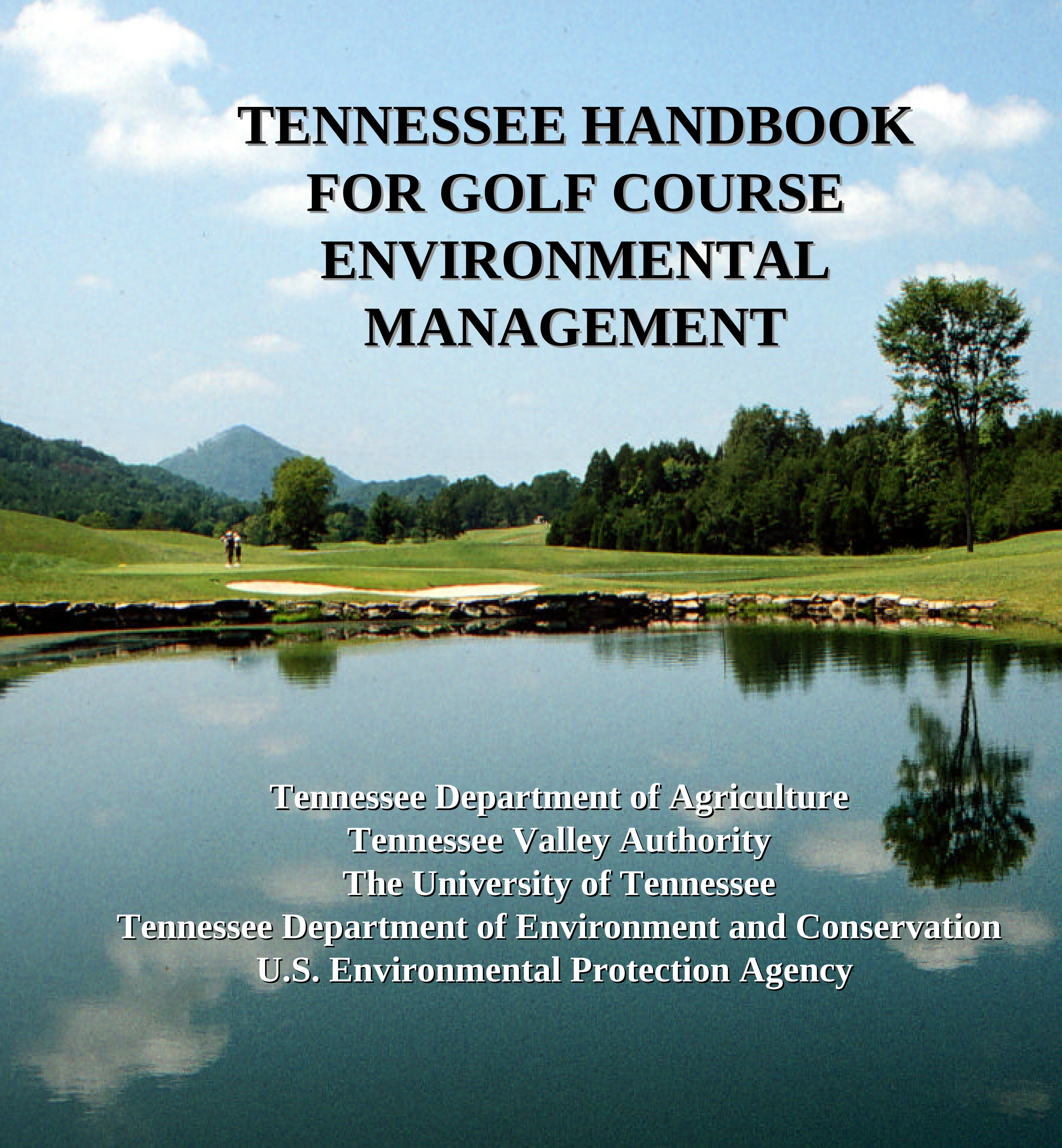
TENNESSEE HANDBOOK FOR GOLF COURSE ENVIRONMENTAL MANAGEMENT



Tennessee Department of Agriculture
Tennessee Valley Authority
The University of Tennessee
Tennessee Department of Environment and Conservation
U.S. Environmental Protection Agency

TENNESSEE HANDBOOK FOR GOLF COURSE ENVIRONMENTAL MANAGEMENT

EXECUTIVE SUMMARY

For the past six years, several federal, state, and local organizations have worked cooperatively to conduct an extensive pollution prevention program in Tennessee. The main focus of the program is to reduce or eliminate potential contamination of Tennessee's water resources from fertilizers and pesticides. The program consists of several components, including development of a state management plan for protection of groundwater from pesticides, initiating an environmental stewardship public awareness campaign, and providing environmental information and technical assistance to enterprises and businesses involved in fertilizer and pesticide handling.

The Tennessee Department of Agriculture (TDA), its partners, and the golf course industry recognize the need for cooperative development and promotion of ecologically sound management of golf courses. This is especially important for maintaining an economically stable, viable business and recreation enterprise in an era of increasingly complex technical and regulatory issues.

This publication was a cooperative effort of the TDA, Tennessee Valley Authority (TVA), The University of Tennessee (UT), and the Tennessee Department of Environment and Conservation (TDEC) in consultation with the Tennessee Golf Course Superintendent's Association (TGCSA) and other organizations. It is provided as a source of readily available, multi-disciplinary data, information, and references for conducting golf course fertility and pest control operations in Tennessee in an environmentally sound manner.

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SECTION 1.0
INTRODUCTION

Golf has become one of the leading participatory sports in the United States. Today, more than 26.4 million people age 12 and over play the game (NGF, 2000a). In 1986, less than 20 million people played golf. However, in the past ten years, the sport has witnessed a 33 percent increase in participants, including an 11 percent increase among females and a 43 percent increase among junior golfers. Consequently, there is an increased demand for more golf courses.

The number of new golf courses in the United States has grown more than 25 percent over the past 14 years (NGF, 2000a, 2000c). Within the past ten years, the rate of new golf course construction has significantly increased from an average of almost 150 courses per year to more than 400 per year. Today, there are a total of 16,743 golf courses in the United States This includes regulation, par-3, and executive length courses. Of these, 71 percent are open to the public.

In 1999, a record 509 new golf courses located throughout the United States were officially opened (NGF, 2000c, 2000d). Of this number, 13 were reconstructed courses, 169 were additions to existing facilities, and 241 were 9-hole courses. At the end of the year, 936 courses were under construction and 903 were in the planning phase. Today, almost half (46 percent) of golf courses being considered or being constructed are a part of real estate development, with about 15 percent of all golfers permanently residing in a golf course community.

Tennessee has contributed to the expansion trend in the United States golf course development. With over 300 golf courses in operation, the state currently ranks 21st in the United States in total number of golf courses (NGF, 2000c). Of these, about 47 percent are daily fee, 20 percent are municipal, and 33 percent are private courses. Presently, ten new courses are under various stages of development, with six of these involving other real estate (NGF, 2000b).

The average acreage of golf courses varies depending on the type of course, layout, and topography. Generally, the average acreage of a 9-hole course is about 62 acres, and an 18-hole course is about 133 acres. Golf courses in the United States occupy approximately 1.3 million acres (Balogh, 1992a). In Tennessee, golf courses cover a total of about 22,745 acres.

One of the major environmental issues and public concerns with golf courses is contamination of both surface water and groundwater with nutrients and pesticides used in intensive management of turfgrass. In many cases, chemical application rates can rival and even exceed those used in intensive agriculture (WPT, 1994). For instance, research in Maryland (Klein, 1990) of comparative chemical application rates for a golf course (reported in pounds/acre/year, including fairway, greens, and tees) and corn/soybean rotation showed 334, 145, and 113 more pounds, respectively, of nitrogen, phosphorus, and pesticides applied on the golf course than cropland.

Investigators have suggested that the extent of acreage subject to intensive water and chemical management is a better indicator of nonpoint-source pollution and environmental problems than total amounts of chemicals or water used on specific sites (Balogh, 1992a). Also, the spatial extent of fertilizer and pesticide application may be more important than total amounts of chemicals applied on a single site when evaluating local and regional impacts of chemical management on water and environmental quality.

From 1994 to 1996, the Tennessee Department of Agriculture (TDA) conducted a statewide survey to measure pesticide levels in groundwater in areas with the highest pesticide use (Bennett, 1999). Of 6,809 samples analyzed, 66 samples were contaminated above 20 percent of the Maximum Contamination Levels (MCL - safe drinking water standards established by the Tennessee Division of Water Supply), and only 10 were above the MCL for pesticides in drinking water. Although pesticides were detected in less than one percent of the well water samples analyzed, the survey indicated that pesticides had greater potential of contaminating groundwater in areas where soil and geological characteristics made groundwater susceptible.

