IRRIGATION ASSOCIATION & AMERICAN SOCIETY OF IRRIGATION CONSULTANTS

Landscape Irrigation Best Management Practices

May 2014

Prepared by the Irrigation Association and American Society of Irrigation Consultants

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The Irrigation Association and the American Society of Irrigation Consultants have developed the *Landscape Irrigation Best Management Practices* for landscape and irrigation professionals and policy makers who must preserve and extend the water supply while protecting water quality. The BMPs will aid key stakeholders (policy makers, water purveyors, designers, installation and maintenance contractors, and consumers) to develop and implement appropriate codes and standards for effective water stewardship in the landscape.

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Foreword

The Irrigation Association [IA] and American Society of Irrigation Consultants [ASIC] have developed these landscape irrigation best management practices [BMPs] to promote efficient use of water in the managed landscape. There are a number of stakeholders including: water purveyors, system owners, irrigation consultants/designers, contractors, irrigation managers and landscape professionals as well as state, federal and public agencies, code developers, and building officials.

Managed landscapes, while highly visible users of water, provide ecological, economical and recreational benefits. It is the stakeholders' responsibility to advocate for efficient irrigation and to incorporate and promote all reasonable practices that minimize water consumption and waste. The broad and comprehensive nature of the best management practices and related practice guidelines define the elements of an efficient irrigation system and responsible water management. Specific benefits include:

- Enjoining the water purveyor and the landscape and irrigation industries in water planning and development of local strategies to manage irrigation water use.
- Improving irrigation efficiency to optimize water use in both existing and new landscapes.
- Reducing energy costs of treating and pumping water.
- Providing criteria to achieve the desired results of water use efficiency that fit the purpose and function of the managed landscape.

Landscape Irrigation Best Management Practices includes:

- Three BMPs that address the design, installation and management of irrigation systems.
- Practice guidelines that address ways to effectively implement the respective BMPs and can be adapted locally.
- Appendices that provide related information for the implementation or understanding of the BMPs.

The BMPs and related practice guidelines provide the basis for sensible, informed decision making regarding regional water use and potential response to drought.

As professionals engaged in making decisions about how water is used, it is important to consciously seek to evolve fundamental attitudes and values to better serve the community.

John W. Ossa, CID, CLIA
Chairman, Landscape Irrigation BMP Task Group

Section 1: Introduction

1.1 Purpose

The primary purpose of a landscape irrigation system is to deliver supplemental water when rainfall is not sufficient to maintain the turfgrass and plant materials to meet their intended purpose. A quality irrigation system and its proper management are required to efficiently distribute 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, and management. In particular, this includes the following:

- The irrigation system shall be designed to efficiently deliver water to the landscape.
- The irrigation system shall be installed according to the irrigation design specifications.
- The irrigation system shall be managed to maintain a healthy and functional landscape while conserving and protecting water resources.

1.2 Definitions

1.2.1 Landscape Irrigation Best Management Practice

Landscape irrigation BMPs improve water use efficiency, protect water quality and are sensitive to the watershed and environment. Landscape irrigation BMPs are economical, practical and sustainable, and they will maintain a healthy, functional landscape without exceeding the minimum water requirements of the plants or the maximum water allowance where applicable.

1.2.2 Practice Guidelines

Practice guidelines are recommended practices or principles that aid in successfully accomplishing the related BMP. The practice guidelines are meant to be a guide to develop criteria that address site-specific landscape irrigation needs. It is the responsibility of the framers of such specifications to adapt the guidelines to meet their local needs.

1.3 Qualified Irrigation Professionals

The implementation of these irrigation BMPs and practice guidelines requires a commitment from qualified irrigation professionals. "Qualified" includes being formally trained, certified, licensed where required, having successful experience completing projects of similar scope, or other similar qualifications that meet state and local requirements.

IA certifies individuals in design, contracting, and management of irrigation systems. The ASIC recognizes professional irrigation consultants [PIC] as irrigation professionals who have been peer reviewed and board approved for the design and management of irrigation systems. The best results come when there is collaboration between landscape and irrigation disciplines.

A listing of certified individuals can be found on IA's website at *http://www.irrigation.org*.

A listing of professional irrigation consultants can be found on the ASIC website at *http://www.asic.org*.

There may also be regionally appropriate certifications.

The BMPs as described in this document recognize there are other licensing and certifying organizations in the irrigation industry but these programs stand on their own merit and were not evaluated for this document.

Section 2: Landscape Irrigation Best Management Practices

To assure the overall quality of the irrigation system and to promote irrigation efficiency; the following best management practices need to be implemented.

BMP 1: Design the Irrigation System for Water Use Efficiency

The irrigation system shall be designed to deliver water precisely and efficiently to maintain the function and purpose of the managed landscape while complying with any local limitations and requirements.

BMP 2: Install the Irrigation System to Meet the Design Criteria

The irrigation system shall be assembled and installed according to the irrigation design specifications, locally applied codes and standards, and manufacturers' product requirements. The qualified irrigation contractor or installer shall execute the installation per the plans and specifications and be capable of quality workmanship and the safe use of proper equipment.

Each BMP 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 BMP must

1. *Be applicable to any location, while allowing for site-specific conditions.*
2. *Protect the watershed and water quality and conserve water resources.*
3. *Be sustainable by allowing for improvement through adoption of new technology, knowledge, and innovative solutions.*

BMP 3: Manage Landscape Water Resources

To conserve and protect available water resources, the management of the irrigation system will optimize the efficient use of water to maintain a healthy and functional landscape with optimal irrigation system performance. This entails careful and active management of the system and adherence to all applicable watering limitations within the jurisdictional area. Management includes active irrigation system maintenance, scheduling, monitoring, and evaluation of water use, landscape health, and appearance.

> "A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise."
>
> Aldo Leopold
> *A Sand County Almanac*, 1949

Section 3: Practice Guidelines

All water resources are important and these practice guidelines will hold true for projects that use water supplied by a purveyor as well as on-site developed water resources. Vital to water efficient design and management is a plant palette that is appropriate to the region and soils that have been properly prepared. Knowledgeable landscape water management must focus on how the soil and irrigation work together creating the foundation for a healthy landscape. Not all of the listed guidelines will be implemented on each site, but the landscape water manager needs to be aware of the ones that have specific application.

PG 1: Practice Guidelines for Designing an Irrigation System

Practice guidelines can be used to develop site-specific irrigation plans, details and specifications while optimizing system efficiency. Implementation of these guidelines is best done as a collaborative effort between landscape and irrigation practitioners and the authority holding jurisdiction. The practice guidelines shall be compatible with state and local laws, rules, regulations, codes, or ordinances.

The irrigation designer shall perform a project analysis and a comprehensive site inventory as part of the design process to ensure that the irrigation system is designed to efficiently apply water, which enables the effective management and protection of water resources.

The landscape irrigation BMPs are principles that work interdependently with each other to efficiently use water. The Practice Guidelines may be adapted in principle to suit the constraints and opportunities inherent in water issues that are best solved on a local basis.

The landscape irrigation best management practices and practice guidelines should work in harmony with local or state initiatives such as California's Model Water Efficient Landscape Ordinance or state licensing

1. Irrigation Design Package

1.1 Project Analysis and Basis of Design

a. Include statement or narrative that identifies the assumptions used for design purposes such as: water sources to be used, need for a temporary system, total landscape water demand based on area, effective rainfall, water window, assumed irrigation efficiency and energy constraints for system operation.
b. Confirm the irrigation design plan accounts for local water laws or regulations, permitting requirements and applicable codes.
c. Convey how the system should be operated to use water resources efficiently to achieve the desired function of the landscape.
d. Select product preferences.
e. Identify a project budget and phasing.

1.2 Plan Submittal

a. When required, a complete plan package including the design, details and specifications shall be submitted to the appropriate governing agency for approval prior to installation of the system.
b. Typically, the irrigation designer submits plans to the client for package submittal with a landscape design.

1.3 Other

a. Consider future needs such as expansion of the system to accommodate further development.
b. The irrigation designer shall verify that a detailed controller map showing the location of sprinklers, valves and valve zones, etc., for the irrigation system is provided to facilitate water management and maintenance.
c. When the irrigation system needs to be inspected after installation or commissioned to verify proper performance, the irrigation designer should be involved in that process. See appendix A for additional information.

Minimum Plan Requirements

- The graphic presentation of the diagrammatic design shall include clear and concise reproducible drawings with all components sized, symbolized and keyed in a distinctive manner.
- Drawings are to be at a suitable scale to be clearly legible and have a north arrow.
- Sheet sizes are to match whole package documentation.
- Complete installation details shall accompany the drawings. Details to be project specific.
- Written specifications unique to the project shall supplement the drawings detailing materials and workmanship to be used in the installation.

2. Site Inventory

2.1 Identification

a. Weather considerations
   1) Historical temperature and rainfall data
   2) Prevailing wind direction and speed
b. Physical features
   1) Base area measurements (square footage)
   2) Site grading and drainage plans
   3) On-site water bodies/water features
   4) Conservation, utility or right-of-way easements, etc.
   5) Buildings, decks, parking lots, roadways and other structures
   6) Roof-top gardens, living walls, etc.
   7) Walkways, patios and other secondary hardscape features
   8) Exterior lighting plan when available
   9) Location of site utilities when available
c. Hydrozone areas
   1) Soil type (e.g., clay, loam, sand, etc.) and soil profile if applicable
   2) Exposure: sun/part shade/full shade — consider seasonal variation
   3) Reflected light and/or heat from adjacent building or hardscape
   4) Plant materials
      - Type of turfgrass
      - Annual color/bedding plants
      - Herbaceous perennials
      - Ground cover
      - Trees, shrubs/woody plants
      - Desert or drought tolerant plants
   5) Sloped areas/topography
   6) Special situations, such as building overhangs, on-structure planting such as green roofs or living walls, container planters, shallow planting areas, etc.

2.2 Calculations

a. Estimate water requirement.
   1) Identify the peak water demand month during the growing season (greatest reference ET and least rainfall).
   2) Estimate plant-water requirement for each hydrozone and/or irrigation zone by modifying the reference ET with appropriate plant factors that consider the functional purpose and aesthetic quality intended. Sum the total water need for each hydrozone and/or irrigation zone to calculate the landscape water requirement.
   3) Where water budgets are used to influence the landscape design, verify that the landscape water requirement is less than the landscape water allowance or allotment including expected irrigation efficiency. See appendix B for more information.

There are regional variations in key terminology and methodology; for example:

California's Model Water Efficient Landscape Ordinance uses "maximum applied water allowance," or MAWA.

Sustainable Sites Initiative uses "baseline water requirement," or BLWR.

4) If the water requirement is greater than the allowance, consult with the landscape architect or designer to make landscape modifications or adjust plant performance expectations within specific hydrozones.
5) Estimate any leaching fraction needed when a lower quality water source is used.

b. Establish water window and frequency.
1) Reasonable water windows should be less than 10 hours during normal conditions.
2) Irrigation frequency should be appropriate for the climate, soil type and plants used in the landscape including the establishment period.
3) Comply with local watering restrictions.
4) Water source, size and pressure and/or pump sizing must be considered.
   - If the water source and point of connection [POC] already exist, determine the water window that will be needed to meet peak demand.
   - For new water connections, the water window is used to determine the required capacity of the water tap or POC.

c. Calculate base irrigation schedule.
1) Determine minutes of run time for each irrigation zone to meet peak demand.
2) Compare total minutes of run time to water window.

