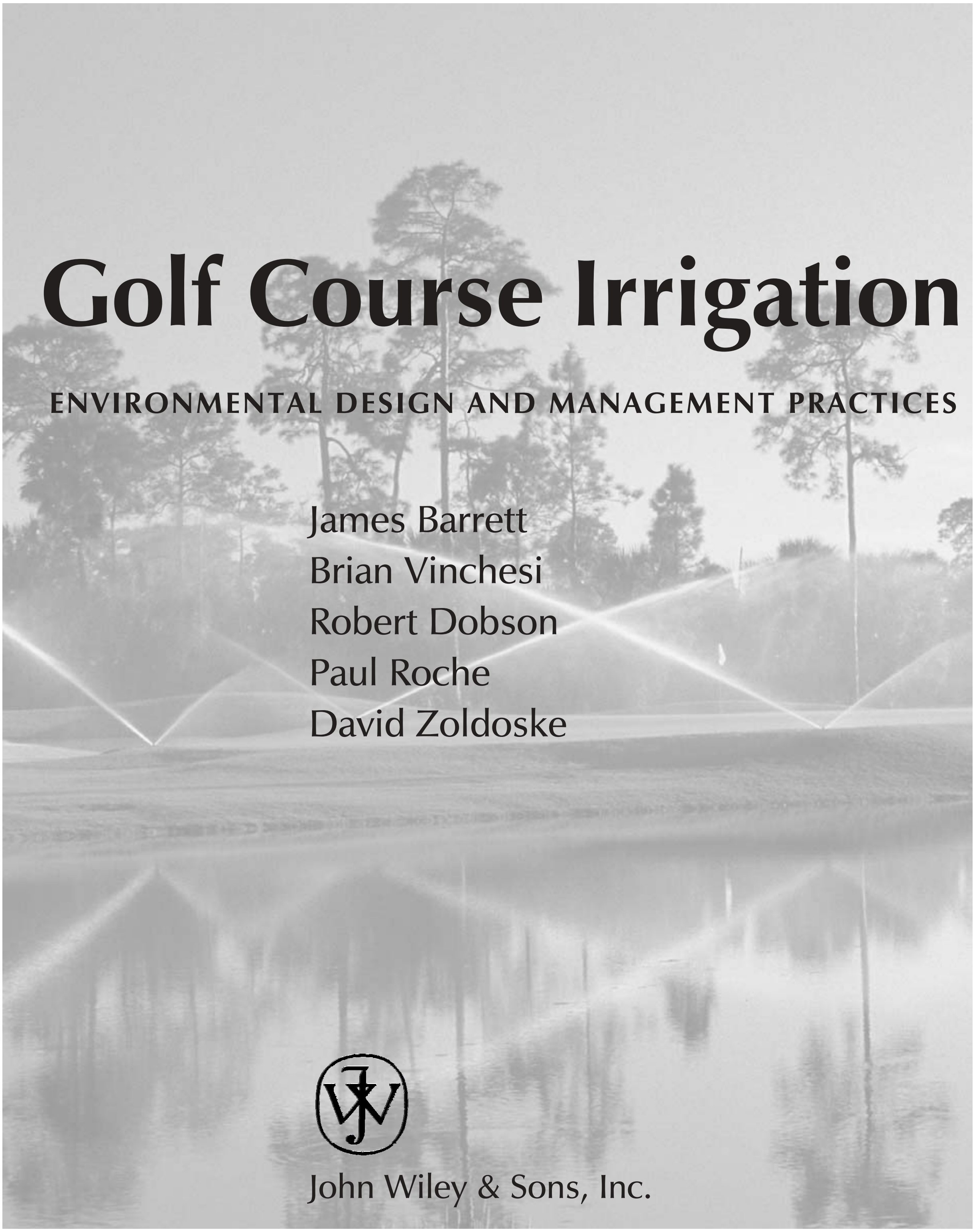

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ENVIRONMENTAL DESIGN AND MANAGEMENT PRACTICES

James Barrett
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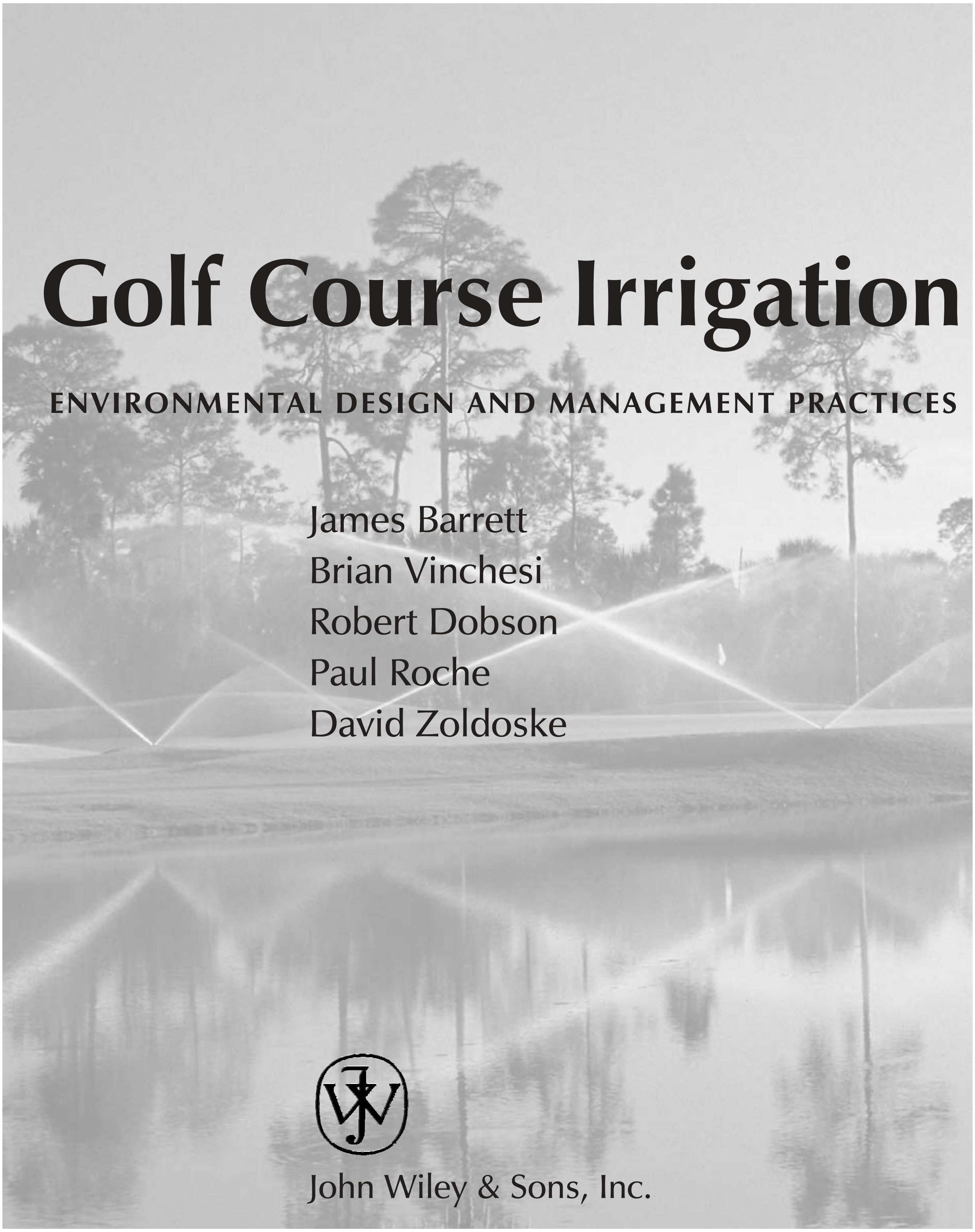

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This book is printed on acid-free paper. ∞

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Preface

There are approximately 17,000 golf courses in the United States alone; more than 300 new ones opened in each of the years from 1991 to 2001. According to the National Golf Foundation, more than 26,000,000 Americans play the game on a regular basis. U.S. golfers spend $22.2 billion per year in equipment purchases and fees.[1] U.S. golf courses spend $8.4 billion per year on maintenance.[2] Golf courses in the United States occupy 2500 square miles,[3] and irrigate approximately 1.3 million acres. U.S. golf courses consume more than 476 billion gallons of water annually.[4] Efficient irrigation is vital to the success of golf course operations. It is equally important to the national and international efforts to efficiently manage water and power.

Golf course irrigation systems range from simple hose outlets for portable sprinklers at greens to elaborate layouts with wall-to-wall coverage by pop-up heads, multiple pump stations, and highly sophisticated automatic control systems. The vast majority of existing systems in the United States are automatic, as are most of the new ones being installed. The cost of materials and installation for an 18-hole automatic system can range from $400,000 to more than $2,000,000.

Regardless of its scope or cost, an irrigation system is the single most important maintenance tool available to the golf course superintendent. The condition of the course has an obvious and direct effect on the success and bottom line of a golf facility, not to mention the effect it can have on the status of the superintendent's employment. The lack of a reliable and efficient irrigation system severely limits the superintendent's ability to produce playing conditions of the highest quality.

