CHAPTER 7
TURF IRRIGATION SYSTEMS

This chapter will provide the information necessary to design an economical irrigation system for delivering the water required to keep plants healthy and to ensure that this water will be applied evenly to all cultivated areas of the site. Generally accepted means of estimating the amount of water needed, selection of equipment (heads and piping), head-spacing criteria (to produce an even distribution of water), and design criteria for sizing the piping system, choosing timers, and sectioning will be described.

GENERAL

The Department of Agriculture has estimated that grass is the largest irrigated crop in the country. Much of the time, the water used for irrigating this crop is the most expensive water available. Watering on a regular basis is necessary for the continued beauty and health of the grass in these areas, not to mention protecting the investment that the owner has made in the cultivated areas.

In order to find the amount of water that is considered adequate for irrigation purposes, the expected rainfall, soil type, plant type, and irrigation requirements for the site must be known. The total overall quantity of water required to keep plants healthy is based on the difference between the natural rainfall and the minimum amount of water necessary for a healthy lawn. The design must consider the worst condition, which is during times of drought when no rain has fallen. This is the basic criterion used to determine the irrigation rate.

The design of cultivated lawn and turf areas requires the planning and advice of landscape architects. The assistance of a landscape architect will be required in order to answer questions regarding plant types and to confirm the criteria that will be developed for each specific project. In some cases, the design of an extensive and diverse site may be beyond the ability of any design professional. It may then be necessary for an irrigation specialist to be called in to assist in the design.

SYSTEM COMPONENTS

A complete irrigation system is composed of a network of piping, valves, sprinkler heads, electrical controls, timers, and wiring. If the water supply is connected to a potable water source, a water meter and backflow preventer will also be required.

CODES AND STANDARDS

There are no mandated standards concerning the design of turf irrigation systems. If connected to the potable water system, the installed system must conform to plumbing and building codes and other ordinances of the locality.

GENERAL DESIGN CONSIDERATIONS

Examine the local codes for any restrictions that would prohibit the use of potable water for irrigation purposes or ordinances that require the application of water be done only during certain times of the day. Inquire about requirements for the use and installation of meters and backflow preventers. Restrictions may also exist that limit the amount of water available for irrigation. If there is an ideal time to irrigate, it is in the early morning when there is generally less wind and there is a minimum loss of water to evaporation before the water droplets reach the ground. In tests conducted at the University of Wyoming, there was a 15 percent increase in efficiency in the amount of water reaching the ground between midday and morning or evening. This percentage decreases in the Northeast.

The location, pressure, and availability of the water must be determined. If pressure is not adequate, a pump may be required. Separate metering of the water may be required.

The quality of the water source is an important consideration. If the project is to use potable water, there is no question as to its adequacy. If, however, a private well, river, or other nonpotable source is used, the water should be tested and the results discussed with the landscape architect. Using gray water in arid parts of the country has proven successful. The reason for this is that some plants cannot tolerate certain minerals or salts, so either the plants or source have to be changed.

It is impossible to work without an accurate site plan, complete with the proposed location and designation of various types of plants and the topographical elevations indicated to develop the slope of the land. Unlike a cash crop, the color of grass is the determining factor for the care given to a lawn. The green color is controlled by a combination of nutrients and water. If the grass is overirrigated, the excess water will carry away nitrogen, slowing growth and causing the grass to turn yellow. In addition, grass roots use oxygen from the air along with water. Excess water robs the roots of oxygen, restricting their growth. If less than the ideal amount of water is put on a lawn, the grass will grow more slowly, lengthening the time between mowings.

THE SOIL

Soil is composed of particles of sand, silt, and clay called *separates,* and organic matter. The percentage of separates (also called *factions*) determines the texture of a soil. With the addition of organic matter, the separates and organic matter form a complex called the *soil structure.* The spaces between the separates are called *pores.*

Water Absorption

When water first moves into average soil, it forms a thin film around the soil particles and is held in place by adhesion. As more water is added, the film enlarges to fill the pores and becomes heavier. Gravity pulls the water deeper into the ground. The speed at which the water travels deeper into the soil structure varies with the texture and structure of the soil, and is called the *percolation* (or *infiltration*) rate. At the point of balance between the cohesiveness of the water (keeping it adhered to the soil particles) and gravity (pulling the water down), the soil is holding the maximum amount of water possible.