2.3 Minimum Design Requirements

a. Provide separate irrigation zones to meet unique water requirements for each identified hydrozone.

b. Follow manufacturers recommendations for equipment performance.

2.4 Additional Considerations

a. Note if special trenching or installation techniques are required.

b. Identify existing specimen or heritage trees or other special features.

c. Consult with landscape designer to identify additional efficient water-use strategies in the landscape.

Intent: *The irrigation system shall be designed to facilitate installation and the long-term maintenance of the system as the landscape matures. Where systems are to provide a temporary plant establishment service or are for a specific function such as leaching, hardware appropriate to that function and longevity requirement shall be selected.*

3. Select Water Sources for the Irrigation System

3.1 Identification

a. Consider all sources of legally available water on-site that can be used for irrigation and will help minimize the amount of potable water to be used for irrigation.
1) On-site developed water
   - Rainwater harvesting
   - Storm water capture
   - Graywater
   - Process water
   - Foundation water
   - Air-conditioning condensate

2) Municipally reclaimed water (abide by local codes and constraints)
3) Groundwater
4) Surface water such as lakes, streams, rivers or canals
5) Potable water supply
6) Identify class of contaminant in water supply (e.g., particulate, biological, chemical)
7) Other

b. Show source of water and POC for irrigation system.
   1) Exact location/address of each POC specifying water source/type
   2) Type, size and length of meter service piping
   3) Meter type and size
   4) Static pressure and available flow
   5) Pump station or booster pump location and performance requirements (flow and pressure) when required
   6) In freezing climates, provide a method to winterize the system.

c. Dedicated irrigation-only meters and flow sensors (sizes and locations).

d. Backflow prevention assemblies (type, size, and location).
   1) Locate downstream of POC on potable water service.
   2) Place in non turfgrass areas where possible and accessible for servicing.
   3) Protect the backflow assembly from vandalism or theft.
   4) Protect the backflow assembly from freezing where necessary.

3.2 Calculations

a. For municipal water supplies, calculate maximum safe flow rate.
   1) The maximum allowable pressure loss through the meter should be less than 10 percent of the static pressure at the meter.
   2) The maximum flow rate through the meter should not exceed 75 percent of the maximum safe flow through the meter (refer to charts for the specific type of meter).
   3) The velocity of the water through the service line supplying the meter should not exceed 7.0 feet per second.

b. For on-site developed water sources.
   1) Calculate reliable yield for all available water sources.
   2) Determine practical storage capacity for the water sources to match climatic conditions.
   3) Match available water and storage with water requirements.

Local plumbing codes and water purveyor service rules shall determine appropriate backflow type. Designer shall specify enclosure if required.

3.3 Additional Considerations

a. Comply with all state and local laws regarding alternate water sources.
b. Comply with all state and local laws regarding storage tanks and/or reservoirs.
c. Use lowest acceptable quality of water and supplement with higher quality of water when necessary.
d. Assure water quality will not harm plant growth and development.
e. Provide cost-benefit analysis for using alternate water sources and help the owner make an informed decision.

4. Irrigation Components

4.1 Identification

a. Appropriate emission device for each zone
   1) Sprinkler zones
   2) Drip/microirrigation zones
b. Valves sizes and locations
   1) Remote control zone valves
   2) Manual and specialty valves
c. Pipe layout including sizes, main line and lateral lines
d. Controller(s) and location(s)
e. Sensor types and their locations
   1) Weather sensors such as solar radiation, temperature, rain, and/or freeze sensors
   2) Soil moisture sensors
   3) Flow sensors
f. Drip/microirrigation devices
   1) Drip valve, pressure regulator, filter assembly
   2) Supply/exhaust manifold location
   3) Flush plugs and/or air/vacuum relief valves
   4) Emitter flow rate and spacing if using inline drip tubing
   5) Tubing depth
   6) Lateral row spacing

4.2 Design Requirements

a. Use symbols indicating the location of the various irrigation components.
b. Specify manufacturer, model, type and size of all components.
c. Develop a key of the symbols to facilitate plan reading.
d. Provide specific installation details for all components.
e. Provide written site-specifications for the project including general conditions.

5. Sprinkler Selection and Spacing

5.1 Identification

a. Select specific sprinkler heads and nozzles to apply water uniformly to the target area.
b. Select products suitable to the landscape requirements.
c. Select products to facilitate long-term reliability and serviceability.
d. Select products that are compatible with the quality of the proposed water source.

5.2 Calculations

a. Calculate the precipitation/application rate of the sprinklers for each zone.
b. For turfgrass areas, specify a minimum low quarter distribution uniformity [DU_{lq}] based upon size and geometry of the area.

5.3 Minimum Design Requirements

a. Do not exceed manufacturer's sprinkler spacing recommendations.
b. Design system so sprinklers operate within manufacturer-recommended operating pressure.
c. Use matched precipitation rate sprinklers (+/– 5 percent) within a zone.
d. Design system to target each planting area with no overspray of impervious surfaces or adjacent planting areas. Prevent runoff of water from the site.

e. Space sprinklers a minimum of 2 inches from hard surface edges but farther than 2 inches where possible to minimize overspray, back-splash or wind drift.
f. Specify a pop-up height of the sprinkler to clear interference from vegetation.
g. Include protective covers/lids specifically designed for use on athletic fields for sprinklers in “play” areas such as athletic fields.
h. Include purple markings on sprinklers and valves when using municipally reclaimed water sources.
i. Design the system to avoid or eliminate low-head drainage.
j. Avoid above ground fixed risers near pedestrian walkways, bicycle paths, etc.

5.4 Additional Considerations

a. If pressure exceeds equipment recommended operating range, use pressure regulating equipment to optimize performance.
b. Use lower precipitation rate sprinklers on slopes or heavy soils to reduce runoff potential.
c. Use check valves to control low-head drainage.
d. In areas of high vandalism use vandal-resistant products and parts to minimize potential damage or theft of the sprinklers.
e. Use drip irrigation instead of spray sprinklers in narrow or complex shaped areas.

6. Valves and Valve Boxes

6.1 Identification

a. Remote control zone/station valves
b. Manual isolation valves
c. Pressure-regulating valves appropriate for the water source
d. Specialty valves
   1) Pressure relief valves
   2) Air release valves
   3) Quick coupling valves
   4) Drain/flush valves
   5) Strainers and filters

6.2 Calculations

a. Designate an acceptable operating pressure range (minimum to maximum).
b. Calculate the flow rate for each zone control valve.

6.3 Minimum Design Requirements

a. Install valves to accommodate identified hydrozones.
b. Size the zone control valve so that flow through the valve is within the manufacturer’s stated flow range and so that pressure loss does not exceed 10 percent of static pressure.
c. Install valves either above grade or below grade in a valve box large enough to service or access.
d. Valve box location should consider safety and aesthetics of the site, along with long-term durability of the valve box.
   1) Keep valve boxes out of athletic fields or recreation areas where they may interfere with use or aesthetics of the area.
   2) Keep valve boxes out of pedestrian or equipment pathways.
e. Use valve boxes colored purple when using municipally reclaimed water or as applicable by code.

f. Install the valve and valve box over a layer of coarse stone or gravel for stability and drainage. Maintain a physical separation (air space) between the layer of stone/gravel and the valve.
g. Valves installed at or below grade shall be enclosed in a valve box with sufficient strength to withstand the loads reasonable to expect in the installation location.

6.4 Additional Considerations

a. Install a master valve on larger systems.
b. When pressure is excessive (greater than 15 percent above recommended operating pressure), the following equipment could be used:
   1) Pressure-reducing valve(s) at point of connection
   2) Pressure-regulating device that can be added to the zone control valve
c. Specify zone control valves with flow control.
d. Specify fittings to allow for the easy removal of the remote control valve for servicing if necessary.
e. Use isolation valves on larger systems to facilitate servicing.
f. Install chemigation or fertigation equipment downstream of an approved backflow prevention assembly.
g. Consider locking lids on all valve boxes.

7. Pipes and Fittings

7.1 Identification

a. Type of pipe to be used for main lines and laterals lines:
   1) Polyvinyl chloride [PVC] polyethylene [PE], high-density polyethylene [HDPE] or other
   2) Pipe classification shall be indicated on plan key and specifications.
   3) The pipe shall be clearly marked with the manufacturer, size, schedule and/or pressure rating.
b. Colored pipe shall be used when required by code:
   1) Purple pipe for reclaimed or alternate water sources
   2) Brown or UV resistant pipe for aboveground installation (usually on steep slopes)
c. Minimum size for each pipe section
e. Type of fittings to be used for main lines and for laterals
f. Type of swing joint to be used with each type of sprinkler head

7.2 Calculations

a. Pressure loss for the "worst-case" zone. This may be the largest zone and/or the farthest zone from the POC and/or the zone with the greatest elevation change.
b. Flow in plastic pipe operating at full system capacity
   1) Velocity shall not exceed 5 feet per second for pipes 3-inch diameter or smaller. For pipes larger than 3-inch diameter the velocity should be lower.
   2) Pressure variation within a zone shall have less than 10 percent variation.
   3) Surge pressures in the main line shall be less than the safety factor of the piping.

7.3 Minimum Design Requirements

a. Piping
   1) The working pressure rating of the mainline pipe should be a minimum of 200 psi or at least twice the anticipated design pressure of the system, whichever is greater.
   2) Mainline piping should be sized to optimize pressure/flow conditions and should have the same pressure rating throughout.

3) Lateral pipes should have a pressure rating at least two times the operating pressure of the sprinklers.
4) Lateral piping should be sized to minimize pressure losses and optimize flow conditions.

b. Depth of pipe bury

1) The minimum depth of soil cover shall conform to local codes and/or as shown or listed in the drawings, details or specifications. When pipe bury is not listed on the plan, the generally accepted practice for pipe bury is the following.

Minimum cover measured from the top of pipe (or as specified)		
	Main line {in.}	Lateral lines {in.}
Residential	12	8
Commercial	18	12
Under vehicular paving	24	24

2) Backfill shall not have rocks or debris greater than ½-inch in size next to the pipe.

c. Fittings

1) Pipe fittings and connections shall be suitable for the type of pipe, exposure, operating pressure and flow applications.
2) Gasketed fittings on piping shall have restraints or thrust blocking.
3) HDPE fittings that are fusion or socket joined shall have the same dimension ratio [DR] as the pipe.
4) Fittings for PE pipe shall be insert-type or compression-type, suitable for the size and pressure rating of the system and using suitable clamps.
5) Threaded PVC pipe for nipples shall be Schedule 80 or better.

