipitation rate, and general condition of an irrigation system and its components. (Water Mgt Committee 2001)

irrigation contractor []{}Any person who is in the business of installing, repairing, or maintaining landscape irrigation systems. See also **Certified Irrigation Contractor** (Water Mgt Committee 2001)

irrigation design []{}Drawings and associated documents detailing irrigation system layout, and component installation and maintenance requirements. (Water Mgt Committee 2001)

irrigation designer []{}Any person who is in the business of designing irrigation systems. See **Certified Irrigation Designer**.

irrigation efficiency. See **irrigation system efficiency**.

irrigation interval [IN]{days}The number of full days between irrigation applications. (Water Mgt Committee 2001)

irrigation run time. See **run time**.

irrigation schedule []{}Set of data describing when and the amount of irrigation water to be applied to each station/zone. (Water Mgt Committee 2001)

irrigation system []{}Set of components which may include the water source, water distribution network, control components and other general irrigation equipment. (Rain Bird, 1997)

- **drip/trickle/micro irrigation** Method where water is applied at, or below, the soil surface and at low pressure and low volume.
- **sprinkler irrigation** Type of irrigation using mechanical devices with nozzles (sprinklers) to distribute the water by converting water pressure to a high velocity discharge stream or streams.

irrigation system efficiency, overall irrigation system efficiency, irrigation efficiency [E_s]{%} Percent of irrigation water supplied to the landscape that is beneficially used for plant growth; that is, that contributes directly to the plant water requirement. (Water Mgt Committee 2001)

Irrigation System Rating [ISR]{dimensionless; scale of 1 to 10 with 10 as the best rating} Quality rating term for an irrigation system based on operational distribution uniformity. (Water Mgt Committee 2001)

irrigation water budget [V_{IWR}]{ccf, gallon}Volume of irrigation water required to maintain a functional, healthy landscape with the minimum amount of water. This volume of irrigation water is equivalent to the base irrigation water requirement. (Water Mgt Committee 2001)

irrigation water management, landscape []{} Process of comparing landscape irrigation water usage to an expected amount, and then making improvements to the landscape, irrigation system or schedule to achieve irrigation objectives. (Water Mgt Committee 2003)

irrigation water requirement, base [IWR_{base}]{in./period} The amount of irrigation water (in inches) required to meet the supplemental needs of the landscape. The irrigation water requirement includes the plant water requirement plus an extra amount to account for non-uniformity and other irrigation losses. (Water Mgt Committee 2003)

landscape coefficient. See **coefficients**.

landscape contractor []{}Any person who is in the business of constructing, installing, and/or maintaining turf, trees, or ornamental plant material and associated hardscaping in an urban environment. (Water Mgt Committee 2001)

landscape irrigation water management. See **irrigation water management**.

landscape water allowance, landscape water allotment, landscape water allocation [LWA]{ccf, gallons} A volume of water allocated to the entire landscape area for some period of time. This allowance is established by the water purveyor for the purpose of ensuring adequate supply of water resources. (Water Mgt Committee 2003)

landscape water requirement [LWR]{ccf, gallons} A volume of water that is necessary for the landscape to be healthy and functional. (Water Mgt Committee 2003)

low-volume irrigation. See **irrigation drip/trickle/micro irrigation.**

management allowable depletion [MAD] {%} The percent of total plant available water (PAW) that can be depleted from the active plant root zone before irrigation is applied. (Water Mgt Committee 2001)

matched precipitation rate []{}System or zone in which all the heads have similar precipitation rates is said to have matched precipitation rates. (Monroe, 1993)

microclimate []{}A subdivision of a landscape characterized by environmental conditions that may differ from the typical site condition to a degree that ET_o will be affected, either higher or lower than the expected ET_o for the site. Examples of conditions that might create a separate microclimate include reflected heat, breezeways, wind exposure, topography (slope) and shading. Also see **site conditions**. (Water Mgt Committee 2001)

microclimate factor. See **coefficients**.

moisture sensor []{} Device that monitors or measures soil water content or tension. (Water Mgt Committee 2001)

net plant water requirement. See **plant water requirement, net.**

overall irrigation system efficiency. See **efficiency**.

permanent wilting point [PWP] {in./in.}The amount of water in the soil, at or below which the plant may permanently wilt and not recover. Also see **field capacity** and **plant available water**. (Water Mgt Committee 2001).

permeability [] {in./h} Rate at which water moves downward through the saturated soil.

plant available water [PAW] {in.} The amount of water held within the root zone after gravitational drainage has ceased, less the amount of water that adheres tightly to soil particles. Commonly expressed as PAW = (FC - PWP) x RZ where FC = amount of water (in. of water per in. of soil) held in the root zone at field capacity, PWP = amount of water (in. of water per in. of soil) held in the root zone at the permanent wilting point, and RZ = root zone depth (in.). Also see **field capacity** and **permanent wilting point**. (Water Mgt Committee 2001).

potable water []{} Water from any source which has been investigated by the health agency having jurisdiction, and which has been approved for human consumption. It can be used as a source of irrigation water, but once water enters an irrigation system (and passes through the backflow device) it is no longer considered potable. (Cross Connection, 1988).