Water Loss

Water is lost from the soil in two ways. The main loss of water is from evaporation. Water in the soil moves by capillary action to the surface and is evaporated. Water is also absorbed by plant roots. The water travels upward through the plant and is lost to the air through transpiration. Evaporation and transpiration are combined into a single factor called *evapotranspiration* or ET. If water is not replaced in the soil, a point will be reached where the adhesion of water to the soil particles is stronger than the plants' ability to capture it. This lack of water stresses the plants causing them to wilt. Refer to Fig. 7.1 for a graphical diagram of the evapotranspiration cycle.

Irrigation Requirements

Water must be applied to the soil in a greater quantity than the ET rate, or the reservoir of water necessary to avoid constant irrigation will not be met. Over an extended period of time, the difference between the maximum water capable of being held in the soil and the water needed by plants to avoid the stress point is the actual amount of water required for irrigation. A primary goal is to determine the instantaneous rate, while also considering the total amount of water used for irrigation purposes so that water will not be wasted.

System Efficiencies

More water than the actual amount absorbed into the ground must be discharged by the sprinkler system due to the following system distribution inefficiencies:

1. The uniformity of water applied throughout the entire individual sprinkler head pattern is not even. The difference ratio can be as large as 9 to 1. A coefficient of uniformity is used to calculate this loss, and is dependent upon the pressure at a head, symmetry and speed of rotation if applicable, and the symmetry of the discharge orifice of the head.

2. Water is lost through evaporation into the air from the time it is discharged from the head until it lands on the ground. This loss is greater during the daytime than at night.

3. Loss of water through wind drift must be allowed for.

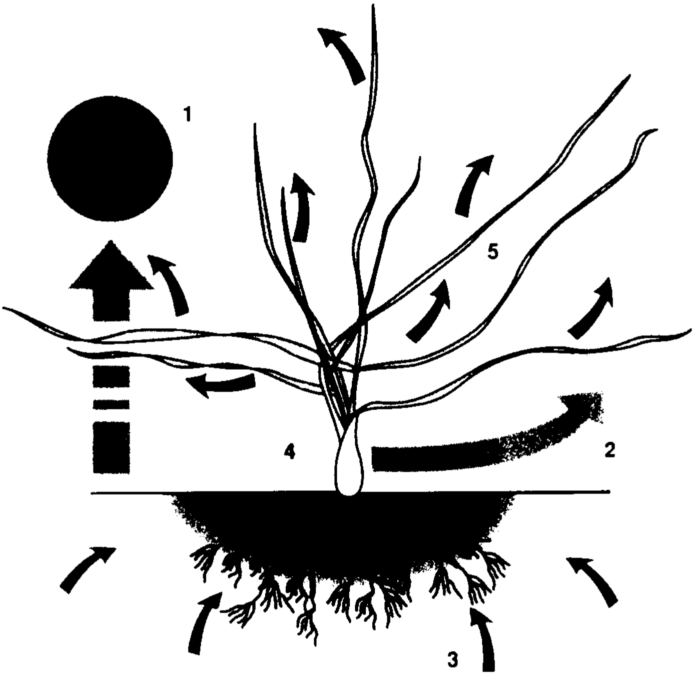

FIGURE 7.1 The evapotranspiration cycle. The sun (1) and wind (2) evaporate water from both the soil and the plant. Water is absorbed by the plant roots (3), is passed upward via its tissues (4), and evaporates through stomata in leaves (5). This transpiration process cools the leaves and aids the absorption of nutrients. The two systems form evapotranspiration (ET). (*Courtesy: The Toro Company.*)

4. Systems are rarely shut off at the exact instant that the soil demand has been satisfied.

5. Water should not be applied faster than the infiltration rate of the soil (the rate at which the soil can accept the water), otherwise water will be lost through runoff on the surface of the ground. The infiltration rate and the slope of the land determine the maximum infiltration rate.