Golf courses built on top of karst topography, particularly those located in eastern and middle Tennessee, have greater potential for adversely impacting groundwater. Karst topography is characterized by sinkholes, abundant springs, disappearing streams, abrupt ridges, and caverns. The majority of karst occurs in limestone. Sinkholes are surface openings of large channels and underground caves. These features act as direct conduits for the entry of surface water, entrained sediments, and dissolved surface runoff chemicals into underground channels and caverns, allowing rapid and unimpeded transport to groundwater (Balogh, 1992b). Karst aquifers are highly susceptible to contamination not only by surface runoff, but also sediment-adsorbed chemicals, microorganisms, and low-solubility pesticides usually not transmitted by drainage water. Preventing potentially contaminated surface runoff from entering these features is of utmost importance in an environmental management program.

Several methods, including soil and water conservation practices and best management practices (BMPs), have been developed and used in turfgrass systems to address environmental impacts on water quality associated with fertility and pesticide operations (Balogh, 1992b). These systems, alone, have not always proven effective in preventing movement of contaminants to surface and groundwater. A combination of these practices in an integrated system framework has proven effective in reducing potential environmental impacts. This approach combines several systems, including the design and use of environmentally sound facilities for pesticide operations, integrated pest management, soil and water conservation practices, and best management practices.

Stewardship, that is protecting and improving the resources entrusted to us, is the key to a better environment. Stewardship begins with an understanding of how the environment can be harmed. It includes taking steps to prevent contamination, correcting problems created by accidents and past abuses, obtaining knowledge of new and current environmental regulations, and initiating approved and appropriate environmental safeguards.

Many golf course superintendents and staff members have excellent environmental records. Many have also taken steps to ensure that environmental compliance and stewardship are practiced in daily operations. However, some questions may arise during the course of operations that will require an immediate answer. This book may not contain all the answers. Hopefully, however, it will provide some of the answers, or contacts from which answers may be obtained.

SECTION 2.0
ENVIRONMENTAL MANAGEMENT ISSUES

2.1 SOIL AND WATER PROTECTION

One of the major environmental concerns is contamination of both groundwater and surface water with nutrients and pesticides from intensive management of agricultural and turfgrass systems (EPA, 1986). A recent survey of drinking water wells revealed nitrate was the most common contaminant and atrazine, bentazone, simazine, and DCPA (all registered for use on turfgrass) were found in some samples (EPA, 1990). A degradation product of the pre-emergence herbicide, DCPA, was the most common pesticide residue detected. The EPA and members of the golf course industry recognize the need for cooperative development of ecologically sound management of fertility and pests. In 1991, the USGA began sponsoring research to examine the environmental impacts of golf course management. Initial emphasis was on the fate and movement of nutrients and pesticides applied to turfgrass and the potential for contamination of surface and groundwater supplies. In recent years, research emphasis has been expanded to improve pesticide and nutrient fate models, and address other environmental issues including wetlands, water quality buffers, and habitat management for aquatic and terrestrial wildlife.

In agricultural systems, a primary goal of BMPs is to reduce the transport of sediment and sediment-bound chemicals. Since sediment loss is not a serious problem in established turf, BMPs for turf management are designed to prevent the transport of soluble chemicals in runoff and leachate. Other goals of BMPs are to control the rate, method of application, and type of chemical being applied. Also, integrated pest management and soil testing are used to reduce the total annual chemical and nutrient load.

2.1.1 Pesticides

Throughout this book, pesticides refers to all manufactured organic compounds used to control pests including herbicides, insecticides, fungicides, nematicides, and miticides. When a pesticide is applied to turf, initial distribution determines how much reaches the intended target and how much will be lost from the turfgrass system. The four processes that control the fate of pesticides are volatilization, adsorption, decomposition, and water transport. Volatilization and drift are the principle means of widespread dispersion of pesticides in the environment (Balogh and Anderson, 1992c). Volatile losses from plants and moist soil can be as high as 90 percent for volatile compounds (Glotfelty et al., 1984). Pesticide properties and management practices influence the amount of volatilization.

Adsorption provides the only temporary storage of pesticides in the environment. The amount of pesticide adsorbed by soil and organic matter is in direct proportion to the amount of pesticide in the soil water. Retention and release of pesticide into the soil water is primarily a function of pesticide chemistry and concentration, adsorptivity of the organic and mineral soil, and the amount of water leaching through the soil.

Degradation is the only process that permanently reduces the total environmental load of pesticides that are applied to turfgrass. Though all pesticides eventually degrade, the relative degradation rates or persistence varies considerably. The key to minimizing adverse environmental impacts of pesticide use is to manage or control those processes and mechanisms which result in pesticide loss or off-target transport. These include selecting pesticides that are less volatile, less leachable, and more biodegradable. The important chemical and physical properties that influence the fate of pesticides, as well as environmental BMPs for pesticide use, are described in **Section 3.5, Turfgrass Management**. BMPs for preventing point-source pollution from pesticide and fertilizer handling operations are discussed in **Section 3.1, Material Management**.

2.1.2 Nutrients

Nitrogen, in particular nitrate, is the nutrient posing the most serious threat to water quality as a result of turf fertilization. Water quality impairment from phosphorus loading is normally associated with sediment transport. Consequently, phosphorus losses are a major concern during turf establishment and less important after the turf is established. Nitrogen can be transported by surface runoff, particularly when significant runoff occurs after fertilizer application. As the time between application and a runoff event increases, the amount of nitrogen subject to transport in runoff decreases. Losses of nitrate in runoff water are associated with heavy applications of organic residues or nitrate-based fertilizers.

Initial findings of the USGA-sponsored research demonstrated that leaching of nitrate is minimal when turfgrasses are properly maintained (Snow, 1996). The potential for leaching increases, however, when nitrogen is applied in excess of plant needs, especially on sandy soils or following heavy irrigation. Plant stress induced by drought or high salinity can also increase nitrate leaching. Nitrate leaching losses are reduced by using insoluble or less quickly available nitrogen sources. The timing of application and limiting of irrigation water to the amount needed to replace that used by turfgrass are the most important practices for minimizing nitrate leaching. Constructing greens with a mixture of peat moss and sand instead of sand alone also reduces leaching losses in the year of establishment. Physical and chemical properties that influence the fate of fertilizers applied to turfgrasses, as well as BMPs for minimizing nutrient losses, are described in more detail in **Section 3.5, Turfgrass Management**.

2.1.3 Operational Wastes

Operational waste is generated by the maintenance of vehicles, mowers, and other off-road equipment. Operational area waste includes used oils, grease, tires, batteries, cleaning solvents, and empty containers. Chlorinated solvents are the most common source of soil and groundwater contamination near industrial sites. Contamination has resulted from large spills, unmanaged small spills, container leaks, and improper disposal. Even though golf course management is not likely to generate large quantities of hazardous waste, pollution prevention measures, waste recycling, and other BMPs should be adopted to minimize the risk associated with these types of wastes. **Section 3.3, Hazardous and Operational Waste Management,** contains a list of BMPs for dealing with hazardous and solid waste.

2.1.4 Permitting

Permitting associated with the construction and maintenance of golf courses is covered under the National Environmental Policy Act (NEPA). This act was enacted to create a national policy for protecting and enhancing the environment, while providing for mandatory "action-forcing" procedures for all federal agencies. There are five state and federal organizations that have regulatory impact on golf course management. In the state of Tennessee, the contact agencies are the Department of Environment and Conservation (TDEC) and the TDA. Federally, the United States Army Corps of Engineers (USACE), the Tennessee Valley Authority (TVA), and the United States Environmental Protection Agency (USEPA) share responsibility for regulation of golf courses. Most of USEPA's regulatory authority is delegated to TDEC and TDA in Tennessee; therefore, most USEPA issues will be addressed through these two state agencies. In addition to state and federal agencies, local governments and business services can assist golf course superintendents with permitting issues.

All construction which affects the waters of the Tennessee River Basin within the state of Tennessee falls under the purview of the TVA and the USACE. These two agencies have a Memorandum of Understanding (TVA/USACE MOU) which allows them to cooperate in issuing environmental permits. Depending on who is the lead agency, either a 26a (TVA) and/or a Section 404 or Section 10 (USACE) permit must be issued for construction affecting the waters of the Tennessee River Basin within the state of Tennessee. The extent of the intended action will determine whether an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) must be done as part of the permitting process. For all 26a and Section 404 permits, TDEC must be contacted. This agency then decides if a Water Pollution Control (WPC) Aquatic Resources Alteration Permit (ARAP) needs to be issued.