7.4 Additional Considerations

a. Sleeving and conduits

1) Under vehicular paving, pipe shall be installed in a sleeve made of a permanent rigid material (e.g., PVC at least Schedule 40 or Class 160, whichever is strongest).
2) Sleeving should be twice the size of the piping or wiring bundle that it will hold (2-inch pipe in a 4-inch sleeve and wires that fit in a 1-inch conduit shall have a 2-inch sleeve).
3) Pipe and wire shall be in separate sleeves.
4) Conduits for wiring should be laid parallel, not stacked, to facilitate future service with horizontal separation between the conduits.
5) Sleeving should extend a minimum of 2 feet beyond the edge of hard surfaces.
6) Subject to local authority holding jurisdiction.
7) Pipe sleeves should be marked for future location.

b. Fittings

1) Fittings for PVC
   - Fittings 4 inches and larger shall be gasketed fittings, preferably ductile iron.
   - Fittings 3 inches and smaller shall be gasketed, solvent welded or push-on style.
2) For PE pipe, worm gear clamps shall be used exclusively in sizes 1½-inch and larger.
3) Connection to sprinklers
   - For sprinklers with a ½-inch inlet, flexible swing pipe assembly or swing joints shall be used.

- For sprinklers with a ¾-inch inlet and larger, use swing joints that are made with rigid piping and multiple elbows to allow for multidirectional adjustment.

8. Drip/Microirrigation

The rate of soil drying and the elements that influence the drying of the landscape edge may be significantly different than the middle areas of an irrigation zone.

8.1 Identification

a. Statement of intent: Identify if system is intended as a permanent system for long-term maintenance or a temporary system for plant establishment, after which it is to be abandoned. State what period of time constitutes "plant establishment."
b. For design purposes, identify the soil type.
c. Identify emitter types for various hydrozones.
   1) Specify pressure-compensated emission devices to improve overall uniformity.
   2) Identify flow rate and operating pressures.
d. Water quality
   1) Identify the proper type of filtration.
   2) Identify the need for chemical additives.
   3) See table 1 for water quality recommendations.

8.2 Calculations

a. The water delivery rate should be proportional to the plant type and size.
   1) Application rate per zone
   2) Management allowed depletion factor
   3) Monthly zone run times based on local historical evapotranspiration [ET]
b. Create a separate schedule for plant establishment.

8.3 Minimum Design Requirements

The emission product and system layout is based on plant density. A grid layout tends to be employed in high density plantings, while point source placement is used in lower density plantings.

a. Create separate drip irrigation zones for each hydrozone type where drip irrigation will be used. Don't mix subsurface drip with other drip areas.
b. Keep drip/microirrigation zones separate from other sprinkler zones.
c. Emitter placement
   1) For line-source drip irrigation, provide emitter and row spacing guidelines based on soil type and site conditions.
   2) For subsurface line-source drip irrigation, provide guidelines for location of subsurface drip irrigation laterals from hardscape edges and uncontained landscape areas.
   3) For point-source emitter systems, emission points to new plants should be located midway between the edge of the root ball and the crown of the plant.
   4) For permanent drip irrigation systems, provide sufficient emitters to wet at least 70 percent of the mature root zone.
   5) Provide isolation valves to separate drip lines used for establishment from those to be used for long-term maintenance.
   6) On slopes, locate the majority of emission points on the upslope side of the plant crown.

7) Where soil texture, tilth, or slope are likely to induce runoff, provide for small basins to mitigate runoff.

d. Piping
   1) Systems shall be looped (where practical) to improve system hydraulics and mitigate possible contamination of tubing if system is damaged. Avoid any dead ends that cannot be flushed.
   2) On slopes, run the tubing on contour to the slope to keep each run of the tubing at approximately the same elevation.
   3) For line-source systems, expand row spacing over approximately the lower third of a slope. Conversely, compress row spacing at the top of the slope.
   4) Ensure main and lateral sizing will allow for proper flushing.
   5) Specify trench filling and compaction method for subsurface drip irrigation installation.

e. Pressure regulation
   1) Pressure shall be regulated to the manufacturer’s recommended range for distribution hardware.
   2) Pressure regulation devices shall be sized for the design flow rate of the irrigated zone and should accommodate flow rates during system flush.

f. Filtration
   1) Identify class of system contaminant: particulate, organic or chemical.
   2) If filtration element is a screen filter, specify mesh size and equivalent micron rating.
   3) If filtration element is a disk filter, specify mesh size and equivalent micron rating.
   4) If filtration is by media filter, identify media sand sizes and their micron equivalent.
   5) Identify acceptable pressure loss through filter and threshold for maintenance event.

g. Flush valves
   1) Install flush valve in a valve box.
   2) Follow the manufacturer’s recommendation for maximum system size per flush valve.
   3) Multiple flush points on a zone may be necessary for large or complex shape areas.
   4) Ensure adequate flow is available to remove contaminant during flush/back flush as appropriate.
      - Suggested flushing velocity for potable water is 1 foot per second.
      - Suggested flushing velocity for nonpotable water is 2 feet per second.

h. Air/vacuum relief and check valves line-source installations
   1) Use air/vacuum relief valves to minimize ingestion of contaminants into distribution piping.
      - All laterals within the elevated area shall be connected with an air relief valve except for emitters that incorporate a check valve and meet manufacturer requirements for proper operation.
   2) Follow manufacturer’s recommendation for maximum system size per air relief valve.
   3) Determine air vent sizing by the operating flow rate for relatively flat sites.
   4) Determine air vent sizing in accordance to the maximum drainage flow rate for sites with slopes and varied topography.
   5) Install check valves in the headers and footers to mitigate lateral drainage to the low point if not included in the emitter device; accompany the check valve with an air relief valve at the highest location within the (sub) section of the zone.

8.4 Additional Considerations

a. Consider differing plant-water requirements, root zone-depths and slope. Use separate drip/microirrigation zones where practical.
b. Recommend the use of the same emitter type and output within a zone.
c. Recommend a fitting at the flush valve to accommodate a pressure gauge.
d. Utilize a visual pop-up indicator to verify the drip/microirrigation zone is pressurized and operating. Locate this system operation indicator within a foot of the flush valve.
e. For trees and shrubs it may be necessary to place tubing (permanently or temporarily) on top of rootballs during establishment to hydrate root ball.
f. Management strategies
    1) Recommend the installation of a water meter or flow sensor, where possible, to capture data for management purposes.
    2) Recommend a controller with capability of multiple start times or cycle/soak feature to deliver pulse irrigation for establishing and sustaining a wetted pattern as well as achieving optimum irrigation efficiency.
    3) Establish system maintenance protocols.
        - Based on water quality, consider installation of chemical-injection system to address tubing /emitter maintenance.
        - Identify vertebrate and insect control strategy.
        - Identify strategy to manage soil salinity, when necessary.
g. Special considerations for subsurface drip irrigation [SDI]
    1) When designing subsurface drip, the primary movement of water through the target root zone will be by capillarity rather than gravitational.
    2) Nutrient management must be considered based on climate conditions.
    3) For seeded areas, provide guidelines for the use of temporary overhead spray to augment seed germination.
    4) For sod, provide guidelines for ensuring adequate soil moisture in advance of sod installation.

Table 1.

Water Quality Assessment

Water Quality – Irrigation water should be assessed to determine its suitability for irrigation. This is done in order to recommend water treatment when required. The assessment should identify the chemical characteristics of the water and address possible problems with soil salinity and plant health caused by the use of the water. The following table includes water quality tests to be completed before designing or installing a system when non-potable water sources are considered for use.

			Level of concern	
	Units	**Low**	**Moderate**	**High**
pH		<7.0	7.0–8.0	>8.0
Electrical conductivity [EC]	dS/m	<0.75	0.75–3.0	>3.0
Total dissolved solids [TDS]	mg/L	< 500	500–2,000	>2,000
Suspended solids	mg/L	<50	50–100	>100
Nitrate nitrogen [NO_3]	mg/L	<5	5.0–30	>30
Iron [Fe]	mg/L	<0.2	0.2–1.5	>1.5
Hydrogen sulfide [H_2S]	mg/L	<0.2	0.2–2.0	>2.0
Manganese [M_n]	mg/L	<.01	0.1–1.5	>1.5
Boron	mg/L	<0.7	0.7–3.0	>3.0
Chloride	mg/L	<142	142–355	>355
Chloride	meq/L	<4.0	4.0–10.0	>10.0
Sodium	Adj SAR	<3.0	3.0–9.0	>9.0
Bacteria count	# / mL	<10,000	10,000–50,000	>50,000
Escherichia coli [E. coli]	CFU			<100 CFU /100 mL

Adapted from Hanson et al., 1994 and Hassan, 1998

9. <u>Controllers and Wiring</u>

9.1 Identification

a. Controllers shall list manufacturer, model number, and station count and how it will be installed in the field.
b. Wiring shall identify the gauge of wire and insulation rating for underground installation.
c. Coverage depth for wires
   1) Wires and cables carrying up to 30 volts shall be installed with a minimum of 12 inches of cover.

2) For irrigation controller output cables carrying more than 30 volts (such as decoder-to-solenoid) and where the controller is UL-listed as a "power limited power source" (Class 2 or Class 3), minimum depth of burial is 12 inches.
3) For wires and cables carrying more than 30 volts, follow local and national codes.

9.2 Minimum Design Requirements

a. Controllers
   1) Specify the location of the controller(s) on the plans.
   2) Specify any required sensors.
   3) Ensure the controller features include multiple programs, multiple start times, sensor inputs, lithium battery to retain programs during power outages, etc.
   4) Controller map to denote the boundaries of each irrigation zone (differentiated by using colors). The controller map should be developed by the designer and handed off to the installer.

Sensors

1) Rain, freeze, and/or wind sensors can suspend irrigation during weather conditions that are unfavorable for irrigation.

2) Soil moisture sensors will monitor soil moisture and can suspend or initiate irrigation depending on the soil moisture conditions.

A separate common wire from the controller to each hydrozone type will provide flexibility in the use of sensors to manage the irrigation system.

b. Wiring
   1) All underground wires shall be insulated copper conductors and UL-listed for direct burial.
      - Low voltage wiring (less than 30 volt) to control valves shall be type PE or type UF.
      - Gauge of wire shall meet manufacturer's recommendations depending on length of run.
      - Wiring for two-wire systems shall be specifically manufactured for the control system being used.
      - Use of decoder-to-solenoid cable (paired multicolored wires in a single cable) may be appropriate on two-wire systems.
   2) Wires must be installed to allow for expansion and contraction, using
      - "Snaking" the wire on straight runs.
      - Wire loops at bends.
      - Expansion coils at connections or at the solenoid valve location.
   3) Electrical connections
      - All electrical connections shall incorporate a solid mechanical connection of the copper conductors using a UL-listed device and a waterproof kit for electrical insulation of the mechanical connection.
      - Connector assemblies shall be listed under UL 486D.
      - Grounding, when required, shall follow the detailed plan, manufacturer's recommendation, and local and national codes.

9.3 Additional Considerations

a. Controllers
   1) Use smart controllers that can incorporate ET information or sensor inputs to initiate or suspend irrigation and that can adjust irrigation schedules to meet plant water needs.
   2) Use controllers that can be monitored remotely or send alarms to notify the water manager of flow problems in the field.
   3) When selecting a controller that has two-way communication such as Internet access, consider units that track and report levels of water usage.