6. The difference in water pressure between the first head in any branch and the last head causes the head with less pressure to discharge less water. Good practice calls for a maximum difference of 10 percent.

Sprinkler Head Selection

The sprinkler head is the most visible and critical of the components making up the irrigation system. Deciding which sprinkler head to use depends upon the following criteria:

1. Size and shape of the area to be irrigated
2. Type of plants to be irrigated
3. Water pressure and flow available for system
4. Required rate of head discharge
5. Compatibility of sprinkler type with others in area
6. Obstructions preventing proper distribution of water
7. Client preferences

There are three general types of sprinkler heads used to apply water for lawn irrigation purposes:

Spray Heads. As the name indicates, spray heads are stationary and discharge water continuously over a fixed area in fanlike sheets in the form of either fine droplets or small individual jets. Surface spray heads were the first type to find widespread use. They are fixed in height and are rarely used today. By far the most popular are the ''pop-up'' spray heads. They are retractable and are mounted below the top of the grass at ground level. When water pressure is applied, the head rises (or pops up) above the top of the grass and starts to spray in a fanlike pattern. When the pressure stops, the heads retract back to grade level and do not provide any obstruction to lawn mowers or people. These heads are available to cover a full circle or any part of an arc.

Rotating Heads. Rotating heads discharge water in a single, large stream, similar to that of a garden hose. The heads rotate to throw water evenly over the distribution area, and the arc can be adjusted. Impact heads have a separate piece of freely attached metal that gets in the way of the stream (or impacts the stream), causing water to deflect randomly. These heads are available to cover a full circle or any part of an arc. Rotating heads can be the pop-up type, exposed stationary, or removable from the piping system with a quick disconnect coupling.

Bubbler and Drip Heads. Bubbler heads are similar to spray heads. They discharge a fan of very small diameter jets of water in smaller amounts and have a smaller pattern. Drip heads are actually lengths of hose with holes that allow water to drip out over their entire length. The amount of water is controlled by the diameter of the pipe, diameter of the holes, and the water pressure.

SYSTEM DESIGN

To minimize the amount of time spent in designing a system, there is a progression that should be followed. The one assumption made is that there is a reasonably unlimited supply of water available for the irrigation system. The progression is an iterative one and should generally follow this order.

1. Determine the source, location, pressure, and quality of the water supply.
2. Obtain the local code and permit requirements for the system.

3. Obtain the regulatory requirements for mandated components of the system, such as meters, backflow preventers, and pipe materials. Locate these components inside or outside the building as required by the specific design or code requirements of the project. Select a tentative location for the control panel and valve boxes for control of different piping zones.
4. Using the complete site plan, select and lay out the irrigation heads and the piping system. Divide the entire site into zones as necessary. Identify the walkways, patios, and so on, that will not need to get water. Identify where the meter and BFP (if required) will be located.
5. Calculate the water flow requirements for the system as a whole and the various sections in particular, select the piping material, and size the piping system.
6. Select desired automatic features of the irrigation scheduling system and schedule the various sections.
7. Make adjustments to the pipe sizes based on the actual calculated flow, head requirements, and actual friction losses in the system and components.

Determination of Available Water Pressure

The available water pressure for the system is found by using standard flow tests and other information that give static and residual flow rates. First, select the source of water. Then determine the residual pressure at the source (accepted practice is to reduce the static pressure by about 15 psi if the residual pressure is not available). From the code, list the mandated components (such as additional meters, backflow preventers, and the like) and find the preliminary pressure losses through them. Add the pressure losses in the piping system and other components from the main to the connection point of the irrigation system. Subtract from the residual pressure the losses just calculated. The result is the pressure in the service line at the connection point for the irrigation system. The above method is an iterative one, with substitutions made to various items as the detailed design progresses.

Water Supply Requirements

There is no quick and easy method available to calculate the exact amount of water needed for irrigation purposes with any degree of accuracy. Specialists use a plant list along with a soil chart based on climatic conditions to establish an accurate ET. More general information will be discussed here. If a project presents a particularly complex problem, a specialist in irrigation should be consulted. For design purposes, a general figure for the necessary amount of water can be used to design a simple system with acceptable accuracy.