In Tennessee, the use and disposal of pesticides and fertilizers for golf courses and all other types of applications is governed by TDA.

The number and types of permits vary depending upon the state in which the golf course is located. **It is wise to first determine which federal, state, and local permits are necessary before beginning construction on golf courses and other related projects.** Since permitting issues are site specific and it is impossible to predict all scenarios that could occur, golf course superintendents may need to check other sources for additional information.

Section 4, Regulatory Contacts, contains a list of federal and state agencies to be contacted for information regarding permits and regulations concerning all aspects of golf course construction and maintenance.

This handbook should not be construed as a legal document or a final authority on permit issues.

2.1.5 Water Quality Buffers

Studies have shown that surface transport of dissolved, suspended particulate or sediment-bound nutrients or pesticides in surface runoff poses a greater problem than leaching for golf courses, especially for heavy-textured soils in high rainfall areas of the country (Kenna and Snow, 1998). Grass buffer strips reduce runoff losses of nitrogen and pesticides when soil moisture is low prior to rainfall events (Snow, 1996). Grass buffer strips are less effective in reducing runoff losses, however, when soil moisture is high prior to rainfall.

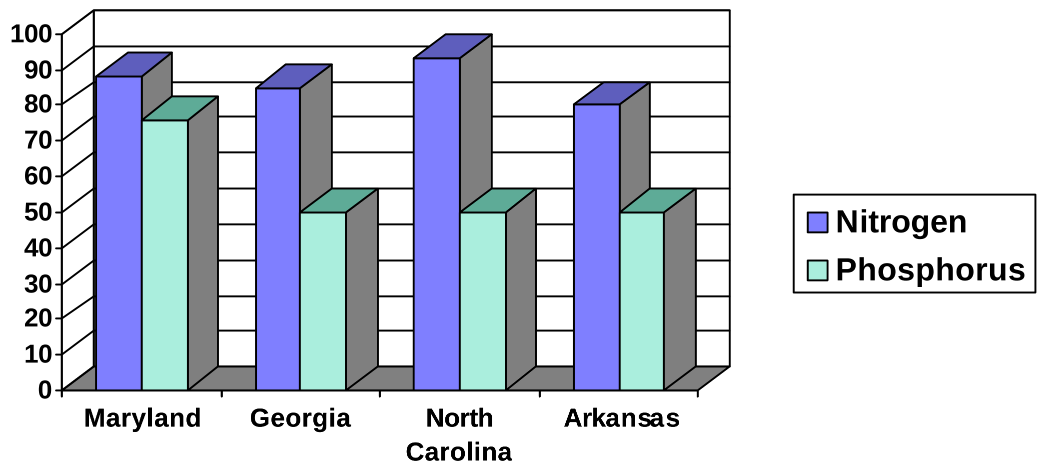
A variety of filtering systems utilizing grass vegetation can be used to convey and/or treat storm water runoff. These systems include drainage channels, grass swales, sand filters, and infiltration trenches. Drainage channels are designed to convey storm water to prevent erosion, but usually provide little or no pollutant removal. Grass swales and filter strips designed to slow runoff, provide a modest contact time during runoff events, and promote infiltration. They perform much better than drainage channels for removing pollutants in runoff. In general, buffers that are wide enough to provide a minimum of nine minutes residence time for storm water runoff can be expected to remove up to 80 percent of total suspended solids (Herson-Jones et al., 1995). Performance data and design specifications for a variety of grass systems were described by Herson-Jones et al. (1995) and Schueler (1996).

Buffers containing woody vegetation are generally more effective than grass swales or filter strips for storm water treatment and water quality protection. Water quality buffers, defined here as forested areas adjacent to water bodies, often represent the last line of defense to intercept and remove sediments, fertilizers, pesticides, and clippings in surface runoff. Consequently, water quality buffers are widely recommended to protect environmentally sensitive areas on golf courses, including wetlands, sinkholes, erosion-prone areas, and water bodies receiving runoff or groundwater discharge from golf tees, greens, and other intensively managed areas (Balogh and Watson, 1992b; Balogh and Anderson, 1992c; Klein, 1990; Kosian et al., 1992; Schueler, 1994).

Trees, shrubs, and other woody vegetation offer several advantages over turfgrasses and other types of vegetation for water quality protection. Woody vegetation accumulates nutrients in biomass, is less likely than grass to be smothered by sediment deposits, and provides diverse habitat for wildlife. Woody plants have extensive root systems (10-20 feet) that bind soil particles together reducing erosion and physically stabilizing streambanks or shorelines. Leaves and other aboveground parts of these plants intercept precipitation reducing the erosive energy of raindrop impact. The trunks, stems, and leaf litter at the soil surface act to slow down runoff, resulting in an increase in infiltration (10-15 times more than grass) and a reduction in erosion. Forest litter also provides carbon needed to fuel microbial processes that remove or deactivate pollutants, including denitrification and pesticide degradation. By slowing runoff, increasing infiltration, and promoting microbial activity, these plants act as a living filter to trap and remove sediments and other contaminants. Forest vegetation can also reduce maintenance, provide screening for privacy or noise reduction, and enhance scenic quality.

Riparian forest buffers have been shown to be effective in reducing nonpoint-source pollution from agricultural sources (Lowrance et al., 1995; 1997). The effectiveness of water quality buffers for removing pollutants in runoff varies depending on site conditions, buffer design and composition, intensity of runoff and adjacent land-use impacts, and type of pollutant. Riparian forest buffers have been shown to remove 80 to 90 percent of nitrate and 50 to 75 percent of the phosphorus in agricultural studies (Figure 1). Data from agricultural, forestry, and wastewater treatment studies indicate removal rates ranging from 15 to 99 percent for nitrate, 23 to 96 percent for phosphorus, 45 to 99 percent for total suspended soils, 70 percent for grease and oil, 40 percent for lead, and greater than 60 percent for copper, zinc, aluminum, and iron (Herson-Jones et al., 1995).

Figure 1. Nutrient removal by riparian forest buffers (adapted from Forestry Work Group 1993)



2.2 WILDLIFE HABITAT

Golf courses offer excellent opportunities to provide habitat for wildlife. With more than 15,000 courses in the United States comprising in excess of 15 million acres, golf courses can be an important part of the conservation landscape (Kenna and Snow, 1998). Golf courses have excellent potential for becoming habitat refuges for wildlife in urban areas that are being developed in Tennessee. The average 18-hole golf course covers about 133 acres of land (Terman, 1997), and as the state becomes more urbanized these pieces of land could become crucial links of wildlife habitat. Wildlife habitats within golf courses will help correct some of the habitat fragmentation that occurs with development. Also, golf courses provide a sense of a “natural setting” in an otherwise urban area. This adds great aesthetic value to the area and the community.

In the beginning of the game, wildlife was welcomed to the course and actually helped to influence some present day rules. Rabbit scrapes had formed targets, and sand pit burrows created by sheep later became sand bunkers (Bearden, 1992). In the recent past, the shift to perfectly maintained turf and unobstructed fairways has proved to be less than ideal for managing wildlife. Heavy construction on golf courses can also destroy wildlife habitat, one of the key factors in wildlife management. Removal of most shrubs, grasses, and trees robs wildlife of their niche and forces them to relocate. The removal of shrubs and trees can also increase runoff and erosion. Due to the use of pesticides and fertilizers often associated with intense turf maintenance, activities that increase erosion and runoff can adversely impact nearby ponds and streams. Improper or excessive use of pesticides can also have a detrimental effect on groundwater supplies. All species, including humans, are ultimately subject to potential exposure as the result of chemicals (pesticides) applied on golf course turfgrass (Tietge, 1992). Public concern over the impact of pesticide use has made environmental preservation a key factor in golf course development.

2.2.1 Recognition of Habitat and Construction Benefits

When planning the construction of a golf course, it is important to assess the ecology of the area and wildlife habitats. The area may already be environmentally sensitive due to presence of endangered species, sink holes, or wetlands, or the area may be prone to flooding. Recognizing and managing these issues can eliminate future conflicts associated with course development. Habitats consisting of wetlands and sensitive areas for wildlife (terrestrial/aquatic) should be preserved whenever possible. The presence of wetlands and sinkholes can enhance a golf course by making it unique or more challenging to play. It is also equally important to preserve natural surroundings that already exist when developing the course. Native trees, shrubs, and grasses should be used when possible. Exotic species should be avoided. Preservation of the existing natural conditions and wildlife habitats will make it easier to manage wildlife after the course is placed into service.