> ***Smart Controllers***
>
> *Smart Water Application Technologies [SWAT] is a collaborative initiative between water providers and the irrigation industry. SWAT identifies irrigation products that can improve irrigation efficiency and writes testing protocols to validate manufacturer claims for product performance.*
>
> *Reports are available for climate-based smart controllers, soil moisture sensors and rain sensors, and testing protocols have been written for irrigation sprinklers and nozzles.*
>
> *Performance reports and summaries are posted at www.irrigation.org/SWAT.*

b. Wiring
   1) Wire splices should be in valve boxes so they can be readily located.
   2) Wire shall be in electrical conduit meeting local codes using sweep ells when installed into the controller location.
   3) For two-wire systems, specify appropriate tools for wire stripping.
   4) If the controller location is at a low point, ensure adequate drainage of the conduit and pull boxes.
   5) Wireless sensors (rain, soil moisture, flow, etc.) shall follow manufacturer's recommendations for proper operation and installation.

10. <u>Controller Maps and Base Schedule</u>

10.1 Controller map

a. The controller map should be developed by the designer as part of the design package and handed off to the installer on new projects.
b. The controller map should be modified in the field after the project has been installed.
c. The controller map should denote the boundaries of each irrigation zone (differentiated by using colors.) See appendix D for an example.
d. The controller map should correlate with the stations on the controller showing
   1) Area of the irrigation zone
      - Station number
      - Square footage
      - Plant type or water use category
   2) Location of point of connection, meters, sensors, etc.
e. The controller map should be laminated and placed adjacent to or within the controller.

10.2 Base Schedule

a. Base schedule should be for a week of peak demand showing:
   1) Amount of water to be applied
   2) Precipitation rate of the zone
   3) Minutes of run time and number of cycle starts
   4) Seasonal adjust settings for other periods of the growing season
   5) Flow rate of the zone
b. Settings to be used if a smart controller is installed
   1) For weather-based controllers
      - Soil type and slope
      - Plant factors
      - Precipitation or application rates
   2) For soil moisture-based controllers
      - Settings for the soil moisture sensor to initiate or suspend irrigation
c. Base schedule information should be posted adjacent to or within the controller.

10.3 Record Keeping

a. Provide copies of the updated record drawings to owner, owner's representative, and landscape and irrigation managers.
b. Irrigation designer shall store electronic copies of the plans for a minimum of three years.

PG 2: Practice Guideline for Installing an Irrigation System

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

The following practice guideline helps meet the requirements of BMP 2. PG 2 intends to facilitate the development of minimum requirements and expectations for the proper installation of an efficient irrigation system. The successful implementation of these guidelines is best done as a collaborative effort between practitioners, property owners and governing agencies to meet local conditions and circumstances that will protect the watershed while maintaining a viable and functioning managed landscape. The means, methods, and outcomes derived from these guidelines should seek to be economical, practical, and sustainable.

The contractor shall adhere to the following:

1. **<u>Prior to Installation</u>**

1.1 Contact all appropriate utility companies prior to beginning installation to locate underground utilities including gas lines, electrical, telephone, cable TV, and so forth. Installation shall not start until all underground utilities are located and marked.
- a. The contractor/installer shall coordinate with the property owner to locate, identify and mark all privately owned underground utilities.
- b. The following free notification services are available: call 811 or www.call811.com.

1.2 Prior to beginning the installation, verify that the water sources, various points of connection (including pump stations), flow rate, and static and dynamic pressures meet design criteria. If there is a discrepancy, notify the irrigation designer to make irrigation design modifications.

1.3 Review irrigation plans and actual site conditions prior to installation. Provide submittals where required by plans and specifications. Substitution of materials must be pre-approved prior to installation. Inform the designer of conflicts and obstacles not shown on design (such as hardscape features, plantings, utility boxes, etc.) and review possible solutions.

1.4 Obtain any required permits prior to beginning the installation.

2. **<u>During Installation</u>**

2.1 Irrigation systems shall be installed in a manner conforming to the irrigation design plans and specifications, the design intent, applicable codes and standards, in conformance to the manufacturers' installation instructions.

2.2 Avoid disturbing and damaging existing trees, shrubs, and other plant material including root systems from construction and installation activities.

2.3 Inform the property owner or his/her representative and irrigation designer of unusual or abnormal soil conditions that may impact the design and management of the irrigation system.

2.4 Ensure sediment and erosion control measures are included in the scope of work and comply with local codes and regulations.

2.5 Ensure all sprinklers and valve boxes are set to proper grade and that valve boxes are properly supported.

2.6 Wire the valves in a logical sequence (for example, walking order clockwise from the controller) for ease of maintenance and management.

2.7 Make all necessary final sprinkler adjustments to avoid unwanted overspray and to ensure sprinklers are precisely set to water only the target areas.

3. Following Installation

3.1 Test the irrigation system to verify the operating pressure and ensure that there are no leaks and components are adjusted correctly to meet the design criteria.

3.2 Program the irrigation controller with the irrigation schedule that will meet the landscape water requirement for the current time of year. The schedule will take into account site conditions and will mitigate runoff. Produce a written copy and post the controller settings so they can be used for review and reference.

3.3 Explain to the end user (owner, owner representative, or landscape maintenance personnel) the location and operation of the controller, valves, sensors, pressure regulators, backflow device, sprinkler heads, and drip/microirrigation devices. Inform the owner of features and capabilities of the system and furnish product literature, warranties, or operating manuals.

3.4 Provide the end user (or owner) with recommendations and schedule for irrigation system maintenance.

a. Maintaining proper operation of system components
b. Winterization procedures (including spring start-up) where applicable
c. Testing of backflow prevention assembly per local code
d. Periodic visual inspection of the system while operating
   1) Leaks
   2) Missing or broken components

Irrigation Association
Consumer Bill of Rights

Preamble: IA reminds you to exercise your rights when making an irrigation purchasing decision.

Hiring a Contractor: The right to hire only licensed irrigation contractors in states that require licenses • The right to hire only those contractors certified by IA's nationally recognized Select Certified Program • The right to examine a contractor's past work and to check references.

Insurance: The right to hire a contractor who is insured for liability, workers compensation, and bonded (if applicable).

Workmanship: The right to quality workmanship, as presented in the *Landscape Irrigation Best Management Practices* and *Irrigation, Sixth Edition* • The right to know that all construction codes are being followed and that the proper backflow prevention device has been installed, as per local code.

Contract and Payment: The right to negotiate a contract that includes specific descriptions of work to be done, materials to be used, a written guarantee, and form of payment including payment schedule prior to the start of the project • The right to insist that all changes, additions and deletions to the contract are in writing • The right to redress in court if the contract is broken.

3) Sprinklers out of adjustment
4) Drip irrigation filter and flush valve
5) Others

3.5 Record Drawings

a. Contractor shall designate and maintain a set of construction plans to become the field record drawings and shall record any deviations on a daily basis.
   1) Convert the schematic layout to portray the precise physical location of all piping, sprinklers, valves and other installed components.
   2) Show measurements from fixed or permanent locations such as building corners, man holes, electrical/utility boxes, street lights, etc., to facilitate locating the irrigation components in the field.

b. Upon completion of installation, deliver the field record drawings to the irrigation designer so that the construction documents can be updated to reflect the "as-constructed" condition of the irrigation system.
   - Sprinkler locations
   - Remote control and other valves
   - Sleeving
   - Sensor locations
   - Main line and lateral line routing
   - Routing of wires
   - Drip irrigation flush plugs
   - Major tree locations

c. Contractor shall keep on file a set of construction documents and field record drawings for a minimum of three years.

PG 3: Practice Guideline for Landscape Water Management

The purpose for having an irrigation system is to support the health and viability of the managed landscape by delivering supplemental water to the plants when natural precipitation is not adequate. The irrigation skills and horticultural knowledge required for implementation of best practices come from proper training, experience, and continuous monitoring of the soil-water-plant relationship. Effective landscape water management is one way landscape and irrigation professionals demonstrate responsible stewardship of water resources.

The following guidelines cover the key elements of landscape water management: communication, system maintenance, water budgeting, irrigation scheduling, monitoring and evaluation of water use, irrigation system performance, and landscape health and function. All of these elements are interdependent. Water efficient landscapes are created by appropriate design and installation, but landscape water management and appropriate horticultural practices are what produce and ensure desired results.

The Art and Science of Water Management

Water management can be as simple as turning the water off, but maximizing the potential of a landscape while reducing its water use can be complex. The correct amount of water can be quantified — it is science-based. Proper management, however, is both a science and an art. A skilled water manager has in-depth knowledge of multiple disciplines and may utilize advanced technology to improve water use efficiency.

The Management-Maintenance Connection

Proactive system maintenance will ensure the integrity of the irrigation system. As the landscape matures, and plants mature, the system may require adjustment and enhancement to meet the design intent for the landscape. System maintenance and repair shall seek to support site management objectives. Depending on company structure, one person, or many individuals, may be qualified to perform multiple management functions.

1. Communication and Accountability

The water manager, property owner, and landscape maintenance personnel need to work together to achieve the desired results.

1.1 Communication Among Key Players

a. Property owner/agent should ensure a loop of communication exists with the industry professionals to implement proper site and water management.
b. Property owner/agent and the landscape water manager should engage the water purveyor as a resource. The water purveyor may provide rebates, system evaluations, and water efficiency and conservation initiatives.
c. Recommendations
    1) Establish a regular interval to review contract performance and resource use.
    2) Authorize an amount of money that can be spent to perform unforeseen repairs.
    3) Provide the landscape water manager access to water bills and records for each project.
    4) Develop a drought/water shortage contingency plan.

> ***Key Players***
>
> *Identify who has the authority to implement change.*
>
> *Identify who shall make changes to the irrigation scheduling.*
>
> *Identify relevant regulatory agencies – such as National Pollutant Discharge Elimination System [NPDES] permits.*

1.2 Landscape Water Manager Responsibilities

a. Communication
    1) Water manager shall advise and educate field personnel on their role in managing resources and meeting the owner's expectations (see "Monitoring" section).
    2) Coordinate maintenance activities that will affect water use efficiency.
    3) Determine who has authorization to make changes to the system, the irrigation schedule and emergency service calls.
b. Documentation
    1) Establish a record keeping system.
        - Track weather conditions.
        - Track water usage.
        - Track system maintenance activities (see "Maintenance" section).
    2) Perform on-site observations/verify existing conditions (see "Evaluation" section).
    3) Identify quantitative and qualitative metrics for the site.
    4) Identify and understand special conditions.
        - Site usage (special events, maintenance activities, etc.)
        - Water source and new water sources
        - Drought/water shortage conditions
c. Calculations
    1) Estimate site water usage (see "Section 3: Water Budgeting").
    2) Develop irrigation schedules (see "Scheduling" section).
    3) Develop a system maintenance budget for owner approval.

d. Recommendations
    1) Utilize technology
        - Technology helps the manager do a more thorough and complete job.
        - Online/Internet-based technology allows for more rapid response to problems.
    2) On a new site design, feedback with the designer may be beneficial to improve overall efficiency.