Competition among golf facilities to attract players is currently fueling a movement to improve all aspects of courses. In recent years there has also been an increasing demand by players for improved aesthetics and playing conditions on golf courses. This is probably due in large part to the fact that American golfers have been watching televised tournaments for nearly forty years. Tournament courses, particularly those used for the majors, are specially prepared for three years in advance. In the weeks immediately preceding a tournament, and during the event itself, extraordinary (and, some would say, outrageous) maintenance procedures are undertaken to ensure that the course looks and plays the best it possibly can.

Few, if any, courses can afford these extreme measures on a year-round basis, and turfgrass cannot survive for more than a few weeks under tournament conditions anyway. Nonetheless, golfers are demanding optimum conditions at the courses they play on a regular basis.

The endeavor to raise the quality of a course parallels a superintendent's ongoing efforts to be environmentally responsible and to conserve water and energy by all means possible. There is a finite supply of fresh water on the planet. Ninety-seven percent of the world's water is in the salt oceans. The remaining 3 percent is fresh water, but two-thirds of that is tied up in glaciers and polar ice caps. Therefore, only 1 percent of all water on the planet is available for all of humankind's use.

There are already shortages in many areas, and the mushrooming world population will continually increase pressure on the existing supply of fresh water. Although golf is not a big consumer of water in comparison with agriculture or manufacturing, it is still a significant user and a highly visible one. It is absolutely imperative that superintendents, equipment manufacturers, consultants, and system designers take all possible measures to eliminate the waste of water and optimize its use.