Some experts suggest that the area should remain 70 percent in natural cover (Lowe, 1991). By leaving trees (snags), developed understory (brush, young trees), and native grasses, the amount of work needed to prepare the course is reduced while habitat for wildlife survival is maintained. Time and cost for manpower and machinery required to reshape topography will also be reduced. Natural cover around the course will also serve as a buffer to filter pesticides and nutrients from runoff entering streams or ponds. The design and use of vegetative water quality buffers will be discussed in a later section. A golf course design which incorporates areas of natural cover can be less expensive to maintain as well as construct. The end result is that operating costs and use fees can be reduced allowing more people to enjoy the sport.

2.2.2 Forested Buffers for Wildlife Habitat

Since pesticides and fertilizers are used only on certain portions of golf courses, potentially large areas are available to provide key habitat and sanctuaries for fish, birds, and other wildlife. Forested buffers along golf course streams and wetland areas can also provide valuable wildlife habitat while protecting water quality.

Forest vegetation along streams and other water bodies protects aquatic habitat in several important ways. Stream-side trees and shrubs provide temperature moderation through shading which lowers water temperature in summer and increases water temperature in winter. Shading can also reduce the growth of filamentous green algae and promote the production of diatoms which provide an important food source for aquatic macoinvertebrates.

Fallen and submerged logs and root systems of woody, stream-side vegetation provide cover for fish and invertebrates while leaves, branches, limbs, fruits, and other types of forest detritus form the basis of the aquatic food chain in headwater or low-order streams.

It is well-known that forested areas along streams and other water bodies are among the most biologically diverse wildlife habitats in the natural landscape. Many experts agree that maintaining a 50- to100-foot forested water-quality buffer along water courses in developed areas is adequate to protect water quality and improve stream conditions for fish and other aquatic organisms. A buffer of this size can also provide suitable habitat for many wildlife species including wood ducks, herons, kingfishers, songbirds, fox, deer, raccoons, turtles, snakes, and salamanders.

Well-designed water quality buffers on golf courses should contain a mixture of fast- and slow-growing native trees, shrubs, and grasses to provide a diverse habitat for wildlife. Selection of appropriate vegetation and buffer design will ensure that these buffers function properly to: trap and remove upland sources of sediments, nutrients, and chemicals; protect fish and wildlife by supplying food, cover, and shading; and maintain a healthy riparian ecosystem and stable stream channel.

Protection of wildlife habitat on golf courses is especially important in urban environments where highly fragmented forested areas often provide the best, and sometimes only, habitat for many wildlife species. Fragments of forests along streams and wetlands usually represent the largest contiguous forest within urban areas and can be considered as essential habitat for many important species. Stream-side forests that connect isolated blocks of habitat also serve as important travel corridors for species that would not cross large open areas. Environmental management, especially for courses located in or near urban areas, should include the establishment or preservation of forest vegetation along streams and wetlands to provide quality habitat, wildlife corridors, and water quality protection.

2.2.3 Support

Recently, golf courses that incorporate wildlife habitat are becoming more popular (Klemme, 1995). Audubon International has more than 1800 courses in the Cooperative Sanctuary Program (Dodson, 1990). The U.S. Fish and Wildlife Safe Harbor Program take in courses which have crucial habitat for threatened or endangered species (Terman, 1997). Not only is the importance of wildlife protection being recognized by course developers but also by many of the large golf organizations. Many top supporters of the game, The United States Golf Association (USGA), the Golf Course Superintendents Association of America (GCSAA), and the American Society of Golf Course Architects, are actively promoting environmentally friendly golf course design and management (Terman, 1997). Support continues to grow as other organizations join the crusade for more wildlife- and human-friendly golf courses.

SECTION 3.0
RECOMMENDED MANAGEMENT PRACTICES

3.1 MATERIAL MANAGEMENT

Pesticides, fertilizers, and waste from equipment maintenance represent high risks for point-source contamination of soil, surface water, and groundwater. Properly designed facilities for handling these materials promote storage, handling, and disposal practices that enhance worker safety and minimize the risk of point-source contamination. In addition to secondary containment for potentially hazardous materials, facilities need adequate space for storing and segregating wastes, an office for effective management and communication, convenience areas for employees, and storage for personal protective equipment. Two keys to properly managing materials that pose a pollution risk are facilities and trained personnel who know and understand BMPs.

3.1.1 Pesticide and Fertilizer Mixing and Loading Facilities

Facilities where pesticides and fertilizers are stored and mixed prior to application must be properly designed and managed to prevent the loss of these materials to the surrounding environment. Large quantities of fertilizers are normally not stored at golf courses. However, it is common practice to store concentrated pesticides within a building that is also used to mix and dilute pesticides and fill and rinse application equipment. Risk of polluting the soil and water near mixing/loading facilities is high because a considerable volume of material is handled in a relatively small area. Accidental spills or mismanagement of pesticide wastes can result in contamination of soil or water near mixing/loading facilities. Unlike the applied pesticides which are degraded by natural processes, an accidental spill can result in a concentration of pesticide in the soil that is too high to be degraded by natural processes within a reasonable time frame.

Considerable data from well water studies suggest the presence of pesticides in groundwater is often associated with poor management of pesticides at mixing/loading sites at retail agrichemical facilities (Parry, 1992). Regulators in several midwestern states have estimated that from 45 to 75 percent of agricultural retail sites are likely to require some level of remediation (USEPA, 1994). Even though less pesticide and smaller equipment is used to manage golf course turf, the mixing and loading activities are similar and so are the potential sources of pollution.

3.1.2 Sources of Pesticide Pollution and Prevention Strategies

A number of operations performed at pesticide mixing and loading facilities have the potential to result in the loss of pesticide. Normally, pesticides are received in small containers, (e.g. 2 or 2.5 gallons in size). However, some large facilities may use returnable containers often ranging in size from 30 to 200 gallons. A pesticide is usually mixed with water while filling the tank(s) on application equipment. Spray tanks, spreaders, and spray equipment are most often rinsed daily. The rinsate is recycled into subsequent batches. Rinsate which accumulates from washing the outside of vehicles may be discharged to sewage treatment facilities if it meets specifications set forth by that facility. Spills can occur during these operations. Spills and rinsate must be managed properly to prevent the loss of pesticide and the pollution associated with that loss.

Buildings used for mixing and loading pesticides and rinsing application equipment must be designed to facilitate retrieval of spills and rinsate. The greatest potential for pesticide pollution is associated with mixing, loading, and wash-out operations. Consequently, these operations should be done in an enclosed area protected from contact by precipitation. It is extremely important that used pesticide containers be properly rinsed, stored, and disposed or recycled. Since pesticides are not handled in bulk quantities, there is no great risk associated with container failure. Fires and vandalism, however, can result in the loss of a considerable amount of pesticide. Operations and practices that can result in pesticide loss and subsequent pollution are discussed in the following sections. Management practices and pollution prevention technologies that can remedy these problems are also explained.

3.1.3 Water Supply Protection

One of the most serious risks when handling pesticides near water supplies is direct contamination of the water supply. Many non-agricultural pesticide mixing/loading facilities are connected to public water supplies. Either an air-break tank or reduced pressure principle zone (RPZ) valve are required to prevent pesticides from being backsiphoned into the water supply.

An air-break tank is a supply tank which receives water through a pipe which has an air space between the pipe outlet and the highest level attainable in the tank. Generally, the space between the pipe outlet and maximum water level is twice the diameter of the pipe. Since the pressure in the water system is dissipated across the air gap, a pump is required to deliver water. Tanks on service trucks and spray equipment are often equipped with an air gap at the fill point to prevent backsiphoning while filling.

A RPZ valve is a special device with two independently operating check valves and a pressure differential relief valve located between check valves. When there is a loss of pressure in the water supply, both valves close preventing the reversal of flow. Although RPZ valves are relatively expensive and reduce water supply pressure, they are much more reliable than a single check valve and are required by most states or municipalities.

3.1.4 Wellhead Protection

Wells near pesticide handling facilities must be protected from contamination. Pesticide handling operations should be located a safe distance from a well. States often have minimum set-back distances. In Tennessee, pesticide mixing/loading facilities must be at least 100 feet from a well. Distances are usually greater for wells that serve more than a single residence. The well head should be elevated above the surrounding terrain and should have a concrete slab or clay fill that forces surface water away from the well casing. Wells should have a solid casing that extends down to the water bearing strata. Wells located in frost pits should be modified by extending the casing above ground or should be replaced with another properly designed well. Old, abandoned wells should be retired and sealed. This usually requires a permit. The Agricultural Extension Service or Public Health Office should be contacted for information on well closures.