1.3 Outcomes of Communication Tools

a. Accountability of stewardship
    1) Is the correct amount of water being used?
    2) Is the site in compliance with any watering restrictions?
    3) Are other resources being used wisely?

b. Relationship and trust
    1) Increased communication among key parties
    2) Improved corporate image for both owner and contractor

c. Preserve assets in cost-effective strategy
    1) Healthy and vibrant landscapes
    2) Reduction of hardscape maintenance requirements
        - For example, parking lots, sidewalks, roadways, fencing, etc.

2. <u>Maintenance</u>

Regular and routine maintenance of the irrigation system is best accomplished if directed by the irrigation manager to assure that the system operates optimally. The maintenance schedule will ensure that the proper replacement components are used when required, and a plan to respond to unforeseen problems such as vandalism can keep the system working well and minimize wasted water.

2.1 Initial Steps

a. Establish a periodic and routine maintenance schedule to inspect and report performance conditions of the irrigation system to the end-user/owner/owner's representative.

b. Create and post at the controller a station/zone map for ease of system inspection and controller programming. In the absence of an as-built or record drawing, include the location of key components such as controllers, main shutoff valve, isolation valves, remote control valves, filters and any sensors or decoders.

2.2 Periodic Maintenance

a. Review the system components periodically (i.e., annually or as determined by the water manager) to verify the system functionality.

b. Inspect and verify that the backflow prevention device is working correctly and have it tested as required.

c. Inspect and verify that the water supply and pressure meet system operational requirements for optimal system efficiency.

d. Adjust valves for proper flow, closing speed, and operation as needed.

e. Inspect and verify pressure regulators are properly set and adjusted (if installed).

f. Test system wiring for continuity and integrity, and document readings.

g. Establish a winterization protocol (if required based on climate) and a corresponding process for system activation in the spring.

2.3 Ongoing Maintenance

a. Review the system components regularly (i.e., weekly) to verify the efficient operation and uniform distribution of water:
   1) Examine and clean filtration as needed.
   2) Inspect and verify proper operation of the controller. Confirm correct date/time input and functional backup battery where used.
   3) Inspect and verify that sensors used in the irrigation system are working properly.
   4) Inspect and verify that sprinkler heads are operating at recommended pressures and are properly adjusted — nozzle size, arc, radius, level and attitude with respect to slope.
   5) Ensure that plant material is not blocking or interfering with the operation or output of sprinkler heads.
   6) Inspect drip irrigation zones, check the pressure regulator, service the filter and flush laterals to remove silt and foreign matter. Inspect for clogged and missing emitters or damage to the tubing and make repairs.
   7) Repair or replace broken pipe or malfunctioning components and restore the system to its optimal performance capabilities.
   8) Test and adjust all repairs.
      - Complete repairs in a timely manner to support the integrity of the irrigation system.

b. Ensure that replacement parts will perform the same as original equipment.
   1) Sprinklers or nozzles used for system repairs will maintain matched precipitation rate within the hydrozone.
   2) Valves will have the required performance features to meet site conditions such as flow requirements, pressure, and water quality.
   3) Document maintenance procedures and findings.

2.4 Additional Considerations

a. A thorough maintenance program will extend the useful life of the irrigation system.
b. Good horticultural practices and irrigation management are needed to sustain the efficient use of water.
c. Changes and modifications to the irrigation system will be necessary as the landscape matures.

Note: *Field personnel should not make changes to equipment without performing a site evaluation and communicating with the water manager.*

3. <u>Water Budgeting</u>

Water budgeting, when used as a landscape water management tool, allows the water manager to plan or anticipate the amount of water required to maintain a healthy and functional landscape (see more in appendix B). The total landscape water requirement is based upon summing the water requirement for each irrigation zone or type of hydrozone in the landscape. The landscape water requirement is based on real-time weather conditions using reference evapotranspiration data adjusted with appropriate plant factors and site rainfall. The manager can utilize meter readings to compare the amount of water applied based on the irrigation scheduling to the calculated water requirements. Adjustments can be made to the schedule as necessary to maintain an acceptable plant appearance within the water allowance. Measured water usage is compared to both the landscape water requirement and the landscape water allowance. It is recommended that this comparison be done at least monthly but more often to determine if adjustments to the irrigation schedule need to be made.

3.1 Landscape Water Requirement

a. The landscape water requirement is determined by summing the water requirement for each irrigation zone or hydrozone in the landscape:

$$LWR = WR_{H1} + WR_{H2} + WR_{H3} + \text{etc.}$$

where

LWR = landscape water requirement {gallons}

WR_{H1} = hydrozone water requirement

b. Estimating the water requirement of a hydrozone uses the following information:

$$WR_H = \frac{((ET_o \times PF) - R_e) \times LA \times 0.623}{IE}$$

where

WR_H = hydrozone water requirement {gallons}

ET_o = evapotranspiration for the time period {in.}

PF = plant factor or turfgrass factor for the hydrozone

R_e = rainfall that is effective within the root zone {in.}

LA = landscape area {ft^2}

0.623 = conversion factor to gallons

IE = irrigation efficiency (an expected efficiency that reflects management skill for scheduling, sprinkler performance and maintenance. It is not the same as distribution uniformity.) For example:

- 90 percent efficiency is about 11 percent more water
- 80 percent efficiency is about 25 percent more water
- 75 percent efficiency is about 33 percent more water
- 70 percent efficiency is about 42 percent more water
- 65 percent efficiency is about 54 percent more water

c. Using water meter readings, determine if the irrigation schedule is applying the correct amount of water by comparing water usage with the amount calculated by the above equation.

3.2 Actions

a. Collect water meter readings and rainfall data for the same period as the estimated landscape water requirement.
b. Compare water usage to the estimated landscape water requirement.
c. Observe plant health and soil moisture conditions.
d. Recommend adjustments to the irrigation schedule if needed.
e. Document results.

3.3 Additional Considerations

a. An additional amount of water will be needed to leach any salt accumulation because of poor water quality.
b. Determine how to maximize the benefit of rainfall to reduce irrigation water.
c. If the site has multiple water sources then use the lowest quality water first.

4. Scheduling

Scheduling landscape irrigation is a process that requires knowledge of the irrigation system's performance characteristics (application rate, distribution uniformity, etc.), soil type and soil water properties, plant root depth, and plant water requirements to determine when and how much water should be replaced. The irrigation schedule is dynamic. It is influenced by rainfall events and seasonal weather patterns. Aspects of irrigation scheduling to maximize efficiency and effectiveness include: total run time for each zone, dividing total run times into multiple cycle-start programs to eliminate or minimize runoff, and the frequency of watering events to minimize plant-water stress. Schedules can be simple single program configurations or more complex multiple programs running stacked in sequence or overlapped running concurrently. The irrigation manager must understand the capabilities of the irrigation system, the soil and soil water properties, variations in root zone depth, solar exposure, the intended purpose and function of the landscape, and the plant water requirements in order to properly determine an irrigation schedule.

Technologies are available that monitor weather or soil moisture conditions and auto-adjust irrigation schedules based on factors that the manager enters into the controller. These controllers can operate with manual schedule adjustments, by percentage of preprogrammed watering times that are based on observed weather changes, or by input from weather, soil moisture, or flow sensors.

4.1 Communication

a. Determine if there are any constraints regarding time of day or day of the week for irrigation.
   1) Use of the site (such as sporting events, mowing schedule, etc.)
   2) Watering restrictions in place by water purveyor
b. Expectations for landscape appearance and water conservation potential
   1) What is the intended level of aesthetic acceptance (stress level)?
   2) Is water use at or below the planned amount?
c. Desired benefits
   1) Water use efficiency
   2) Runoff reduction
   3) A more robust plant health
   4) Sound root system
   5) Reduce weed, disease, and other pest problems

4.2 Documentation

a. If not assigned, determine an appropriate water window for irrigation.
b. Utilize information from site evaluation to be used for scheduling (see "Site Evaluation" section).

4.3 Actions

a. Create an irrigation schedule (see appendix C for more information).
   1) How much water should be applied?
      - Based on weather data and calculated plant water requirement since last irrigation or rainfall
      - Based on allowed soil moisture depletion
      - Based on the soil's ability to move water by capillarity
      - Account for rainfall effectiveness.
      - Does it fit within the landscape water allowance?

2) How long are the run times?
    - Total run time is based on the application rate of the irrigation equipment.
    - Use multiple cycle-starts to prevent runoff.
        (i) Based on soil type, amount of organic matter present and compaction
        (ii) Consider slope and compaction issues.
        (iii) Application rate of the equipment
        (iv) As a rule of thumb when observing runoff, reduce subsequent cycles by 20 percent.
            1. Irrigation equipment has a minimum amount of run time required to effectively apply water to all of the area.
            2. Site observations of runoff collected during evaluation activities provides valuable information to use for calculating cycle-soak scheduling.
    - Does the irrigation schedule fit within the watering window?
        (i) Comply with time of day watering.
3) How often should irrigation be scheduled?
    - Best practice is to irrigate when soil moisture has been depleted to a predetermined threshold that does not contribute to unplanned plant stress.
        (i) Run times remain constant, but the interval between irrigation days changes.
    - Regular interval or designated days of the week.
        (i) The irrigation days are constant but the run time changes to match the amount of water extracted by the plants usually based on modified ET information.
        (ii) Comply with any mandatory watering restrictions for day or days of the week.
4) Special considerations
    - Incorporate personal experience of managing the site with the calculated schedules to assure water use effectiveness.
    - If water sources have high salts, additional irrigation events are needed to flush the harmful salts out of the root zone.

b. Program the controller
    1) Understand the features of the controller to facilitate scheduling and management.
    2) If using smart controller technologies, program the controller with site-specific information such as soils, plant type, irrigation performance, etc.
    3) Set inputs to on-site sensors such as rain shutoff devices, soil moisture sensors, wind sensors, or freeze sensors to inhibit irrigation when it is not conducive for effectiveness.

c. Fine tune controller program
    1) After initially programming a conventional or smart controller
        - Evaluate water content in the root zone using a soil probe.
        - Determine if the zone is too wet, too dry or just right.
    2) Make small incremental adjustments to the controller settings about two weeks apart and retest until the water content in all zones is correct.
    3) Take rain fall into account where appropriate.

Irrigation Effectiveness

Irrigation efficiency is irrigation water beneficially used compared to the amount of irrigation water applied or supplied to the site and is expressed as a percentage.

Distribution uniformity is not a measure of efficiency but rather a way to characterize the evenness of application of water to the planted area and is expressed as a decimal value. In landscape irrigation, this has greatest importance in turfgrass areas.

Irrigation Effectiveness is achieved when the plant water requirement has been supplied without runoff or deep percolation. High distribution uniformity is essential to applying the least amount of water to meet the plant water requirements. Irrigation scheduling is applying the right amount of water at the right time to maintain a healthy landscape.

4.4 Additional Actions

a. Research and utilize irrigation scheduling programs that fit needs.
b. Create a method to adjust irrigation schedules quickly and appropriately.
c. Compare proposed schedule with current schedule (feedback loop) with the original designer/company, where possible.
d. Use soil moisture sensor systems and rain/wind/freeze sensors as bypass devices to suspend irrigation if it is not needed or the weather is not conducive to effective irrigation.