For lawn irrigation purposes, it is easiest to find the amount of water to be applied if it is calculated on a weekly basis to discharge enough water to replace slightly more than that lost to ET.

A device called a U.S. Class A Pan Evaporator can be used to establish the ET. This device is a pan of a certain size, which is partially filled with water, set out on the site for a period of time, and the amount of water evaporated from the bucket is measured. Experimentation has determined that the rate of evaporation from a pan evaporator is equal to 80 percent of the actual ET rate. The weekly amount of water to be applied can be derived.

There have been studies made to determine the ET rate for general areas of the United States. One of them divides the country into "hardiness zones," which give the estimated or potential ET, called PET, throughout all areas. Generally, the further south, the greater the water requirements. In addition to the hardiness zone concept, another table has been developed based on the average temperature and humidity of an area. The climate PET values are listed in Table 7.1, which gives the PET rate for one day. Multiply the figure found in Table 7.1 by 7 to calculate the weekly PET rate. The criteria in Table 7.1 correlate with known criteria successfully used for the weekly rate of irrigation. In order to enter Table 7.1 to calculate the actual water flow in the system, the local temperature and humidity conditions must be known. Check with the appropriate sources to find the temperature and humidity design conditions for the project site as it applies to this table.

Another factor to be considered is that a well designed and engineered irrigation system is approximately 80 percent efficient, taking into account all of the inefficiencies previously discussed. This requires that an additional 20 percent be added to the PET to establish the actual amount of water to be discharged from all the heads in a circuit.

Separation into Design Areas

Start with the site plan showing the location of the different plant types and topography, and use the following general guidelines for separation of the site into various zones (or circuits). Consider this a preliminary effort at this point.

1. Separate the areas containing different plant types.
2. Separate any smaller or odd-shaped areas that may cause difficulty due to irregular spacing of the heads.
3. Try to separate the shaded areas from the sunny portions of the site, if practical.
4. Separate any area subject to higher wind velocities than other parts of the site.
5. Exclude all areas that are not to receive water, such as walkways, sidewalks, etc.

TABLE 7.1 Climate PET Table

Climate*	Inches daily	Gallons per ft^2
Cool humid	0.10–0.15	0.062–0.09
Cool dry	0.15–0.20	0.09–0.125
Warm humid	0.15–0.20	0.09–0.125
Warm dry	0.20–0.25	0.125–0.156
Hot humid	0.20–0.30	0.125–0.187
Hot dry	0.30–0.45	0.187–0.218
	↑ Worst case	

*Cool is under 70°F as an average midsummer high. Warm is between 70° and 90°F as midsummer highs. Hot equals over 90°F. Humid is over 50% as average midsummer relative humidity (dry = under 50%).

Source: Rainbird, Inc.

6. Locate zone control valves in underground enclosures that will provide easy access for the wiring to the solenoid operators and for maintenance.
7. Provide drain valves on the low points of all zones or piping laterals that will allow the entire piping system to be drained. This is particularly important in freezing climates where the system must be drained each winter.

One point to be remembered about selecting the different areas or zones is that the actual amount of water applied to any zone changes, depending on decisions by the building management, and will eventually be based on actual operating experience over a period of time. The zones will be scheduled to be watered on a regular basis at first, and the results will be observed. After some time, the condition of the lawn will show if any trouble spots exist. At that time, adjustments of the scheduling control to different zones will be made. The engineer must give the operator enough flexibility to adjust an individual zone without requiring major alterations to the schedule of adjacent areas.

Sprinkler Head Selection and Layout

Heads do not distribute water evenly over their entire design area. This is because the total quantity of water is spread out in ever-increasing concentric areas. Since the difference in area from the closest to the farthest point for a head with a 50-ft diameter spray is about 9 to 1, the same amount of water is spread over 9 times the area. In order to even out the distribution, heads should be spaced so that adjacent sprinklers overlap each other and the end of the spray radius of one head hits the adjacent head's spray. There is still enough adjustment permitted so that an additional 10 percent separation can be used to even out the area covered by the actual spacing requirements.