3.1.5 Secondary Containment

Areas where pesticides or fertilizers are stored, mixed, and loaded, or where containers or equipment are rinsed, must have secondary containment to collect spills and facilitate product recycling. As a general rule, the volume of the secondary containment must be greater than the largest container (mixer, applicator tank, or storage tank) within the secondary containment. Normally the secondary containment volume should be 125 percent of the volume of the largest container, including the space occupied by other tanks and equipment.

Secondary containment structures are usually made of concrete. The floor is sloped to a sump where liquid can be pumped into a holding tank for recycling. Due to concrete's porosity and low chemical resistance, areas coming in frequent contact with pesticides and fertilizers should be protected with a chemically resistant coating or liner. This is particularly important where solvent-based pesticides are used. These pesticides can easily penetrate concrete and persist inside the concrete long after exposure (Broder et al., 1992). Fertilizers not only penetrate concrete but can weaken and destroy it.

To prolong the life of concrete exposed to pesticides and fertilizers, a relatively dry mix is recommended to obtain a more durable, stronger, and watertight concrete. Concrete strength is inversely proportional to the water-cement ratio. That is, the less water in the mix relative to cement the stronger the concrete. Concrete typically used for paving sidewalks and driveways has a water-cement ratio of 0.6. For pesticide and fertilizer handling facilities the water-cement ratio should be 0.45. This yields a stiff mix that may be difficult to place. However, water reducers (plasticizers) that make the concrete less stiff without reducing its strength can be added to make concrete more workable. If concrete will be exposed to nitrogen fertilizer solutions, special formulations of concrete containing additives to reduce its porosity should be used. Micro-fine silica is an excellent additive for reducing concrete's porosity and improving its resistance to harmful nitrogen solutions.

Maintaining a minimum slope of 2 percent can increase the life of concrete by facilitating the removal of spilled product (Broder et al., 1992). Cement for pesticide and fertilizer exposure should have one additional ingredient, a small quantity of air-entraining material. Concrete made from cement with air entraining material has minute, well-distributed, and completely separated air bubbles. This improves the concrete's resistance to freeze-thaw action and to scaling caused by deicing and fertilizer salts.

Rotationally molded polyethylene tubs can be used for secondary containment of small tanks. Among the plastics used for secondary containment, high-density polyethylene or more expensive fluorinated polyethylenes are recommended. Other plastics such as polyurethane, polypropylene, and PVC may not be resistant to solvents in many pesticide formulations (Tennessee Valley Authority, 1996).

Other recommended design features and BMPs related to secondary containment are these:

- Pesticide handling should be isolated from other operations, such as equipment and golf cart maintenance and storage.

- Pesticides and fertilizers should be located in separate secondary containment structures.
- Liquid, even precipitation, which accumulates in containment structures should be pumped from the structure and only discharged if it is free of pesticides and fertilizers.
- Gravity drains are prohibited in secondary containment structures unless the liquid is piped to a separate containment structure or sump where it can be recycled.
- Buried pits or underground storage, even for rinsate, are prohibited.
- Sumps should be emptied and cleaned daily.
- Pesticide mixing, loading, and equipment washing should be done under roof and in a structure elevated above storm-water runoff.
- The loading area should be kept clean to prevent tires of vehicles from tracking pesticide and fertilizer residues out of the loading area. If vehicle tires come in contact with spilled product or contaminated rinsate, they should be washed before being driven off the loading pad.
- Empty pesticide containers should be promptly rinsed and properly stored prior to disposal or recycle. Whenever possible, pesticides should be purchased in larger, reusable containers to reduce the accumulation of container rinsate.

Two pesticide mixing/loading facility designs will be described later in this publication. (See section on “Model Sites for Handling Pesticides at Golf Courses.”)

3.1.6 Rinsate and Spills

When maintaining turf on the golf course, several pesticides may be used. Some are incompatible. Consequently, equipment must be cleaned periodically to prevent cross-contamination of pesticides. There are a number of schemes for managing rinsate from these equipment washing operations. Usually, a system of two or more tanks is needed to avoid contamination problems. The concentration of pesticide in the rinsate is generally about 100 times weaker than the concentration of spray mixture. With these low concentrations, the rinsate can replace 10 to 20 percent of the fresh water used in new mixtures without significantly affecting the formulations. Spills of concentrated product can be recycled; however, their high concentration may necessitate an adjustment in formulation.

Insecticide-laden rinsate can usually be stored in a single tank. Rinsate containing herbicides, however, must be segregated according to the herbicides’ use. Glyphosate and other non-selective herbicides, for example, must be kept out of mixtures that will be sprayed on turf or ornamentals.

Successful recycling of rinsate and spilled product depends, for the most part, on the expeditious retrieval of these products in concert with good housekeeping. In a facility where spills and rinsate are recovered from a single sump, the surfaces exposed to the spill or rinsate must be cleaned after each change in product to keep from contaminating rinsate from subsequent cleanups. During washing operations, rinsate should be confined to the sump so that products are not tracked out of the loading area on equipment tires.

Rinsate from the cleaning of small pesticide containers (2 to 2.5 gallons) must be properly recycled. As a rule, empty containers should be triple-rinsed or pressure-rinsed immediately. The containers should be punctured to render them unusable before being properly disposed. Some reduction in rinsate volume may be realized by pressure rinsing as opposed to triple rinsing. If used containers are stored prior to recycling, they should be stored in a designated storage bin.

Products in larger, returnable containers often deserve consideration. At least one or two products may be purchased in large enough quantities to warrant 30- to 50-gallon returnable containers or mini-bulk containers with a capacity of up to 200 gallons. This can result in a cost savings as well as eliminating containers that have to be rinsed and disposed.

3.1.7 Emergency Preparedness for Fire and Vandalism

Some of the worst catastrophes associated with the storage of packaged pesticides have involved fires. Consequently, fire prevention and the use of fire-proof building materials are recommended for areas where packaged pesticides are stored. The following recommendations are based on standards developed by the Midwest Agricultural Chemicals Association (MACA) (MACA, 1993). The name of this organization has been changed to The Mid-America Crop Protection Association. Secondary containment in packaged storage areas is designed to contain water or foam associated with fire fighting. Most state-of-the-art, packaged pesticide warehouses have a 4- or 6-inch curb around the warehouse. Since many pesticide warehouse fires are caused by activities in adjoining offices, pesticide storage areas and offices should be separated by a four-hour fire wall. Fire extinguishers should be located at every exit or spaced no greater than 50 feet apart. Fire-resistant construction is recommended and steel or masonry is preferred. Wood frame structures are acceptable if fire-resistant wallboard or metal siding is used.

Ventilation is needed to reduce the accumulation of ignitable or explosive vapors and to reduce worker exposure to hazardous levels of fumes or dust from pesticides. A minimum ventilation rate of six air changes per hour is desired (Kammel et al., 1991). Since flammable vapors are usually heavier than air, vents should be placed near the floor. If the pesticide storage area must be heated, sources of combustion should be located outside of the building.

At most pesticide handling facilities there is little risk from vandalism; however, security is needed to prevent arson or the unauthorized release of fertilizers or pesticides. Bulk tanks should have lockable valves. Liquid-level sight-gages should not be used unless they are equipped with a lockable valve at the bottom connection.

3.2 MODEL SITES FOR HANDLING PESTICIDES AT GOLF COURSES

As partners, TDA's Division of Plant Industries and TVA Environmental Research Center initiated a model pollution prevention program for commercial pesticide users in 1994. The program's objective was to introduce to industries such as structural pest control operations, lawn care companies, nurseries, and golf courses, technologies and practices promoting surface and groundwater protection, with expectations that regulations may govern such industries in the future.

The overriding goal of this interagency program is to promote acceptance and adaptation of environmental technologies and practices that will help users manage pesticides in an environmentally safe manner. Two pesticide mixing/loading facility designs have been selected. One has been constructed at a new golf course located in Tazewell, Tennessee, north of Knoxville. The other design was proposed for a course in Tennessee and ultimately built on a course in Mississippi. Brief descriptions of the two facilities and pollution prevention measures are given below.

3.2.1 Woodlake Golf Club, Tazewell, Tennessee

The Woodlake Golf Club course was constructed in 1999. The course adjoins Norris Lake and has drainage feeding directly into the lake, a major water body of the Tennessee River System. Preserving the quality of water in Norris Lake is a primary focus of environmental efforts at Woodlake. Being located over karst topography, groundwater protection is also a major concern. Several structural BMPs were installed to protect water sources.