5. Monitoring

The water manager measures water usage and compares it to the estimated water requirement based on current weather conditions. The water manager works alongside with the landscape manager to assesses the overall landscape health and appearance to determine if irrigation is effective by physically checking soil moisture in the root zone and documenting other potential horticultural problems such as nutrient needs, pest management, etc. The irrigation manager makes adjustments to the irrigation schedule as needed to respond to current soil moisture conditions including responding to drought or water shortages. The information collected during ongoing monitoring provides the data to communicate with interested parties and provides the basis for scheduling refinements.

5.1 Communication

a. Are the expectations realistic for what’s available (resources, money, water, personnel, restrictions and ordinances, etc.)?
b. Water budget comparison feedback loop
   1) Is the water being used within the expected water budget?
   2) Is the water budget realistic and/or flexible? If the water budget is static, modifications to expectations or management may need to vary.
c. If there are drought or water shortages, is a drought management plan being followed?

5.2 Documentation

a. Obtain past water use records.
   1) Three years of historical usage is recommended.
b. Obtain past weather data.
   1) Use local or nearby weather and ET data from a reliable source.
      - Identify sources of real time weather information; and ET data.
      - Monitor drought conditions.
c. If using on-site harvested or collected water sources, note the following.
   1) Document current water levels in storage tanks.
   2) Water test reports
      - Safety of the water — protect people
      - Quality of the water — not too harm plants
   3) Observe changes to water supply and pressure including pump station functionality.

5.3 Measurement

a. Record water usage.
   1) Monitor water usage frequently and at regular intervals.
      - Read meters on a regular basis (at least monthly during growing season).
      - If meters are not available, measure applied irrigation water using precipitation gauges in the irrigated area.
b. Monitor and record on-site rainfall.
c. Monitor soil conditions and root zone.
   1) Record soil moisture based on soil core sample or sensor reading.
   2) Measure soil compaction with an infiltrometer or similar tool.
   3) Verify root zone depth and soil conditions.
   4) Does the amount of soil moisture within the root zone concur with the expectations?

5.4 Action

a. Observe plant health and record problems identified.
   1) Stress — signs of underwatering
      - Identify indicator plants.
   2) Ponding — signs of saturated soils caused by too much water
   3) Weeds, diseases, and pests
b. Compare calculated water need to water applied to refine your schedule.
c. Compare current water usage using real-time weather data to historical water usage.
d. Compare water usage to forecasted water need to see if it is on track or if corrective action needs to be taken.
e. Develop a soil moisture balance sheet to maximize beneficial rainfall.
f. As plant material matures or changes to the landscape occur, ensure that system modifications are implemented by following the *Landscape Irrigation Best Management Practices* PG1 (design) and PG2 (installation).
   1) Ensure that system modifications are in response to changing site conditions.
   2) In accordance with any applicable local codes or mandates.

5.5 Additional Considerations

a. Install a dedicated irrigation meter or private sub-meter to improve management capability.
b. Explore new technology for monitoring soil conditions and root zone conditions.

6. **Site Evaluation**

An evaluation is a (periodic) review of system performance resulting in adaptive management and initiates recommendations for scheduling, maintenance and monitoring. The irrigation manager inspects the irrigation system to verify that system maintenance procedures are being followed, that equipment is working optimally and that landscape plantings are properly considered when scheduling irrigation. A review of system performance assists the irrigation water manager, owner or end-user to develop an effective irrigation water management plan.

A site evaluation will also forecast requirements for a maturing landscape and assess whether the system in its present configuration will continue to meet the overall objectives of the site.

6.1 Communication

a. Establish the goal and purpose of performing a system evaluation.
b. Share the irrigation system performance results.
c. Make recommendations on changes that might be needed.

6.2 Documentation

a. Water supply
   1) Source(s) (potable, groundwater, rainwater catchment, recycled, etc.)
   2) Expected reliability and availability of alternate water sources.
   3) Verify that backflow prevention has been tested and conforms to code.
b. Soils
   1) Texture (sand, loam, clay)
   2) Preliminary estimate of water holding capacity/infiltration rate
   3) Examine soil profile of the root zone.
   4) Measure depth of root zone.
c. Landscape
   1) List of plant types/turf types
   2) Assess condition of plants — by species and by hydrozone.
d. Review existing irrigation system.
   1) Sprinkler/drip type used in system
   2) Identify irrigation zones.
      - Visual inspection of how well system is operating
        (i) Patterns
        (ii) Wet/dry spots
        (iii) Poor plant health
        (iv) Overall level of system maintenance
      - Do irrigation system zones conform to the identified hydrozones?

6.3 Measurement

a. Water supply
   1) Quality of water (pH, salinity, hardness, etc.)
   2) Quantity (available gpm)
b. Soils
   1) Drainage or compaction problems
   2) Consistency of soil type throughout the site
c. Landscape
   1) Determine water requirement for each plant type.
   2) Measure hydrozone area.
   3) Identify sloped areas.

d. Review existing irrigation system.
    1) Consistency in sprinkler type/nozzle and spacing within a zone
        - Estimated precipitation rate
        - Estimated distribution uniformity
        - Recommend catch can test as needed

6.4 Actions

a. Draw conclusions based on
    1) Soils/drainage/compaction issues.
    2) Irrigation design issues.
        - Improper irrigation zones
        - Improper pressure
        - Poor coverage
        - Overspray
    3) Landscape issues.
    4) Improper plant usage.
    5) Mixed irrigation zones.
    6) Water quality issues.
    7) System maintenance issues including age of components.
    8) System functionality issues.
        - Limited programming capacity, lack of sensors, etc.
    9) System management issue.
        - How well are the system and its components being utilized?

b. Recommendations based on
    1) Most critical issues that need to be addressed.
    2) Return on investment when implementing recommendations.

6.5 Communication Feedback

a. Accountability
    1) Owner
        - Final/financial decision maker
    2) Water manager
        - Develops irrigation schedule/program
        - Develops maintenance tasks and intervals

6.6 Additional Considerations

a. Create a maintenance routine including documenting inspections completed.
b. Assess plant material functionality and or placement within hydrozone.
c. Suggest the testing of the soil and follow recommendations for amendments or other remediation practices such as aeration.
d. Suggest the use of technologies, which will help reduce water use and improve irrigation management.
e. Link original design concept to maintenance tasks. See appendix A for more information about inspecting and/or commissioning an irrigation system.

References

Stetson, L.E. and B.Q. Mecham, eds. 2011. *Irrigation,* 6th ed. Falls Church, VA: Irrigation Association.

Von Bernuth, R.D. and B.Q. Mecham, eds. 2013. *Landscape Irrigation Auditor*, 3rd ed. Falls Church, VA: Irrigation Association.

EPA WaterSense. Refer to the irrigation products and outdoor pages website at www.epa.gov/watersense/.

Source of local historical or current evapotranspiration [ET_o] data (if available): Refer to the "ET Connection" on the Irrigation Association's website at www.irrigation.org/.

Soils data: USDA Natural Resource Conservation Service [NCRS], www.nrcs.org.

Climate data: www.ncdc.noaa.gov.

Rogers, D., F. Lamm, and M. Alam. 2003. Subsurface drip irrigation systems [SDI] water quality assessment guidelines. KSU Publication #2575. Manhattan, KS: Kansas State University. Available at www.ksre.ksu.edu. Accessed 11 March 2014.

Appendix A

Irrigation System Inspection and Commissioning

General:
To assure that the irrigation system has been installed according to plans and specifications, and that the equipment is performing optimally for the site, the system shall be inspected or observed periodically during construction for compliance. Commissioning of the irrigation system is a process whereby the performance of the system can be observed and measurements obtained to verify proper operation and scheduling that meets the contractual obligations. Where required, water usage as the result of scheduling can be compared to the water budget or allowance.

Qualified Inspector/Commissioner:
The person or team doing the inspection and commissioning shall be qualified and demonstrate competence through education, training, experience and/or certification in landscape irrigation and landscape water management. The designer of the system or qualified irrigation manager may be permitted to act as the inspector/commissioner of the landscape irrigation system and shall be objective and independent from the contractor responsible for the work being inspected. Examples of qualified individuals include those who are certified by the Irrigation Association as a certified irrigation designer, certified landscape water manager or certified landscape irrigation auditor. Likewise, professional irrigation consultants are accredited professionals by the American Society of Irrigation Consultants. Other programs may exist that would qualify a person or team to perform inspections and commissioning that would be acceptable to the project owner or the authority having jurisdiction. Possible conflicts of interest shall be disclosed to all parties.

Equipment:
The inspector/commissioner shall have all of the necessary equipment to perform the required inspections and commissioning. The equipment shall be properly calibrated.

Inspection vs. Commissioning:
Inspection is to verify the physical presence of the components and that it has been installed correctly. Commissioning is about verification of functionality and operation.

"Inspect what you expect."

Inspections:

- Field inspections shall take place during and after construction while the contractor is on site to verify that irrigation system components have been properly supplied and installed according to the plans and specifications used for installation. Sometimes this is also referred to as construction observation and could be part of the contracted services with the irrigation designer.
- Record drawings shall be maintained with changes to the approved plans by the contractor and available for periodic inspection as needed.
- See the included example worksheets for performing an inspection and noting acceptance, deficiencies, and if corrections are completed.

Commissioning:

- A commissioning plan shall be developed specifically for the project that will identify the following:
    - The turfgrass areas and related irrigation zones will be observed for proper operation.
    - The specific irrigation zones that shall have performance measurement using catch devices to determine precipitation rate (used for scheduling purposes) and distribution uniformity (if required).
    - **Additional data to be collected**
        - Record meter readings if available as part of the audit process.
        - Operate each drip zone and take pressure readings at the beginning and end of the piping run and record pressure.
        - Verify that controller is properly wired and all pertinent sensors are properly configured and wired into or communicating with the controller.
        - Take ohm readings for each station to verify wiring integrity and record at the controller for future reference.
        - Verify that the irrigation map is consistent with the controller settings for each station.
        - Verify that information about the controller settings/schedule is available at the controller so settings can be restored if necessary.
- Review the current irrigation schedule to
    - Assure the run times are proper for the amount of water needed.
    - Assure that cycle and soak times are utilized to avoid runoff.
    - Where required, compare water usage for current schedule with water budget or allowance based upon real time ET information or soil moisture readings.
    - Verify that information about the controller settings/schedule is available at the controller so settings can be restored if necessary.
- Prepare reports outlining the findings of the commissioning activity within 30 days after verification of the system operation and performance.
    - Precipitation rate for each sprinkler zone/station
    - Quality of the system based upon low-quarter distribution uniformity
    - Deficiencies that need to be corrected
    - Schedule to measure system performance to assure maintenance is being properly completed.
- Other documents:
    - Verify that record drawings of the irrigation system and installation are completed and copies are available to the property owner, property manager and landscape water manager.
    - Operator's manual that includes the basis of design and system operation, equipment list including manufacturer, model number and size and the intent of how the system should be managed including an irrigation system for peak demand showing station run times and watering days (Copies should be available to the property owner, property manager and who will be managing the irrigation system.)
- Contact information for system design, installation and maintenance

Example forms for recording system settings and performance are included to facilitate the inspection and commissioning of the irrigation system.