The same concerns apply to electric power. The application of unnecessary or excessive amounts of water and/or pressure results in a parallel waste of electric power at the pump station. Unnecessary use of power not only contributes to the frequent brownouts and outages experienced in summer months, but its generation also requires consumption of other natural resources, negatively impacting the environment.

In response to the demand for improved conditions, superintendents are employing more intensive maintenance practices, and one of the key ingredients is an efficient irrigation system. Such a system is also a necessary tool in conservation efforts. Manufacturers of irrigation equipment have responded with improvements to existing products and with the development of more efficient and reliable sprinkler heads, nozzles, sensors, valves, controllers, and pump stations.

Consultants and designers of golf course irrigation systems have risen to the challenge with innovative concepts intended to provide more precise and efficient irrigation without waste of water and power. Examples include low-pressure heads, individual head control, shorter-radius heads at closer spacing, part-circle perimeter heads around greens and other areas, and special treatment of areas such as south-facing slopes and the steep framing mounds often found around bunkers and greens. More sensors are being incorporated into designs and combined with “if/then” logic in the controls so that system operation can be automatically modified in response to changing conditions even during an irrigation cycle.

The resulting systems combine more uniform distribution with more accurate control and more precise timing. The key result on the golf course is more uniform playing conditions, with the ball landing and rolling the same speed on all fairways, on all approaches, and on all greens throughout the course. Turf in irrigated rough will also be more consistent, so that shots hit off-line will be uniformly penalized. Equally important, the improved accuracy and precision of properly designed systems helps in the effort to minimize the waste of water and power.

There are many differences between irrigation systems on golf courses and most of those intended for residential and commercial projects. These differences help to explain why golf course irrigation must be treated separately from other forms of turf and landscape irrigation. The components (pipe, fittings, sprinkler heads, valves, etc.) in golf systems are larger. System flow rates and operating pressures are substantially higher. With the higher operating pressures, designing to accommodate surge pressure or water hammer is more critical in golf systems. Typical golf course pump stations are complex and involve much higher voltage and amperage power. The hydraulic and electrical networks in golf systems are a great deal more elaborate and complex because of the nearly infinite flexibility of the control systems. The higher pressures and voltages in golf course systems make the safety of operating and maintenance personnel (and even players) a serious consideration. The potential for personal injury makes liability issues a real concern for manufacturers of irrigation equipment and for the designers, installers, owners, and operators of the systems.

Whereas most residential and commercial systems get their water from municipal potable distribution systems, golf course water sources can be wells, wastewater treatment plants, rivers, ponds, or lakes, and thus there can be significant water quality issues. And although most residential and commercial systems rely on the municipal system for operating pressure, nearly all golf systems require a dedicated pumping installation.

The end user (the golf course superintendent) is much more knowledgeable about irrigation and turfgrass management than most residential or commercial clients. He or she, therefore, has considerably higher expectations for system design, performance, and reliability.

The value of the turf on a golf course is generally much greater than that in a residential or commercial project. The potential for serious financial loss in the event of an irrigation system failure is also much higher for a golf course. Off-color or dead turf can result in very unhappy home owners or mall developers, but they usually do not lose money because of it. Inconsistent playing conditions or loss of turf on a golf course will definitely reduce the bottom line on the balance sheet and may cost one or more people their jobs.

This book is intended to be a practical tool for hands-on people involved in golf course irrigation rather than an in-depth explanation of the theoretical issues involved in the design and operation of irrigation systems and their components. The information it offers can prove valuable to golf course superintendents and irrigation technicians; golf course architects, irrigation consultants, and system designers; golf course developers, builders, and irrigation installers; and irrigation manufacturers and their distribution personnel. It can also be of value to instructors and students of irrigation, both in a college setting and in professional or vocational training programs such as those provided by the Irrigation Association and various local or state agencies and associations.

The construction of modern golf courses is expensive, as is the maintenance of the finished product. The irrigation system is a key tool in both the grow-in and long-term maintenance of the course. It is imperative that the system be designed, installed, operated, and maintained so that it will remain efficient and reliable for a long period of time.

Golfer demands for better playing conditions, growing pressure from regulatory authorities, new and ongoing environmental issues, and increasingly critical shortages in water and energy supplies all highlight the need for the most accurate, efficient, and reliable irrigation systems possible. Golf courses are highly visible users of our limited water supplies, so the design, installation, management, and maintenance of their systems must be of the highest quality to provide the best possible playing conditions, to avoid waste of water and energy, and to prevent adverse effects on the environment.

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1 Plant Irrigation Requirements

This chapter introduces the relationships between the turfgrass plant, the host soil, and the irrigation water, which are key to proper irrigation design and management. It provides information on water movement through different soils and water uptake by plant roots. It discusses the concept of evapotranspiration (consumptive use) and its role in the calculation of water requirements. The chapter also includes information on various turfgrass types, their water requirements, and their relative drought tolerances.

SOIL-WATER-PLANT RELATIONSHIPS

Irrigation concerns the relationship between how a soil holds and stores water and how a plant uses water. Although you do not need to know a great deal about soil physics or plant physiology for proper irrigation, you do need to have a general knowledge of soils and to be familiar with how a plant, in this case turfgrass, uses water and uptakes it from the soil. There are a number of terms and concepts you should be familiar with in order to understand the soil-plant-water relationship.

Soils

A soil is made up of various amounts of sand, silt, clay, and organic material, as well as pore space. The pore space is filled with either air or water. The ideal mixture is 50 percent soil, 25 percent water, and 25 percent air. Under these conditions the turf expends a minimal amount of energy to uptake water and nutrients.