The mixing/loading facility (see Figure 2) is located on the north end of the equipment storage building and occupies a space 50 by 26 feet. The western portion of the area is for loading and washing equipment and covers about 34 by 26 feet. The loading area has a 2- by 2- by 1.5-feet-deep sump in the center to collect all spills and rinse water. The eastern portion of the mixing/loading facility is for mixing and storing pesticides. It covers an area roughly 16 by 26 feet. Like the loading area, it is sloped to a sump for retrieving spilled product and wash water. Piping was installed from the sumps to a rinsate recovery station to facilitate transfer of spills and rinsate from the sumps to the rinsate storage tank. For the sake of security and to better manage the use of pesticide in small containers, a lockable trailer equipped with shelves and a watertight floor was placed within the pesticide handling area.

The entire concrete floor surface is protected with an epoxy coating. The coating prevents pesticides from penetrating the concrete and protects the concrete from fertilizers. The slab is 6 inches thick and is reinforced with No. 4 reinforcement rods. The sumps were poured as an integral part of the slab and expansion joints were placed in the slab to control cracking.

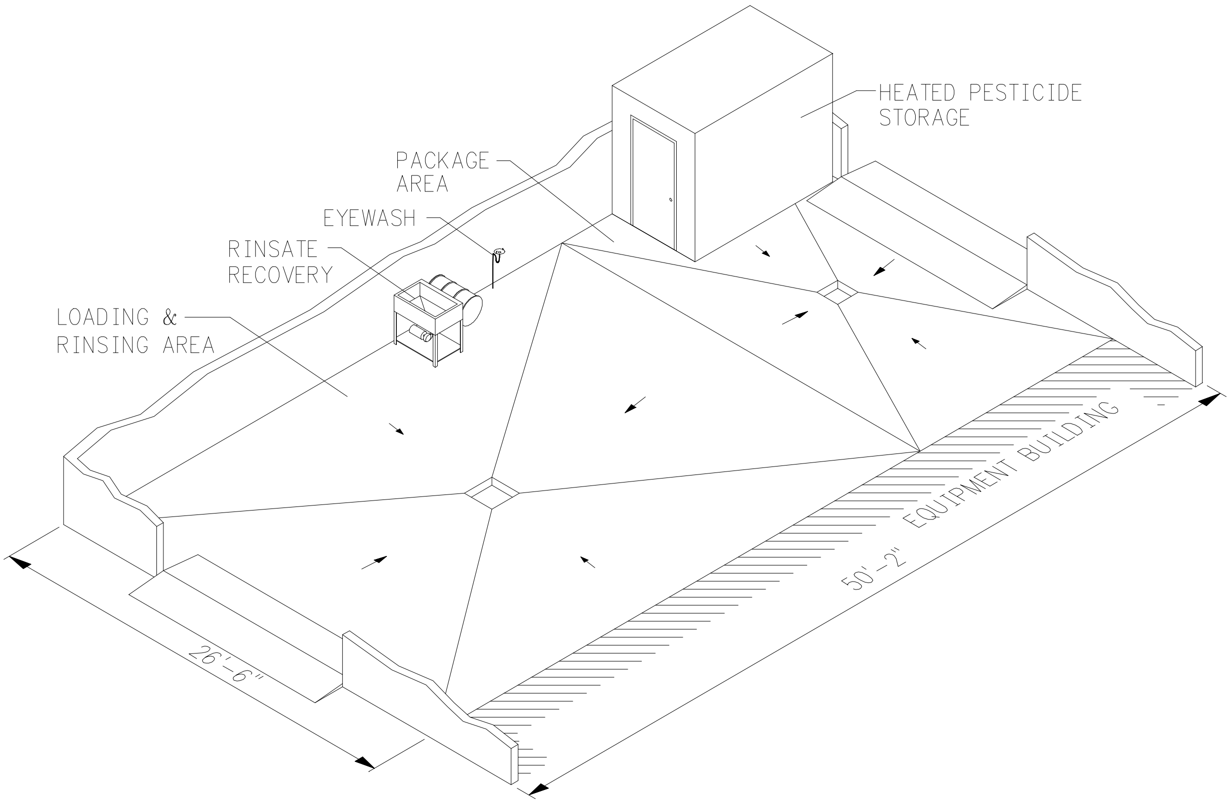


Figure 2: Woodlake Golf Club Pesticide Handling Facility

The concrete surface was finished with a powered steel trowel to produce a smooth, hard, dense surface that could be more easily coated with a chemical and abrasion-resistant coating. An important aspect of the concrete design is the slope. To ensure that liquids drain from the surface without ponding, the concrete should be sloped at least one percent; preferably two percent (1/4 inch per foot). This is recommended for any concrete exposed to chemicals that can weaken the concrete or soften protective coatings, as can solvents in many pesticide formulations.

Other structural BMPs were installed at Woodlake Golf Club. Approximately 600 trees were planted to restore a riparian area bordering Norris Lake (see Figure 3). About five tons of waste was removed from sinkholes. Two sinkholes were filled in according to the state of Tennessee Class V Injection Well Permitting requirements. An open sinkhole near the 7th green is protected by trees and shrubs that act as a buffer to keep pollutants in runoff from entering the sinkhole (Figure 4). Over 1000 wet-area tree species were planted in a wetlands area along the 4th-hole fairway to improve the wetland's pollutant removal capabilities and provide habitat for waterfowl and other wildlife. Storm water runoff retention and diversion structures were installed during construction of the course to reduce runoff volumes and erosion damage. A 300-feet stretch of a small stream that was impacted during construction was restored by sloping the banks and planting native grasses, shrubs, and trees in the riparian zone (Figure 5).

Figure 3: Riparian Buffer Along Norris Lake

Figure 4: Open Sink Hole Protected by Trees and Shrubs

Figure 5: Stream Restoration at Woodlake Golf Course

3.2.2 Proposed Facility

The facility shown in Figure 6 was to be located near an existing equipment maintenance building and would have required the excavation of part of a hill. Due to the high cost of site preparation and other factors, the facility was not built in Tennessee; however, the design was used for a course in Mississippi.

The proposed design features a separate area for filling, rinsing, and storing backpack spray equipment, separate rooms for storing herbicides and fungicides, and an office. The main loading and washout room has a trench drain in the floor that slopes to a sump near the edge of the loading area. This permits access to the sump while application equipment is parked over the trench. Drains in the herbicide, fungicide, and backpack work areas are piped to the main sump in the loading and washout room. The use of a common sump makes it easier to retrieve spilled product; however, this complicates rinsate recycling by making it more difficult to separate residues from products labeled for different uses.