Sprinkler heads can be located in either a square or triangular pattern. The triangular method results in wider spacing and is usually better for irregular area boundaries.

If there is a wind condition and the prevailing direction is known, shorten the spacing perpendicular to the wind direction. Refer to Table 7.2 for adjustments to spacing recommended for estimated wind velocities.

1. In each zone, select the different types of sprinkler heads suitable for each plant type, water application rate, geometrical shape of water distribution, and distance of water throw. Use the manufacturers' specification guides to obtain this information.

2. Try not to mix different heads on the same circuit. This is not because the different heads will not work with each other, but they may require adjustment at

TABLE 7.2 Adjustment in Head Spacing for Wind Conditions

For wind velocities of:	Use maximum spacings of:
0 to 3 mph	60% of diameter
4 to 7 mph	55% of diameter
8 to 12 mph	50% of diameter

Source: Rainbird, Inc.

different times in the future. If necessary, it is acceptable to put a few heads of a different type on a circuit as long as the application rate and pressure requirements are the same.

3. Keep the discharge of a different arc head relative to that of a full circle head. For example, the 180° head should have half the discharge of a full head; a 90° head, one-quarter of the discharge of a full head; and so forth.

4. Select a head that operates in the pressure range calculated for the individual zone and is capable of discharging the estimated flow at that pressure.

5. Where heads that deliver a very small amount of water are selected, it is a good idea to provide a strainer in the supply line to prevent the heads from clogging.

Scheduling the System

The piping system as a whole is sized to provide the maximum instantaneous amount of water discharged by the selected heads at the calculated pressure. Scheduling is meant to provide the minimum overall amount of water necessary for a healthy lawn over a period of time. It is quite common to overirrigate a cultivated area. Overwatering is potentially more dangerous to plants than underwatering.

Most irrigation systems are automatically controlled by the use of preassembled and programmable timing devices. They consist of electrically operated time clocks with multiple programmable features and self-diagnostic capability. The system should include the possible connection of moisture sensors to avoid watering in the rain or when there is enough moisture in the soil. The controller is usually connected to a 120 V power supply through a plug. The purpose of the controllers is to turn on and off the zone control valves at predetermined intervals. Locate these controllers in an accessible location at eye level, allowing for easy changes to the timing programs. An electrical engineer will usually be responsible for wiring the controller to the valves and sensors throughout the site.

The most important aspect of the scheduling process is the determination of exactly what the minimum amount of water is. This is accomplished either through experience or with the use of moisture sensors. Other important considerations are that the watering times are consistent with good practice (such as when wind velocity and evaporation losses are at a minimum), the watering is done within the required "water window" of the time frame required by the specific project, the application rate does not exceed the absorption of water into the soil, and the total water applied falls within the range of water capable of being held in the 4- to 6-in soil root zone, which is the depth of grass roots.

Moisture sensors called tensionometers measure the adhesion of water to the soil particles. Since the force required by the roots to take the water from the soil particles is known, the amount of water available for the plant roots can be determined. These sensors, which are placed in the ground and wired to the control panel, will automatically open zone valves to start the water supply. If the soil water tension is too great, more water must be added to the soil. At this time, there are different products available, and a difference of opinion exists between experts as to the number of sensors required to provide adequate information for scheduling the system. Obtain sensor spacing and location criteria from the individual sensor manufacturer. It has been found that when using moisture sensors, more frequent and shorter watering periods work better.

Another way to determine the overall watering requirement is to compare the average rainfall data for the area where the project is located with the PET. The difference is the amount the irrigation system must provide. The Toro Company has a tabular compilation for the United States and Canada (form number 490.1358). If such a document is not available, the National Oceanographic and Atmospheric Administration has the rainfall data for specific areas, and the Soil Conservation Service can provide the PET rate. Shrubs and areas with plants other than grass should use 50 to 75 percent of the grass figure for the amount of water, depending upon the plants.