Texture is defined as the relative proportions of sand, silt, and clay in a soil. Texture cannot be changed or destroyed. Using an estimate of the percentage of each type, a soil can be classified in one of the 11 categories shown in the textural triangle in Figure 1.1. For example, as indicated in the textural triangle, a soil consisting of 50 percent sand, 30 percent clay, and 20 percent silt would be classified as a sandy clay loam.

The structure of a soil is defined by the arrangement of the various components that make up the soil texture. There are many types of soil structures, each with a specific name for its formation. In irrigation, a structure that allows for a high water-holding capacity is preferred. This structure is one that has medium-size pore spaces that

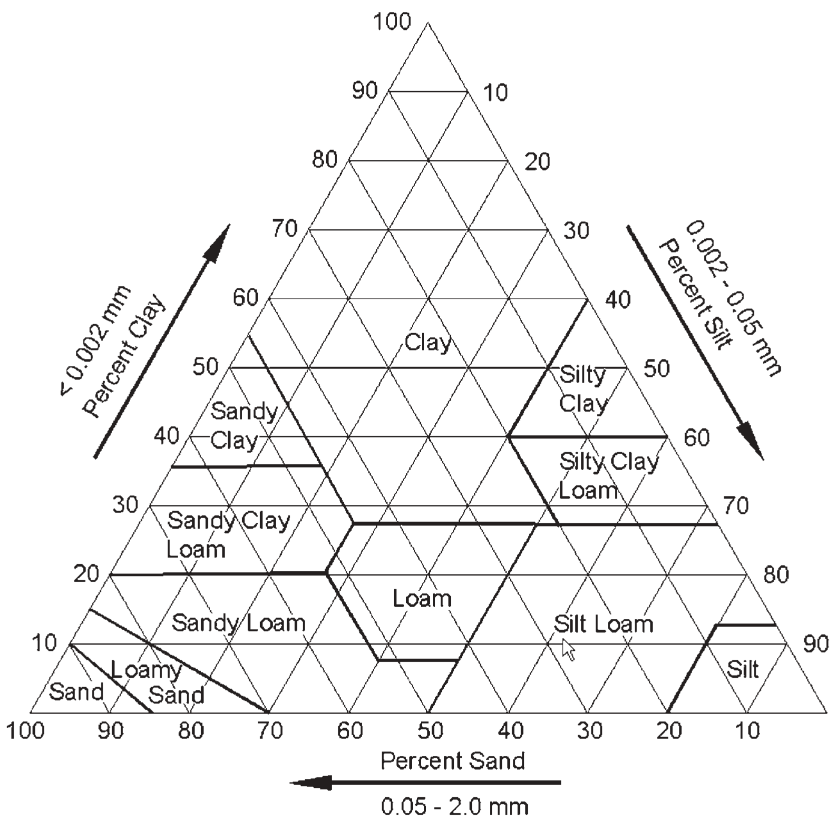

FIGURE 1.1
A textural triangle is used to generalize soils based on the percentages of silt, clay, and sand contained in the soil. *(Courtesy of the Irrigation Association.)*

allows for some drainage but does not hold the water too tightly to the soil particles, such as clays. The structure of a soil can be easily changed with the use of various types of mechanical equipment such as rototillers, aerifiers, or bulldozers.

If you were to dig a deep hole in the ground with a backhoe and then jump into the hole, you could see how a soil consists of different layers. Each time the soil changes color, structure, texture, or other characteristics, there will be a distinct layer. These layers are called soil horizons. The makeup of all of the horizons in a soil create the soil profile. In a soil profile, the top layer, the soil growing the turf, is the first, or A, horizon. A small difference in the soil characteristics may make it the A1, A2, or A3 horizon. A significant change in the soil will change it to the B horizon. The C horizon is usually the parent material from which the upper horizons descended. In an undisturbed soil these horizons can be very old and quite consistent over large areas. On a golf course, significant grading has probably taken place as well as substantial amount of cutting and filling. As a result, the soil profile has been manipulated and the sequencing of the horizons disturbed. It is not uncommon to have the C horizon on top, with the original A horizon buried and the new A horizon probably brought in from another area of the site or imported onto the site. In dealing with a manipulated soil, it is important to figure out how the soil characteristics change with depth. On golf courses it is not uncommon to have a highly compacted impermeable layer of soil beneath the topsoil, or the A horizon, causing some irrigation and drainage problems.

Intake Rate

A soil's intake (infiltration) rate is a measure of how fast the soil will take in water, measured in inches per hour. In a dry, bare soil, the soil intake rate will initially be very high, but it slowly decreases to a point where it becomes consistent over time. Although the rate will be high at the beginning, in irrigation it is the leveled-off or basic intake rate that is of interest. Ideally, an irrigation system would never apply water at a rate greater than the intake rate of the particular soil being irrigated. On a United States Golf Association (USGA) regulation green, this ideal is easily obtainable, as the intake rate is significantly higher than the precipitation rate of the sprinklers. On a push-up green (constructed simply by shaping the existing soil—no drainage, gravel layer, or soil amendments are installed), however, the precipi-