Practice Guideline [PG]{} A recommended practice that fulfills the requirements of the related Turf and Landscape Irrigation Best Management Practice. The PG is meant to guide and facilitate the development of local specifications. (Water Mgt Committee 2001)

precipitation rate [PR] {in./h} Rate at which a sprinkler system applies irrigation water. Also known as the **application rate.** (Water Mgt Committee 2003)

pressure, dynamic []{psi} Working or operating pressure at a point within the irrigation system.

pressure regulator []{}Device which maintains constant downstream operating pressure (immediately downstream of the device) that is lower than the upstream pressure. (Rain Bird, 1997)

pressure, static []{psi} Pressure in a closed system, without any water movement. (Rain Bird, 1997)

water rate [C_R]{$/ccf or $/1000 gallons} Unit water rate.

rain amount [R]{in./period} Actual amount of rainfall during a period of time. (Water Mgt Committee 2001) See also **historical and effective rainfall**.

rainfall factor [RF]{%} Factor used to convert historical rainfall to effective rainfall.

rainfall, historical [R_h]{in.} A multiple year average of recorded rain from a weather station in a given geographic location. This value is typically a monthly average of the specific month in a given multi-year time frame. (Water Mgt Committee 2001)

rain shut-off device, rain sensor, rain switch []{}A device that causes the controller to suspend or override an irrigation cycle or that opens the circuit to a valve or set of valves when a preset amount of rain occurs. Ideally, the device will also override the irrigation cycle as long as rain is withheld in the root zone and is available to the plants. A soil moisture sensor may be considered a rain shut-off device if the sensor overrides or suspends an irrigation cycle based on the conditions above. (Water Mgt Committee 2001)

reclaimed water []{}Partially treated municipal waste water, comes in varied levels of treatment. (Water Mgt Committee 2001)

record drawing []{} Set of construction plans, mylar film, or computer file, including the original design and noting all design deviations. These drawings should also show the location of all major underground components, dimensioned from permanent features. (Water Mgt Committee 2001)

reference evapotranspiration [ET_o]{in./period} See **evapotranspiration**.

root zone [RZ]{in.,ft} The depth of the soil from which the crop roots extract water and nutrients. (USDA, 1993)

runoff [RO]{in.}Portion of irrigation or rainwater that leaves the target area, primarily due to slope or the precipitation rate exceeding the soil infiltration (intake) rate. (Water Mgt Committee 2001)

run time [RT]{minutes, hours} Length of time to operate an individual station/zone for a single cycle or single irrigation event. Can also be the run time of the station/zone for the entire month or other time period. (Water Mgt Committee 2001)

run time, base [RT_{base}]{minutes} See **run time, event**.

run time, cycle [RT_{cycle}]{minutes} Station/zone run time for one cycle start.

run time, event [RT_{event}]{minutes} Station/zone run time for one irrigation event based on whole day intervals between irrigations. (An event is all cycle start times for the irrigation.)

run time multiplier [RTM]{dimensionless} Factor used to increase zone run time to account for lack of distribution uniformity within the root zone. Roughly it is $1/DU_{LH}$ (Water Mgt Committee 2001)

service connection []{} The terminal end of a service connection from the public potable water system, i.e. where the water purveyor may lose jurisdiction and sanitary control over the water at its point of delivery to the consumer's water system. (Cross Connection, 1988)

site conditions []{} Any physical or environmental factor that can affect the evapotranspiration rate of a site, or a microclimate within a site. Conditions can be dynamic (i.e. wind, reflected heat, seasonal shading, etc.) or static (i.e., finished topography, solar exposure and soil types). Also see **microclimate**. (Water Mgt Committee 2001)

slope []{} Ground where grade varies or is not level. (Water Mgt Committee 2001)

soil probe []{}A soil coring tool that allows an intact soil core to be removed from the soil profile for examination. (Water Mgt Committee 2001)

soil texture []{} The size and shape of individual soil particles such as sand, silt, or clay. Soil texture largely determines the amount of water that can be stored in a soil as well as the soil **infiltration rate** and **permeability**.

soil texture class []{} Soil classification defined by the relative amounts of sand, silt or clay in a particular soil.

species factor. See **coefficients**.

static pressure []{psi} See pressure, static

system efficiency. See **irrigation system efficiency**.

velocity, water []{fps} The speed at which water moves through the system (pipe). (Monroe, 1993)

water management factor [WMF]{dimensionless} Describes how much of the total run time of the controller is attributable to the performance of the water manager. (Water Mgt Committee 2001)

water purveyor []{}The public or private owner or operator of the water supplying an approved water supply to the public. (Cross Connection, 1988)

water rate [C_R]{$/ccf or $/1000 gallons} Unit water rate.

watering window []{h} The hours and days of the week available for irrigation to be completed. Site uses and local statutes may limit the time and days on which irrigation can occur. (Water Mgt Committee 2001)

watershed []{} A region or area bounded peripherally by a divide and draining ultimately to a particular watercourse or body of water. (Webster, 1981)

xeric landscape []{} Alternate term is Drought Tolerant Landscape. An approach to landscape design that focuses on utilizing a plant palette limited to species that are adapted to local climate conditions. A xeric design stresses arid region adaptation, but does not limit a design to native species. This term is typically associated with arid geographic regions where natural rainfall is limited in quantity and/or to a narrowly defined ‘rainy season’. As such it is generally applied to native plants, although not all native plants are xeric. (Water Mgt Committee 2001)

Xeriscape (see xeric landscape)