References

Von Bernuth, R.D. and B.Q. Mecham, eds. 2013. *Landscape Irrigation Auditor*, 3rd ed. Falls Church, VA: Irrigation Association.

Auditing Guidelines. Available at: www.irrigation.org/Certification/CLIA/Audit_Requirements.aspx. Accessed 11 March 2014.

ASABE Standards. 2014. X626: Uniformity test for landscape irrigation systems. St. Joseph, MI: ASABE.

Irrigation System Inspection

Project Name_________________________ **Location**______________________________

Date of Inspection_____________________ **Inspector**______________________________

Item Description	Acceptable	Deficient	Corrected
Water Source			
Point of connection size matches plan			
Flow rate matches plan			
Pressure matches plan			
Backflow prevention installed per plan and code			
Water meter / flow meter installed			
Pump station (if applicable) meets plans and specs			
Controller			
Installed per specifications—manufacturer, model, number of stations, grounded properly			
Wiring matches specifications			
Sensors installed and functioning			
Rain shut off device			
Soil moisture sensor(s)			
Flow sensor			
Other (list)			
Controller programmed with date and time			
Irrigation map posted by controller			
Mainline Piping			
Depth of bury meets plans and specs			
Manual valves			
Installed as per plan and specs			
Installed in valve boxes properly set			

Note: If equipment or components are not required, mark as N/A not applicable.

Irrigation Zone/Station Inspection

Project Name_________________________ **Location**______________________________

Date of Inspection_____________________ **Inspector**_____________________________

Zone/Station Number________

Item Description	Acceptable	Deficient	Corrected
Sprinklers			
Sprinkler type and model match plan			
Sprinkler nozzles are correct			
Sprinkler spacing as per plan			
Sprinkler installed correctly (tilt, distance from hard edge, correct depth)			
Valve			
Valve matches plan, specifications and size			
Valve box properly set and identified			
Valve flow control properly adjusted			
Pressure regulator installed and adjusted			
Wire connections meet specifications			
Piping			
Proper pipe type and size is installed			
Depth of bury meets plan and specs			
Trenches backfilled, compacted and grade level			
Sprinkler Activation			
Sprinklers are adjusted correctly (arc and distance)			
Sprinklers are activated by controller			

Note: Items not installed can be marked N/A for not applicable

Other observations:

Drip Irrigation Inspection

Project Name_________________________ **Location**______________________________

Date of Inspection_____________________ **Inspector**______________________________

Zone/Station Number________

Item Description	Acceptable	Deficient	Corrected
Emitters			
Emitter type and model match plan			
Emitter location around plants			
Valve			
Valve matches plan, specifications and size			
Valve box properly set and identified			
Filter installed and serviceable			
Pressure regulator installed			
Wire connections meet specifications			
Piping			
Proper pipe type and size is installed			
Piping is anchored or buried as per specifications			
Flush plugs are installed			
Drip Irrigation Activation			
Drip system is activated by controller			

Note: Items not installed can be marked N/A for not applicable

Other observations:

Appendix B

Landscape Water Budgeting

Landscape water budgeting is a process of comparing the landscape water allowance to the estimated landscape water requirement. The calculation is done using reference evapotranspiration data and an adjustment factor to modify the ET. The adjustment factor should be a reflection of the available water for maintaining the landscape or other goals that are established by the owner of the project or a green initiative such as EPA WaterSense program, LEED, Sustainable Sites or local ordinances such as California's Model Water Efficient Landscape Ordinance. Many programs use the peak demand month (highest reference evapotranspiration and least amount of rainfall) to determine the landscape water allowance, therefore influencing the type of plants that should be used and area and type of turfgrass. Most programs have an extra allowance of water for turfgrass areas used as sports fields. This is becoming a common practice for new landscapes.

Landscape water budgeting can also be used as a management tool to estimate the amount of water the existing landscape requires and then compare to water usage. For most existing landscapes the adjustment factor of 0.80 works well, especially in semi-arid or temperate areas. In the very arid or desert areas, the adjustment factor would likely be less to reflect the available water supply and the type of plants that are used in the landscape.

Landscape water allowance

Following is a general formula for calculating a landscape water allowance for any time period:

$$LWA = ET_o \times AF \times LA \times 0.623 \times LF$$

where

LWA = landscape water allowance {gallons}

ET_o = reference evapotranspiration for the time period {in.}

AF = an ET adjustment factor can be used as follows:

- Normally ≤ 1.0, reflecting water needs of the plant material.
- The maximum water a purveyor or regulatory authority will provide or allow to be used for landscape irrigation. It is typically set between 0.60 and 0.80, depending on the available water supply or to promote conservation.
- A higher adjustment factor should be used for turfgrass areas that are used as sports fields, typically between 0.80 and 1.00 depending on the turf species.

LA = area of the irrigated landscape {ft^2}

0.623 = conversion factor to convert inches to gallons of water.

LF = leaching factor (optional), greater than 1.0 based on water quality and soil type. This is an optional multiplier used in cases of poor water quality (i.e., recycled, surface, or brackish sources).

To estimate the landscape water requirement the calculation would be similar to the following as found in "Practice Guideline 3, Landscape Water Management" and factors in effective rainfall for the site as well as an expected irrigation efficiency to account for less than perfect management and sprinkler system performance.

Landscape water requirement

The landscape water requirement is determined by summing the water requirement for each irrigation zone or hydrozone in the landscape:

$$LWR = WR_{H1} + WR_{H2} + WR_{H3} + \text{etc.}$$

where

LWR = landscape water requirement {gallons}

WR_{H1} = hydrozone water requirement

Estimating the water requirement of a hydrozone uses the following information:

$$WR_H = \frac{((ET_o \times PF) - R_e) \times LA \times 0.623}{IE}$$

where

WR_H = hydrozone water requirement {gallons}

ET_o = evapotranspiration for the time period {in.}

PF = plant factor or turfgrass factor for the hydrozone

R_e = rainfall that is effective within the root zone

LA = landscape area {ft^2}

0.623 = conversion factor to gallons

IE = irrigation efficiency

- 90 percent efficiency is about 11 percent more water
- 80 percent efficiency is about 25 percent more water
- 75 percent efficiency is about 33 percent more water
- 70 percent efficiency is about 42 percent more water
- 65 percent efficiency is about 54 percent more water

To determine the landscape water requirement for the landscape, follow the previous calculation for each type of hydrozone in the landscape and sum the totals for each hydrozone type.

Ultimately the water manager would compare water usage to the allowance. The manager can also determine if the irrigation has been effective by observing the landscape plant material for expected appearance and health.

Appendix C

Basic Landscape Irrigation Scheduling

Irrigation scheduling for landscapes has many complex facets that need to be considered when doing effective irrigation management. Additional information is available in *Irrigation, Sixth Edition*, chapter 13, which discusses the following issues in more detail:

- The landscape water requirement has to account for the water needs of multiple plant types and microclimates found in the landscape compared to an agricultural monoculture not easily influenced by its surroundings.
- Many landscapes deal with disturbed soils that are often imported and layered and require extensive amendment and tillage to make a suitable planting medium.
- Water providers often impose watering restrictions that have to be considered when creating irrigation schedules.
- Irrigating the landscape must meet the purpose or functionality of the landscape as well as maintain an aesthetic appeal.

The irrigation of turfgrass gets perhaps the most attention within a landscape and frequently is the target for many water purveyors when there are water shortages. Therefore, the discussion will be focused on turfgrass irrigation followed by a discussion about the irrigation of other parts of the landscape such as trees, shrubs, ground covers, and flower beds. The principles used to calculate a proper schedule for the turfgrass are applied to all areas of the landscape. Consideration for the amount of water needed by different plants, the density or complexity of the landscape, and the method water is applied to the landscape, are used to create an irrigation schedule.

Landscape Irrigation Scheduling Steps

The steps for creating a landscape irrigation schedule include the following:

- depth of irrigation
- when to irrigate
- how much to irrigate
- how long to irrigate
- restriction or limitation compliance

Depth of Irrigation to Apply

To determine irrigation depth, the user must first identify the soil texture so that the available water-holding capacity of the soil is known. The second step is to determine the depth of the root zone [Z_r]. This step can be aided by using a good soil probe to take several soil cores to observe the presence of roots at various depths. The roots that can be seen by the eye are counted as the root depth and usually more roots are in place to extract water than are visible. Also, it should be remembered that rooting depth can be influenced by irrigation timing. For example, if the area being examined has been watered daily, it may never have developed deeper roots.

The product of available water and root zone depth would be the *total* amount of water held in the root zone. However, only a portion of this is available to the plant because at a certain level of moisture extraction the plant would be stressed. This percentage level separating nonstressed conditions from the commencement of stressed conditions is referred to as allowable depletion. Management allowed depletion [MAD] is a percentage determined by the irrigation manager and depends on soil texture and plant physiology. Generally most practitioners use a MAD of 50 percent or 0.50, which means minimal stress for the plants. If there is managed stress or deficit irrigation is being implemented, the MAD value will be higher.

For most landscapes the goal is to maintain a healthy appearance and functionality of the landscape. Certain levels of stress, then, are acceptable and desirable from a water conservation standpoint. Generally speaking for most landscapes, depleting the available water by 50 percent is acceptable and is called the management allowable depletion. Based upon the soil type and rooting depth of the hydrozone, the following equation can be used to determine a depth of water to be applied:

$$d_{max} = AW \times Z_r \times MAD$$

where

d_{max} = maximum irrigation depth {in., mm}
AW = available water {in., mm}
Z_r = root zone depth {mm}
MAD = management allowed depletion

The concept of MAD is to use the water most readily available to plants first and minimize the amount of stress the plants may experience as they approach the wilting point to get all of the available water. Using MAD also means that irrigation will be more frequent but the amount of water to be applied will be less per irrigation.

When to Irrigate

Allowable depletion is used to determine the frequency of irrigation. During the time of peak water demand such as midsummer, the frequency for turfgrass irrigation could be every two or three days depending on the soil texture and root depth. For extremely arid climates and depending on the type of turfgrass, the irrigation interval could be daily, such as on a golf course. But during the early spring and into fall and winter, the frequency or interval of irrigation could be stretched to every five to seven days, and as the plants go into dormancy it could be every 10 days or more. Even though the interval may seem like an unusually long time, the object of irrigation is to refill the soil reservoir for only the amount that has been extracted. This process is very dependent on plant water demand as plants respond to changing weather.