Many of the figures given are in inches of precipitation or water application. To convert gpm into inches of precipitation, use the following formula:

$$\text{inches per hour} = \frac{96.3 \times \text{gpm}}{\text{ft}^2 \text{ area of head}} \tag{7.1}$$

The Piping System

After the heads have been selected, the spacing of the heads established, and the zones (and zone valves) defined, the next step is to select the piping materials and calculate the water supply requirements for the individual zones in order to size the piping system.

Plastic pipe, because of its cost, ease of installation, and imperviousness, is the most popular pipe material. Polyvinyl chloride (PVC) is generally used for mains under constant pressure and polypropylene or polyethylene for the branches beyond the zone control valves.

The following general rules for sizing the piping system are suggested:

1. In any one zone, keep the friction loss difference to 10 percent between the last head and the first head of the zone. For the system as a whole, use a figure of 20 percent from the last head to the supply source. This is done by selecting pipe sizes that give the required pressure losses.

2. Keep the application rate below the rate where runoff would occur. Table 7.3 lists the maximum precipitation rate based on slope.

3. Use pipe sizing to adjust friction loss between the various branches to meet the 10 percent allowable variation in pressure.

TABLE 7.3 Maximum Precipitation Based on Slope

Soil texture	0 to 5% slope	5 to 8% slope	8 to 12% slope	12%+ slope
Coarse sandy soils	2.00	2.00	1.50	1.00
Coarse sandy soils over compact subsoils	1.75	1.25	1.00	0.75
Light sandy loams uniform	1.75	1.25	1.00	0.75
Light sandy loams over compact subsoils	1.25	1.00	0.75	0.50
Uniform silt loams	1.00	0.80	0.60	0.40
Silt loams over compact subsoil	0.60	0.50	0.40	0.30
Heavy clay or clay loam	0.20	0.15	0.12	0.10

TABLE 7.4 Checklist for Irrigation Designers

Water source/location

- [ ] Meter and size

  or

- [ ] Pump and size

Point of connection

- [ ] Size of pipe
- [ ] Type of pipe
- [ ] Minimum and maximum pressure available
- [ ] Who is responsible for this connection

Backflow prevention assembly

- [ ] Property sized (low friction loss)
- [ ] Meets local code

Master valve

- [ ] Manual
- [ ] Automatic
- [ ] Drain or blowout point

Total system pressure requirement

- [ ] Sprinkler operating pressure

  +

- [ ] Water meter pressure loss

  +

- [ ] Service line loss

  +

- [ ] Control valves loss

  +

- [ ] Backflow preventer loss

  ±

- [ ] Elevation changes

  +

- [ ] Mainline loss and fittings

  +

- [ ] Lateral line loss and fittings (most critical zone)

  +

- [ ] Pump: filter, check valve; regulator: lift requirements

Mainlines and laterals

- [ ] Type of material
- [ ] Depth of bury

Sleeving locations (wire and pipe)

- [ ] Size
- [ ] Depth of bury

Control valves

- [ ] Location
- [ ] Size/flow rate
- [ ] Controller station noted
- [ ] Isolation valve location and size
- [ ] Quick couplers location and size
- [ ] Valve box designation

Control system

- [ ] Controller and location
- [ ] Electrical power and who is responsible for hookup
- [ ] Operations manual with owner documents

Legend and other supporting information

- [ ] North arrow
- [ ] Prevailing wind indicator
- [ ] Scale
- [ ] Water pressure static and design
- [ ] Precipitation rates by zone or area
- [ ] Water schedule and programming calculation
- [ ] Soil type considerations
- [ ] Utilities noted/critical areas
- [ ] Name of firm and designer on all sheets

Detail sheet

- [ ] Rotor detail/swing joint
- [ ] Pop-up sprays/swing joint
- [ ] Stationary sprays/bubbler detail
- [ ] Valve/quick coupler/valve box detail
- [ ] Point of connection detail
- [ ] Controller mounting detail
- [ ] Trenching detail
- [ ] Backflow detail
- [ ] Wire requirements detail
- [ ] Minimum warranty requirements

Source: Used with permission of Eastern Irrigation Consultants.

Table 7.4 can be used as a checklist for any additional basic information that will aid in the preparation of the drawings and the irrigation system as a whole.

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