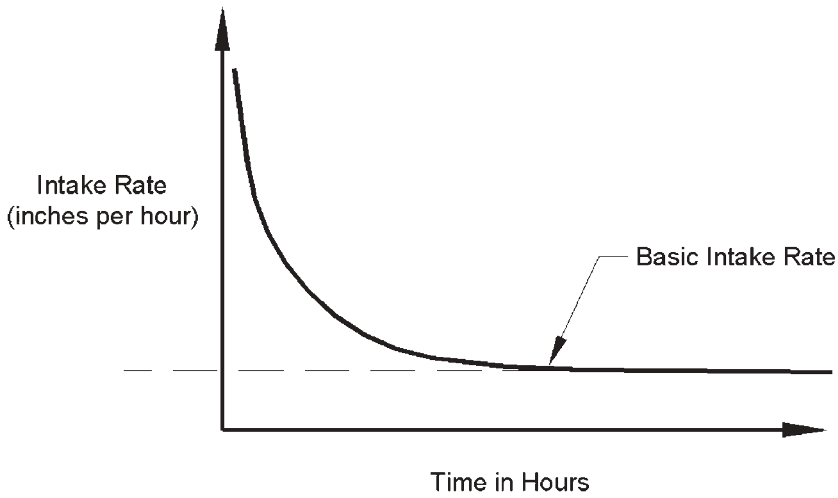

FIGURE 1.2
Generalized soil intake graph, intake rate versus time. *(Courtesy of the Irrigation Association.)*

tation rate may exceed the intake rate of the soil. To properly schedule irrigation and prevent runoff and puddles, the intake rate of the soil must be considered (Figure 1.2). If the precipitation rate of the irrigation system exceeds the soil intake rate, cycle and soak scheduling may be necessary to apply the required water efficiently.

Turf cover, compaction, and thatch all decrease the soil's intake rate. Compaction during construction, or even by the sprinklers operating at a pressure that is too low, will influence the intake rate over time. Thatch buildup will decrease the intake rate, as may the long-term use of effluent water, depending on its quality. If you have identified your soil type from the textural triangle, then a water intake rate can be estimated from information provided in a textbook on soils.

Soil Water Storage and Movement

The storage and movement of water in a soil is of great importance in scheduling irrigation efficiently and effectively. As the soil goes from wet to dry, the relationship of the water to the soil changes, as well as the type of movement and amount of storage (Figure 1.3). If you were to start with a dry soil and then irrigate it until it puddles or runoff occurs, the soil would have all its pore space filled with water and the soil would be saturated. If you stopped irrigating, the soil pore spaces would start to drain over the next 24 to 48 hours, and all of the water movement would be gravitational. At some point in time, the gravitational movement and drainage would slow to a very

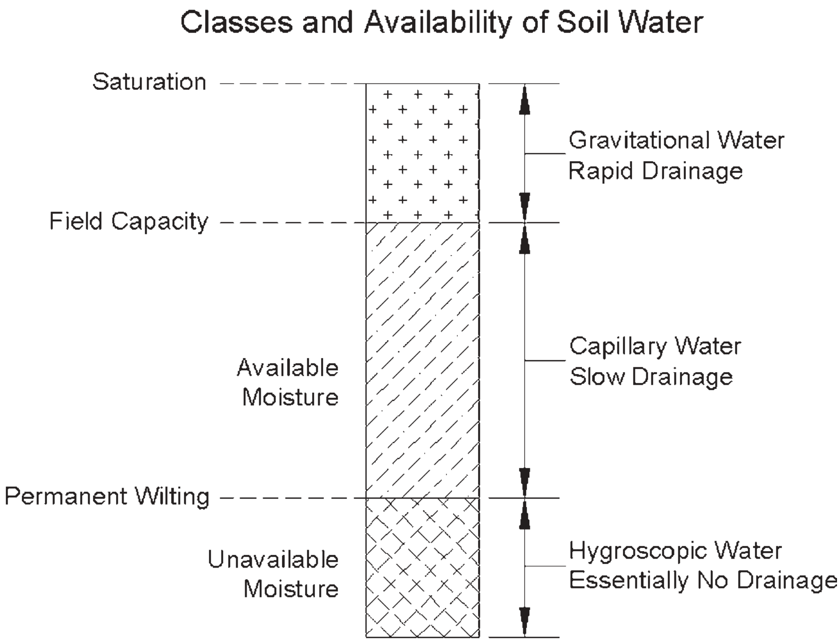

FIGURE 1.3
Soil moisture movement terms.
(Courtesy of the Irrigation Association.)

low rate. At this point the soil pore space would be approximately 25 percent water and 25 percent air. The soil particles would be holding the water to them with adhesive forces (soil to water), thus keeping the pore spaces from draining any further. At this point the soil is said to be at field capacity. Field capacity in regard to soil moisture can be defined as the point where water is most available to the plant. Because the turf consumes water between irrigation or rainfall events, the amount of water available to the plant continues to decrease. The movement of water at this stage is caused by capillary action. The cohesive (water-to-water) forces move the water from the soil pore spaces to the roots for uptake by the turf. This will occur for some time, with the turf having to exert more and more force to pull the remaining water away from the soil particles as the soil dries out. This process will continue until the soil reaches the permanent wilting point. At this point, the soil moisture will be severely depleted and the turf can no longer exert enough energy to pull the water away from the soil. At the permanent wilting point there is still water in the soil, but it is held so tightly by the soil that the plant cannot use it. The remaining moisture is hygroscopic water, which can be removed only by applying heat to force drying (i.e., "oven dried" soils).