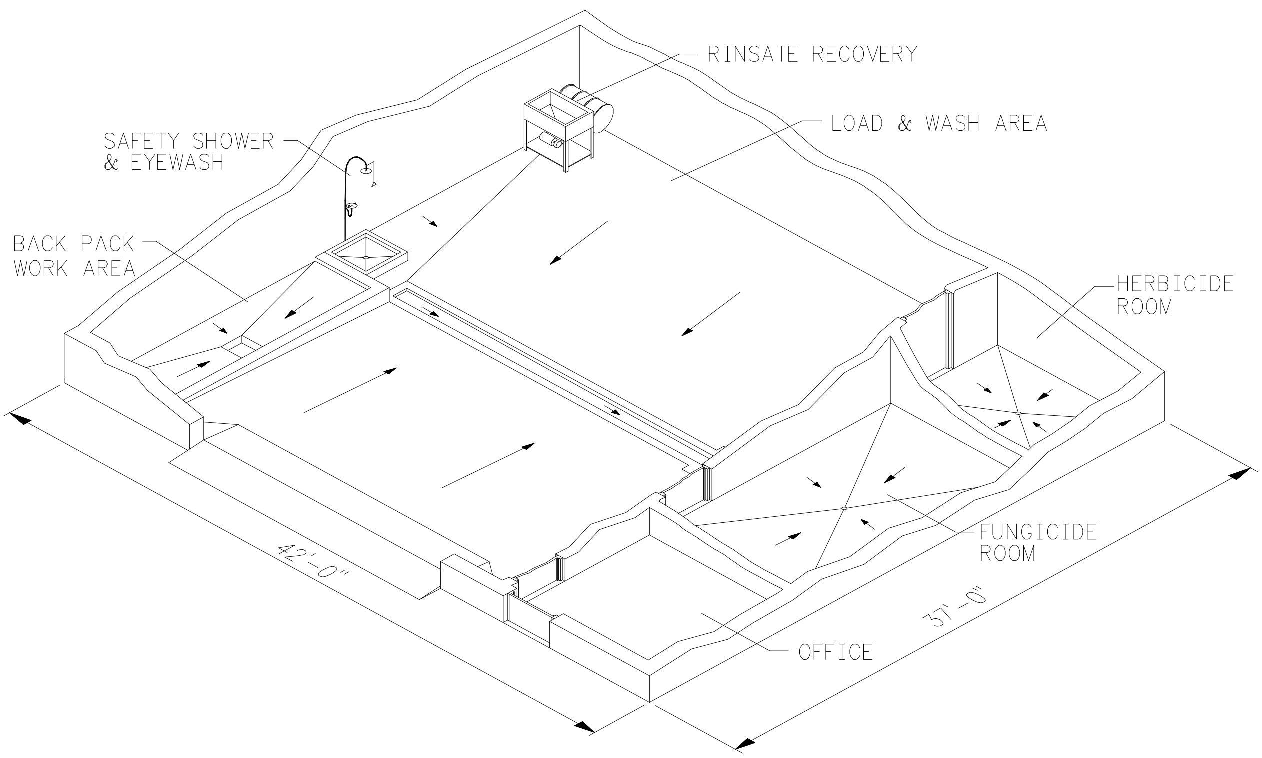


Figure 6: Proposed Pesticide Handling Facility

3.2.3 Upgrading Existing Facilities

The two systems described herein were new facilities. Some facility managers may choose to improve the pollution prevention capabilities of an existing facility. When designing an upgrade for a facility, the current and future operating procedures need to be considered. Pesticides are often handled in a building where vehicles are maintained and mowing equipment is stored. Because of the risk associated with human exposure to pesticides and the environmental risks resulting from improper pesticide handling, pesticide operations should be isolated from other golf course operations. A common shortcoming of existing sites is that they have level floors that make it difficult to retrieve spills and rinse water. Two options are available for remedying this situation: (1) using a portable loading pad, or (2) removing existing concrete and pouring a sloped concrete pad with a sump.

Portable loading pads have been constructed of steel plate and structural tubing. They are usually designed to drain liquid to the side of the pad where it is automatically pumped to a recycle tank. Liquid recycle systems that have a small tank, pump, sink for rinsing small pesticide containers, and valves to permit the pumping of product either from the load pad to the tank or from the tank to a larger tank or spray tank are also available.

Concrete in most existing facilities has neither high strength nor steel reinforcement and is, consequently, not difficult to remove. To provide secondary containment volume in a structure with a level floor, concrete curbing can be installed around the floor. The existing concrete must be scarified where the new curb is to be installed and steel dowels should be used to secure the curb. A chemically resistant caulk or water stop can be placed beneath the curbing to ensure a watertight seal.

Before an existing facility is upgraded, the type of coating on the concrete and the concrete's structural integrity need to be determined. Some coatings may need to be removed as they could be incompatible with new coatings. Stains of petroleum products, solvents, or pesticides may also make a concrete unsuitable for coating. Since coatings typically have tensile strength and adhesive strength much higher than concrete, it is important that the surface of the concrete to be coated has high tensile strength. Since the surface of concrete is much weaker than the concrete below, the recommended practice is to etch the concrete using acid or abrasive blasting to remove the weak outer layer before applying the coating. More information on concrete coatings for pesticide and fertilizer handling facilities is available from TVA (TVA, 1995).

3.2.4 Summary of Fertilizer and Pesticide Management

Golf course management employees handle products that have potential to pollute the facilities or surrounding soil and water. They should know and follow the proper procedures for handling concentrated products, as well as rinsate and other pesticide- and fertilizer-laden residues. The risks to human health and the environment from improper handling of pesticides and pesticide wastes are considerable. Consequently, persons responsible for pesticides need to be trained. Access to pesticide handling areas should be restricted to those persons qualified to handle pesticides. A successful pollution prevention program requires expeditious cleanup and recycling of spills and rinsate. A facility can be properly designed to facilitate pollution prevention; however, BMPs are required for a successful pollution prevention program. A number of tangible benefits can be accrued from successful pollution prevention. These benefits include a reduction in product losses which can pollute property and reduce its value, lower insurance rates, and reduced health risks from employee exposure to pesticides. Intangible benefits that should not be overlooked are improved employee morale and peace of mind that result from successful implementation of a comprehensive pollution prevention program.

When upgrading an existing site or planning construction of a new facility for storing, mixing and loading of pesticides or fertilizers, the Tennessee Department of Agriculture (TDA) or the office in the state that regulates pesticides and fertilizers should be contacted for assistance. Contacts with the TDA and other agencies that regulate golf course activities are provided in **Section 4, Regulatory Contacts**.

3.3 HAZARDOUS AND OPERATIONAL WASTE MANAGEMENT

On-site maintenance of vehicles and off-road equipment often results in used oils, tires, batteries, cleaning solvents, and other wastes. To avoid handling these wastes, some superintendents may choose to hire someone to provide maintenance and repair services. If these operational activities are conducted in-house, all employees associated with these activities need to be properly trained in pollution prevention.

Solid wastes that can be landfilled need to be stored in containers that are covered to prevent contact by precipitation. Universal wastes like batteries and fluorescent tubes should be recycled in order to avoid the full hazardous waste regulations. To prevent breakage during storage and transport, spent fluorescent tubes should be placed back in the box from which the replacement tubes come or in a box specially designed for the tubes. Used batteries should be stored inside prior to their removal.

Whenever possible, waste tires should be stored inside and kept dry. Non-pneumatic tires may be landfilled. Pneumatic tires should be taken to the designated tire collection site in the county. If used tires are stored outside, they should be covered. Left uncovered, they could become ideal locations for container mosquitoes to lay eggs. Container mosquitoes prefer to lay eggs in artificial containers like tires, buckets, and watering bowls. These mosquitoes are not only aggressive but are the most important carriers of blood-borne diseases in the United States. Unlike most mosquitoes that seek their blood meals at dusk, container mosquitoes bite during the day. One of the most aggressive container mosquitoes is the Asian tiger mosquito, named for the white bands on its legs. It is believed to have been imported into Texas as eggs in a shipment of tires during the mid-1980s. More information on control of these and other mosquitoes can be obtained from TVA (TVA, 1996a).

All wastes generated in operational areas need to be segregated and properly stored prior to disposal or recycling. Designated waste storage areas need to be properly labeled and secured to prevent unauthorized access. If stored outside, a berm may need to be constructed around the waste to divert storm water. One of the most important aspects of any activity that has potential to produce waste is housekeeping. All wastes generated need to be disposed of in a timely manner (generally 90 to 180 days, depending on the rate of generation). Table 1 lists BMPs for pollutant source control of operational activities at golf courses.

3.3.1 Solid Waste Management And Recycling

Recycling is an excellent way to help the environment and reduce solid waste disposal costs. In some areas, the local government collects certain recyclable materials such as paper and cardboard. There is considerable variation from one area to the next regarding the types of materials that may be recycled and how they should be segregated. The local solid waste director or recycling coordinator should be contacted for specifics of the local program. Some items to consider are drink containers (plastic, glass, and aluminum), food service steel cans, office paper, and cardboard. Aluminum cans can be donated to local schools and charities. Newspapers can be placed in bins located at schools and civic buildings. A portion of the revenue generated is then given to the school or civic organization.

Table 1.

Source Control BMPs for Operational Areas

Summary of Fueling Station BMPs
• Install spill and overflow protection
• Discourage topping off of fuel tanks
• Reduce exposure of fuel area to storm water
• Use dry cleanup methods for fuel area
• Use proper petroleum spill control
• Encourage employee participation in proper fuel management

Summary of Vehicle Maintenance and Repair BMPs
• Check for and retrieve leaking oil and fluids
• Use nontoxic or low-toxicity materials
• Drain oil filters before disposal or recycling
• Do not pour liquid waste down drains
• Recycle engine fluids and batteries
• Segregate and label wastes
• Buy recycled content products
• Buy non-hazardous products when possible

Summary of Painting Operation BMPs
• Contain and retrieve wastes from stripping or sanding
• Prevent paint wastes from contacting storm water
• Properly store waste paint and solvents prior to disposal
• Recycle paint, paint thinner, and solvents
• Buy non-hazardous products when possible

Summary of Vehicle and Equipment Washing BMPs
• Use phosphate-free detergents
• Use a designated cleaning area
• Use high-pressure, low-volume spray
• Recycle wash water
• Properly dispose remaining sludge from cleaning activities

Waste reduction should be a primary goal for the manager of any golf course equipment maintenance or operational area. Whenever possible, wastes should be recycled or non-hazardous materials should be substituted for solvents or cleaning materials considered hazardous. In-process parts washers are recommended because they do not have the same time limits on storage of hazardous waste as do solvents removed from machine parts. Since sludge remaining from equipment or parts cleaning operations may contain solvents, oil, pesticide residue, or metals, it is important to verify that the sludge meets sewage discharge standards before discharging into the sewage system or on-site septic tank. If hazardous wastes are generated, it is important to select a permitted hazardous waste hauler and waste management facility. The generator of the waste is responsible for its proper management even after it is picked up by the waste hauler.