How Much to Irrigate

The amount of water to apply to the landscape is frequently determined by using evapotranspiration [ET] information and modifying it to better represent the type of plants grown in the landscape as shown in the following equation. Identifying a source of real-time ET information along with appropriate plant or turf factors to modify the reference ET will allow the irrigation manager to create and adjust the irrigation schedules to meet plant water needs. It is best if this is done on a daily basis so as to not exceed the allowable depletion of the soil moisture as previously discussed. Estimating the landscape water requirement or plant water requirement is done as follows:

$$ET_L = ET_o \times K_L$$

where

ET_L = landscape or plant water requirement {in.}
ET_o = grass reference ET information {in.}
K_L = landscape coefficient {decimal}

One approach is to pick a fixed amount of water that would correspond to allowable depletion, 0.50 inch for example. If the plant or turfgrass water requirement is 0.25 inches per day as determined by the use of ET data, the irrigation interval would be every two days. If the plant water requirement is 0.17 inches per day, the frequency of irrigation would be every three days; or if the water need is 0.10 inches per day, irrigation would occur every fifth day. When this approach is used, the number of minutes of run time for each station will remain the same, but the irrigation interval or number of days between irrigation events will change.

Another approach is to use ET information for each day, apply the proper crop or landscape coefficient, and add it up for the number of days in the interval. This would be a fixed-day or interval method. For example if the water requirement for three days were 0.15, 0.22, and 0.19 inches, the amount of water to apply on the irrigation day would be 0.56 inches. The next three-day period could perhaps have a water requirement of 0.47 inches. As can be seen, the amount of water is fluctuating and therefore the number of minutes to apply the water will also need to be changed. When the interval period is fixed because of restrictions that have been imposed by a water utility, or a site has an inadequate water supply, or usage of the site dictates when irrigation can occur such as sporting events, the amount of water to apply will change as the weather changes. Ideally the interval or frequency of irrigation will be close to the managed allowable depletion during peak demand times.

There are a number of other variations for scheduling landscape irrigation, but these two methods, either fixed-amount or fixed-day, are most often used. Typically, in a minimal stress management regime, one-third to one-half of the water within the root zone will be depleted before irrigation or rainfall refills the soil reservoir (maximum allowed depletion). When deficit irrigation practices are implemented, more of the root zone will need to be refilled requiring longer run times. Otherwise, only a part of the root zone will be recharged with water if there are restrictions in place.

Once the amount of water to be applied has been determined, the irrigation manager will subtract any effective rainfall since the previous irrigation to determine if irrigation will still need to be applied or it can be eliminated or postponed for a period of time to maximize the benefit of the rain.

How Long to Irrigate

The number of minutes of run time needed to apply a targeted amount of water is a function of how fast the water is being applied to the landscape, known as precipitation rate or application rate [PR]. Ideally the precipitation rate should be determined from a "catch can" test but otherwise can be determined by the flow rate of the sprinkler nozzle and the spacing pattern of the sprinkler heads in a zone or area. Once the plant water requirement has been determined, the precipitation rate of the sprinklers is used to determine the run time needed to apply that amount of water. This is the number of minutes that will need to be programmed into the controller.

The basic equation for calculating irrigation run times is as follows:

$$RT = \frac{ET_L \times 60}{PR}$$

where

RT = run time for individual station or zone {min}
ET_L = landscape or plant water requirement {in.}
60 = conversion to minutes from hours
PR = precipitation rate of sprinklers {in./h}

Example: Calculating minutes of run time

The reference ET for a given period is 0.62 inches of water, and the species factor used in the landscape coefficient for the grass is 0.70. The sprinkler system applies water at 1.34 inches per hour. How many minutes of run time are required?

Step 1. Determine the plant water requirement [ET_L].

$$ET_L = ET_o \times K_L$$

$$= .62 \times .70$$

$$ET_L = .43 \text{ in.}$$

Step 2. Determine irrigation run time [RT].

$$RT = \frac{ET_L \times 60}{PR}$$

$$= \frac{.43 \text{ in.} \times 60}{1.34 \text{ in./h}}$$

$$RT = 19 \text{ min}$$

Once the run time has been determined, depending on the type of sprinklers being used, the water being applied will be at a rate faster than the intake rate of the soil. In order to mitigate or eliminate runoff, the concept of “cycle-and-soak” is used. This technique will take the number of minutes and break it up into several cycles of shorter duration with a waiting period between cycles to allow the water to infiltrate or percolate into the root zone and then apply some additional water. On coarser soils, one or two cycles are all that might be needed, and on finer soils three or four cycles would be used with adequate soak time. In the above example, using spray sprinklers on a fine or heavy soil might have four irrigation cycles with five minutes of run time duration and 30–40 minutes of soak time between cycle starts. That would amount to 20 minutes of run time, which is roughly equivalent to the calculated run time of 19 minutes.

Controllers

The controllers or timers for turf and landscape irrigation are utilized on small to large landscapes and usually located on-site. Larger landscapes often utilize computerized central control similar to large agricultural operations. Typically the controller is programmed to activate the sprinkler system to apply water to the various zones or areas of the landscape. Controllers can be classified as low, medium, and highly sophisticated. A simple (“low”) controller may have many features, but the schedule must be manually adjusted for changing weather conditions. A “medium” sophisticated controller can make some automatic adjustments to the schedule, for example changing the number of minutes of run time of the base schedule by a certain percentage on a monthly basis triggered by the calendar date. Unusual variations of real-time conditions from the historical average will require a manual adjustment. A “highly” sophisticated controller (also known as a “smart” controller) automatically adjusts the frequency of irrigation or the run time or number of cycles based on current growing conditions influenced by the weather, including rainfall. These systems automatically make the adjustments based on the inputs used to describe each hydrozone within the landscape project.

Some controllers are programmed for fixed irrigation intervals with fixed run times that can be changed manually. Other controllers use fixed irrigation intervals or fixed run times, but the run times or intervals are relatively easy to change. The smart controllers (weather-based and/or soil moisture based), once programmed with the correct inputs, will adjust the schedule automatically; however, they may have to comply with mandated restrictions on when to irrigate and how long the irrigation system should run.

For many years, irrigation scheduling was done simply by choosing watering days, start times, and duration of run time with very little regard for knowing the plant water requirements or the amount of water in the soil reservoir. Because of competing demands for water resources, the expectation is to use water wisely and efficiently. New controllers and the use of sensors have enabled managers to improve water management.

References

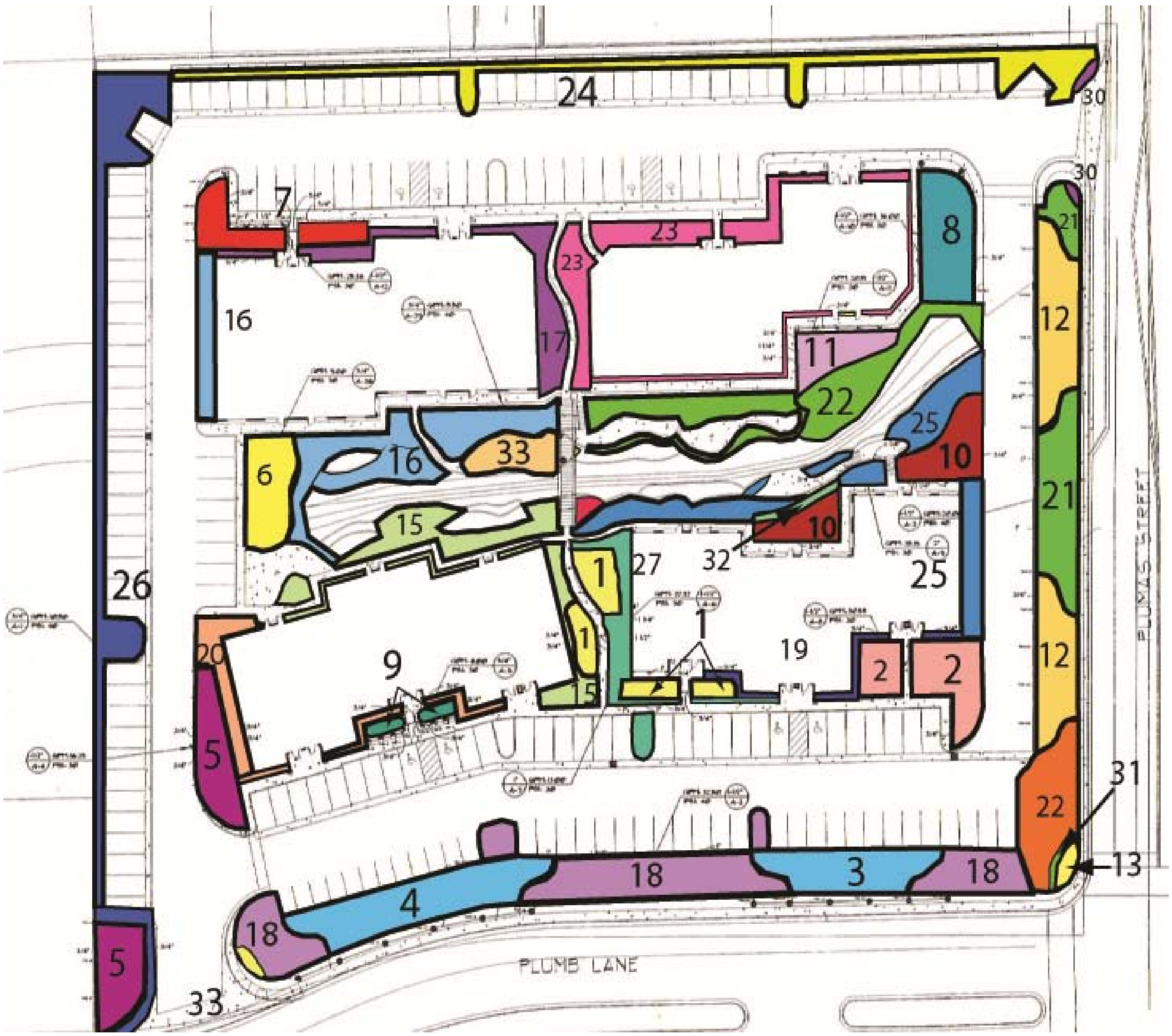
Stetson, L.E. and B.Q. Mecham, eds. 2011. *Irrigation,* 6th ed. Falls Church, VA: Irrigation Association.

Von Bernuth, R.D. and B.Q. Mecham, eds. 2013. *Landscape Irrigation Auditor*, 3rd ed. Falls Church, VA: Irrigation Association.

Appendix D

Controller Map and Station Data Form

An example of a controller map showing by color and controller station number the locations of each irrigation zone. The following station data collection form provides detail about each irrigation zone that can assist in the maintenance and management of the irrigation system.



Station Data Collection Form Example

Job Name:______________________________ Controller Designation:______________________________

Sta.	Plant Type				Soil Type					Slope			Sprinkler						Exposure			
	T	GC	ST	N	S	SL	L	CL	C	FM	MM	SS	SP	GR	IR	SR	RN	DR	SH	PS	FS	RH
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T = Turf/Flowers
GC = Gnd. Cover
ST = Shrub/Tree
N = Natives

S = Sandy
SL = Sandy Loam
L = Loam
CL = Clay Loam
C = Clay

FM = Flat
MM = Med.
SS = Steep

SP = Spray
GR = Gear Rotor
IR = Impact Rotor
SR = Stream Rotor
RN = Rotating Nozzle
DR = Drip

SH = Shade
PS = Part Sun
FS = Full Sun
RH = Reflected