Water-Holding Capacity

Between field capacity and permanent wilting point is the available water-holding capacity of the soil. Again, if you have generalized the type of soil from the textural triangle, a soils text or Internet site can provide information on the particulars of a soil's water-holding capacity in either inches of water per foot of soil or inches of water per inch of soil. For example, a sandy clay loam may hold 1.6 in. of water per ft of soil. Although this is the total amount of water held between field capacity and permanent wilting point, all this water may not be available to the plant. It is difficult for plants to obtain water below the root zone, so root zone depth is an important consideration in irrigation scheduling, as it severely limits water availability and thus dictates the irrigation interval.

By relating the root zone depth to the available water-holding capacity of the soil, the amount of water available to the turf can be determined. For example, if the turf has a 6 in. root zone and the sandy clay loam (mentioned earlier) has a capacity of 1.6 in. per ft, the available water-holding capacity would be 0.8 in. (1.6 in./ft × 0.5 ft). A 3 in. root zone would have half the available water-holding capacity of a 6 in. root zone, or 0.4 in. (1.6 in./ft × .25 ft).

Irrigation Interval

In scheduling irrigation frequency, it is best to replenish the available water supply before reaching the permanent wilting point. Target levels have been identified for different crop types, including turfgrass. A target level is referred to as management allowable depletion (MAD). It is a management decision as to how much of the available water should be depleted before the next irrigation occurs. For turfgrass, the MAD has been determined to be about 50 percent by most agronomists. For example, applying a MAD of 50 percent to 0.8 in. of available water at field capacity results in a target of 0.4 in. of water being extracted by the turfgrass (0.8 in. × 0.50) before the next irrigation event. The next irrigation will be a net water application of 0.4 in. to fully refill the root zone. The time (days) it takes the turfgrass to consume the target MAD of 0.4 in. of water is referred to as the irrigation interval.

EVAPOTRANSPIRATION

Water evaporates from soil and transpires from plant leaves. Together, these two phenomena are referred to as evapotranspiration (*ET*). There are several methods used to estimate the *ET* rate or value. For research purposes, a weighing lysimeter has been used to measure the loss of water from turfgrass plots. Typically, soil is placed in a box that is supported beneath by a weighing scale. Turfgrass is planted on the soil surface, well irrigated, and properly maintained. The surface area of the planted turfgrass and the change in weight due to evapotranspiration (water use) are measured. These two measurements form the water use requirements. These measurements are usually expressed in fractions of an inch of water consumed per day, or daily *ET* rate.

Lysimeters are too complex and expensive for normal water management, so weather conditions, such as wind speed, temperature, sunlight intensity, humidity, and other parameters are often measured to calculate the amount of *ET* or plant water use. Researchers, such as Penman (1948), developed formulas from their investigations to estimate potential crop water use based on changing weather conditions. A modified Penman equation is currently used by most publicly accessible weather stations in California to estimate crop water demand.

There are several variations of the *ET* definition or measurement that may be available. They all have slightly different meanings. ET_c or *ET* crop is the water use rate of the crop (turf) that is being scheduled or managed. ET_c is the amount of water that evaporates from the soil surface and transpires from the leaf surface to the atmosphere.

Calculating the *ET* of turf for an irrigation schedule usually begins with the acquisition of a reference *ET* value. Reference ET_o, as defined by Doorenbos and Pruitt (1975), denotes the "the rate of evaporation from an extensive surface of green grass cover, of uniform height, actively growing, completely shading the ground, and not short of water." This is the most common example of the use of the Penman equation to calculate evapotranspiration for a specific reference plant cover. Other examples often available are ET_p and sometimes ET_r. These are modifications of the Penman equation that calculate *ET*'s for reference crops other than turf. The Irrigation Association website includes an extensive list of *ET* sources for the United States.

Such calculations are widely used in the western United States by the U.S. Bureau of Reclamation to estimate agricultural crop water use requirements. This measurement is based on work developed by Jensen et al. (1970), in which ET_r "represents the upper limit or maximum evapotranspiration that occurs under given climatic conditions with a field having a well-watered agricultural crop with an aerodynamically rough surface, such as alfalfa with 12 in. to 18 in. of top growth." The ET of the plant cover being managed (ET_c) is related to the various ET's (ET_o, ET_p, ET_r) by a value known as the crop coefficient (K_c). The mathematical relationship is defined as:

$$K_c = ET_c/ET_o \text{ or } ET_r$$

where:

K_c = crop coefficient
ET_c = evapotranspiration of the crop or turf being managed
ET_o = evapotranspiration—grass-based
ET_p or ET_r = evapotranspiration—alfalfa-based

However, because ET_o uses grass as a basis, versus ET_r, which uses alfalfa, the resultant crop coefficients can vary considerably. That is why it is critical to match the proper reference ET with the correct K_c adjustments. Using ET_o-based K_c's with ET_r reference values, or vice versa, can result in significant errors in water use estimates.

Crop coefficients are seasonally adjusted values that take into account the crop type, stage of growth, and crop cover. For example, the difference in K_c between a Bermudagrass and a tall fescue grass could be substantial. The K_c developed during April for Bermudagrass is 0.72 or 72 percent of ET_o. For tall fescue during April, the K_c is 1.04 or 104 percent of ET_o. This is a potential difference of 30 percent for applied water. Other months vary to a lesser degree. Also note that the K_c values used in the preceding example apply to southern California geographic conditions. These values or coefficients are developed for specific regions, so be sure to select the appropriate references.

TURF TYPES

A key component in determining the plant water requirement is identification of the species and variety (cultivars) of the turfgrass. For new construction, the type of plant material must also be identified to estimate water requirements in the irrigation design phase.

Of the more than 1200 different turfgrass species available, only 20 to 25 are suitable for the golf industry. The reason is that most of these plants do not meet the requirements of heavy traffic, low cutting heights, disease tolerance, leaf texture, seedling vigor, and drought tolerance. There is a large ongoing effort to breed new turfgrasses that require less water, have deep root systems, and demonstrate improved salt tolerance.

Water has several key functions in a plant. It acts as a nutrient carrier within the plant; as a solution carrying nutrients in the soil to the roots; and, in the plant leaves, as a temperature regulator. Water is also required for absorption by seeds during germination. Of all the water consumed by a plant, only about 2 percent is used for metabolic purposes. The rest is used for cooling and respiration.

Excessive moisture levels can have detrimental effects on turfgrass, such as oxygen deficits and the unnecessary leaching of nutrients from the root zone. The available water must be managed in the root zone between the MAD and field capacity.

Generally, turfgrasses are grouped into two basic categories: warm-season grasses and cool-season grasses. The temperatures in which they thrive and length of growing season classify these two groups. Warm-season grasses are most active when temperatures are between 80°F and 90°F and will go dormant in cool winter months. Cool-season turfgrasses prefer 60°F to 75°F and will stay green year-round. In terms of plant water use, cool-season grasses tend to consume more water than warm-season grasses under similar weather conditions.

Although turfgrasses are classified into cool- and warm-season categories, each species and cultivar may have particular behavioral characteristics. Factors that influence behavior include soil type, shade conditions, air and soil temperatures, water quality, mowing heights, and other cultural practices.

The following guide can be used for estimating relative plant water use requirements:

Relative Drought Tolerance—Cool-Season Turfgrass

Bluegrass	Low to medium
Annual bluegrass	Low
Fescue	High
Ryegrass	Medium
Creeping bentgrass	Low

Relative Drought Tolerance—Warm-Season Turfgrass

Bermudagrass	High
Zoysia	High
Carpetgrass	Medium
St. Augustine grass	Medium
Buffalograss	High

Fescues tend to have the greatest tolerance for drought as cool-season grasses, primarily because of their rolled leaf structure, which protects the stomates from exposure during stress. The warm-season Bermudagrass tends to have an extensive, deep root system that aids it in extracting water from the soil.

Excellent sources for regional information on appropriate turf-grasses are local experiment stations and university programs. In addition, the National Turfgrass Evaluation Program (NTEP) can be contacted for information on regional turfgrass trial data at www.ntep.org.

Water Use Calculations

Reference *ET* values can be obtained from several sources. The most effective is a weather station located on or near the golf course. There are specific siting requirements for weather stations, but they generally include an unobstructed area around the station, irrigated and maintained turfgrass, and available power. Too many sites are located next to equipment yards where buildings interfere with wind measurements and heat is radiated from asphalt and concrete areas. Automated weather stations that read directly to a desktop computer are available with software that will calculate a reference *ET*. Be sure to get K_c values that match the particular reference *ET* calculated by your specific weather station.

Other sources of *ET* values are government-sponsored weather stations and local weather reporting. Some of these sources are available through the Internet. For example, WateRight.org provides *ET* values and matching crop coefficients and calculates irrigation requirements.

The procedure for estimating crop water requirements in "real time" is sometimes explained as the checkbook method. The analogy is that you start with a balance of money in your account; as you write checks and deduct the amounts from your balance, there is less money available in the account. From time to time money must be deposited back into your account or the account will become overdrawn. And just like you, a turfgrass will experience stress when the account (of water) is overdrawn.

In determining irrigation amounts and frequencies, the available water in the root zone should be considered as the bank account. Each day the grass extracts water (writes a check) from the available water account. The amount of water taken from the root zone (size of the check) is determined by the weather conditions (*ET*) and turf type

(K_c). The soil's water-holding capacity and depth of root zone determine the amount of water available (the size of the initial balance). The grass cannot withdraw more water than it has available, or it will die.

Calculating the size of the daily *ET* is the most difficult part of the process. Generally, water use calculations begin with a reference turf *ET* value for the local area. Next, the correct K_c value must be identified and used for the *ET* value (crop, period, and reference). *ET* values are usually expressed for a period of time (e.g., day, week, or month). Weekly *ET* values are normally sufficient to track seasonal changes in water use. There is typically enough water storage in the root zone to accommodate daily swings in *ET* during the week. However, using a monthly average may put the crop health in danger because of extended weather fluctuations.

The calculation is

$$K_c \times ET \text{ reference} = \text{crop water requirements for the calculated period of time.}$$

A more specific example is the use of a reference ET_o (grass-based) value of 1.8 in. per week for a week in May, say the first through the seventh. The calculated K_c value for Bermudagrass in May is 0.79 for a particular area. To estimate the crop water use for this first week in May, the following calculation is performed:

$$\text{Net water requirement expressed in inches for that week (1.42)} = K_c\,(0.79) \times ET_o\,(1.8)\text{ in./week}$$

where

K_c = crop factor for selected crop (Bermudagrass), time of year (May), and geographic region (Arizona)

ET_o = measured grass-based evapotranspiration for period of time (in./week)

The next week the weather could change and the ET_o could be higher or lower, but the calculation would be the same. If the calculation were performed for the last week in April instead, you would use a slightly lower K_c value, 0.72, to multiply by the estimated ET_o value for that week.

In summary, know your reference *ET* (grass- or alfalfa-based), identify the correct crop coefficients, time of year, and geographic region. The total calculated turf *ET*s since the last irrigation will be the amount to use when determining the total net water requirement for the next irrigation schedule.

Remember, the estimated crop water usage is not the amount of water you need to apply. System uniformity must also be accounted for in the total water application amount, along with any leaching fraction.

Leaching Fractions

Leaching fraction or requirement (Lr) is the amount of additional irrigation water required to move salts out of the root zone to maintain a healthy growing environment. The amount is dependent on numerous factors, including the salinity of the soil, soil type, water quality, rainfall, drainage, and crop tolerance. Probably the single most important factor is the quality of the water. This is especially true for golf courses that use effluent water supplies. The water quality sets the lower limit for the minimum salinity that can accommodate turfgrass growth. The water quality is usually expressed as the electrical conductivity (EC) of the water.

When plants extract water from the soil, salts are left to accumulate in the soil. Over time the level of salinity can build up to the point where it is toxic to the plant. Excess irrigation or rainfall will push the accumulated salts below the root zone, maintaining a healthy growing environment for the turfgrass.

In areas of limited summer rainfall, irrigation water is used to leach or "push" salts out of the root zone. With sufficient flushing, the EC of the soil will approach the EC of the water. The challenge is to determine exactly how much overirrigation to apply. The process starts with knowing the salt tolerance of the plant or turfgrass; this sets the minimum salinity level that can be used without damaging the turfgrass. Obviously, the EC of the irrigation water must be equal to or less than the tolerance limits of the crop.

In developing an irrigation schedule when salinity is a concern, it is important to make an estimate of the minimum quantity of water required to move excess salts out of the root zone. This quantity or leaching requirement may be estimated by using the salt balance equation developed by Hoffman and Van Genuchten (1983):

$$Lr = \frac{EC_I}{EC_D}$$

where

Lr = leaching requirement, the percentage of the irrigation that should pass through the root zone

EC_I = electrical conductivity of the irrigation water (dS/m) being applied

EC_D = electrical conductivity of drainage water above which turf damage occurs

In managing conditions of high salinity, the uniformity of the sprinkler system is extremely important. To meet the leaching requirement of the driest coverage areas (10 or 20 percent), a tremendous amount of water is wasted in the wetter areas in the form of overirrigation with nonuniform systems. Because the leaching requirement is only an estimate, periodic monitoring of the salinity in the root zone is highly recommended to maintain the appropriate salt balance.

Maintaining the appropriate salt balance is critical for several reasons. These include the health of the plant and the need to minimize the cost of water and energy wasted through overirrigation. But perhaps most important, when overirrigation occurs, it moves fertilizers and chemicals with the water toward underground aquifers. The intended efficacy of these materials is lost when they are moved below the root zone. Moreover, many of these underlying aquifers are close to cities and homes that use this water source for human consumption. If contaminants show up in public water supplies, and can be traced to mismanagement at the golf course, fines and/or litigation are likely to follow.

SOURCES

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2 Water Supply: Quantity and Quality

This chapter discusses the different types of water sources and the benefits and problems associated with each. Quality requirements for turf irrigation water are covered, as well as information on cross connection, the related health hazards, and backflow prevention procedures and devices.

SOURCES, WITHDRAWAL PERMITS, AND WATER RIGHTS

In the beginning stages of any irrigation system design it is essential to identify and, in most cases, obtain permits for an adequate water supply. The water supply must be large enough to provide the needed amount of water for the irrigation system; it must also supply water of acceptable quality throughout the irrigation season. Water is a finite resource, and there is increasing competition by all parties interested in using it. It is becoming more and more difficult to obtain water for golf course irrigation systems.

There are many ways a golf course can obtain water for its irrigation system. Some courses may have several different sources available, and an analysis of which will be best for a proposed irrigation system will be needed. Factors such as quantity, quality, location, elevation, and the availability of power must all be considered. Some courses may have only one available water source, and others may have to use a combination of sources to get adequate supplies. Sometimes a source will be obvious, and in other cases tens of thousands of dollars may be spent to locate and develop an adequate source of water.

Whatever the source of water, in most eastern states a water withdrawal or diversion permit is required of a party intending to use the water. Such permits can be difficult to obtain in some states or in areas where water supplies are under stress, and relatively easy in others. It will depend on the location of the course, what the competing uses are, how much water is being requested, and what type of water source is being proposed as the supply. In the western states, water rights can be a very large issue. The right to water is deeded to the user just like a piece of property. A water right is not necessarily attached to the property rights, so a developer can own a piece of property but have no right to the water on it or under it. Conversely, a person can own water rights without owning the property where the water is located. A right to use the water may have to be purchased, which usually entails a significant cost. Water right law is a booming business with the ever-increasing competition for water. A thorough investigation should be undertaken to determine whether there are rights to any water before a golf course irrigation project is initiated.

MUNICIPAL SOURCES

Municipal sources offer a consistent supply of water at the designated flow and a minimal pressure, for the most part, without interruption. Because the same system supplies drinking water to the populace, if there is a problem it will be rectified quickly. The water is there, 24 hours a day, 365 days per year. However, during a drought the situation can change significantly. If water restrictions are put in place, the use of municipal water may be curtailed. Under severe restrictions, golf courses may be limited to watering only the greens. With municipal sources, there is a fee for using the water. This fee varies with location and the amount of water used, ranging from a few thousand