Several people within different agencies in Tennessee can be contacted for assistance in dealing with hazardous and operational area waste. **Section 4.0, REGULATORY CONTACTS,** contains a list of agencies that should be contacted for assistance in various types of waste problems.

3.3.2 Purchasing

When making purchasing decisions, attention should be given to buying non-hazardous, recyclable, and recycled-content materials. By using non-hazardous substitutes instead of hazardous materials, the golf course will be subject to far fewer hazardous waste regulations such as annual reporting, manifesting, labeling, and storage requirements. By purchasing recycled content products such as re-refined motor oil and retread tires, the facility personnel will be supporting the recycling process and helping to conserve valuable resources.

3.4 STORM WATER MANAGEMENT

Until recently, little attention was given to rainwater that fell on urban areas or farmland and the threat that it might pose to nearby lakes, streams, and groundwater. Several nationwide studies, however, have identified storm water as a significant source of water pollution. Fortunately, golf courses (specifically turfgrass areas) rank second to undisturbed forests in their ability to prevent pesticides and nutrients from reaching groundwater and surface water. There are two areas associated with golf courses, however, that represent a storm water pollution risk. These are areas under construction or repair where bare soil exists and areas where fertilizer, pesticides, petroleum products or hazardous materials are stored and handled.

Bare areas are a concern because, unlike turf, they do not reduce runoff, nor do they provide leaves, thatch, and organic matter for adsorption of pollutants. In 1989, estimates indicated that 80 percent of the phosphorus and 73 percent of the Kjeldahl nitrogen in streams was associated with eroded sediment (USDA, 1989). Storm water management practices associated with bare areas or ground under construction should be designed according to the runoff potential. If the area is level and surrounded by established turf, the potential for runoff and transport of contaminants to surface water bodies is low. If the site is sloped and subject to erosion, some type of structural BMP should be installed. This could include a silt fence or a protective cover with a berm to divert runoff away from the area. The simplest solution is to establish turfgrasses over the bare soil by installing sod. For areas where erosion is a chronic problem, the local Natural Resources Conservation Service (NRCS) representative should be consulted. Even on bare areas not prone to erosion, care should be taken to prevent the application of fertilizers and pesticides as they may be subject to leaching.

Areas where pesticides, fertilizers, and other potential storm water contaminants are handled are considered operational areas. The best way to manage storm water in operational areas is to place the areas under roof. In federal storm water regulations that were finalized in December 1999, industrial sites that have “no exposure” of industrial activities to storm water are conditionally excluded from the regulation (USEPA, 1999). No exposure means placing all sources of storm water contamination under roof or under cover and diverting runoff away from these potential sources of contamination. Even though golf courses are not considered industrial sites, operational areas should be managed as industrial sites to prevent impairment of surface water. Storm water management practices for fertilizer and pesticide handling areas were alluded to earlier. The key is to keep storm water away from areas where fertilizers and pesticides are stored and handled.

Golf course superintendents can avoid liabilities associated with pollution from vehicle and equipment maintenance and repair by contracting with a local shop for these services. In doing so, handling and disposal of used tires, batteries, and petroleum products all become the responsibility of the repair and service shop. Golf course personnel that conduct equipment maintenance and repair should implement source controls listed in Table 1 to reduce the potential for these activities to pollute storm water. Source controls are the most practical and effective ways to prevent pollution of storm water runoff.

In areas where source controls are not completely effective, the two other management strategies for preventing storm water pollution are runoff control and treatment.

Runoff controls include containment, diversion, and infiltration. Containment was discussed in detail under Material Management Practices for Pesticides and Fertilizers. In addition to secondary containment structures used to collect spills and rinsate from the loading and washing of application equipment, spill collection pans should be used where liquid products are delivered in bulk to a site.

Diversion refers to the use of dikes and berms to prevent runoff from entering operational areas. In most regulations, storm water control structures must be designed to handle the runoff from a storm with a duration of 24 hours and a recurrence interval of 25 years (Tennessee Valley Authority, 1996b). Diversion structures should be used around areas where operational activities are conducted outdoors. Diversion structures may also be needed around buildings that are in the path of runoff. Ordinarily, buildings housing operational activities should be elevated above the surrounding terrain to prevent storm water runoff from entering.

The large number of buildings and paved areas at some golf courses can adversely impact surface water by increasing the amount of runoff and stream bank erosion. It may be necessary, at such sites, to implement management practices that reduce runoff volume. To reduce the amount of runoff around buildings, roof runoff collected in gutters, and downspouts should be directed to areas where the water can soak into soils. Subterranean infiltration basins can be used to facilitate the transfer of roof runoff into the ground.

Other management practices designed to reduce runoff volume are porous pavement, dry wells, infiltration basins, infiltration trenches, and grass swales with check dams. Dry wells are stone filled structures often used to collect roof runoff.

Porous pavement is made with concrete pavement units that have a lattice structure. The hollow spaces are filled with sand that is usually planted in grass. Porous pavement is effective on slopes up to 5 percent. To be effective in reducing runoff, porous pavement must be periodically maintained.

Infiltration basins are in-ground structures filled with sand that collect storm water runoff. These and grass swales are commonly used in urban areas and must be designed and constructed according to exact specifications. Before plans are made to install any type of storm water runoff control structure, a civil engineer or water resources engineer should be consulted for assistance in siting, designing, and installing the structure.

Treatment refers to processes designed to remove impurities from storm water. Normally, storm water treatment is not required at golf courses. However, if a downstream body of water is impaired due to nutrient loading from golf course activities, a storm water treatment system may be considered. Two systems used to improve storm water quality are detention ponds and constructed wetlands. A detention pond acts as a pollutant trap by reducing the velocity of runoff and allowing impurities attached to solids to settle to the bottom of the pond. Reduction in phosphorus loading is the primary function of a detention pond.

Constructed wetlands are engineered, marsh-like areas where specially established organisms and plants feed on organic compounds and nutrients as they flow through the system. Wetlands remove phosphorus, nitrogen, and metals. Like runoff control structures, constructed wetlands, and detention ponds must be constructed according to exact specifications to function properly. An engineer experienced in the design of these structures needs to be consulted to determine the need for, feasibility of, and expected benefit from these water treatment systems. For more information on constructed wetlands of any scale or use, contact the Tennessee Valley Authority, Water Quality Branch, 270 Handley Building, 311 Broad Street, Chattanooga, Tennessee 37402-2801.

3.5 TURFGRASS MANAGEMENT

Management of erosion-resistant ground covers in watersheds is essential to protect water resources and preserve water quality. Recent technological advances in outdoor power machinery, fertilizers and fertilizer coatings, irrigation systems, and pesticides can help superintendents and staff members continue to reduce the potential for pollution of surface and subsurface water bodies as turfgrasses are maintained on the 300 plus golf courses in Tennessee.

The height of cut of both reel and rotary mowers can be easily adjusted, incrementally, throughout the growing season to provide a uniform golfing surface while protecting turfs from scalping, climatic stresses, and soil erosion. Aerifiers and vertical mowers are engineered to cultivate turf and speed the movement of air, water, and nutrients through thatch and into soil. Essential mineral nutrients may be applied as foliar sprays or in granule form. In an effort by manufacturers to improve application uniformity and to reduce the amount of fertilizer collected while mowing, several granule sizes (e.g., greens or fairway grade) are available. Some fertilizers release nutrients to turfgrasses very quickly, while others are slowly soluble. Older, existing sprinkler systems may be upgraded or replaced to take advantage of the newest sprinklers and computer-aided irrigation technologies. Water can be applied very uniformly, automatically, to promote the growth of turfgrasses during favorable weather, to sustain plants as they become stressed, and to limit surface water flow from the irrigation zone. Turfs can be watered, as needed, to activate or incorporate pesticides and syringed to cool the temperature of the air surrounding plants. Herbicides may be applied to turf before weed seeds germinate or after weeds emerge from the soil. Fungicides may be applied on a preventative (e.g., to suppress growth of fungal pathogens when the environment is conducive to disease development) or curative basis. Both biocontrol agents and more traditional insecticides may be available to control troublesome turf insects. These pesticides often vary in mode of action, persistence, volatility, and solubility. The potential to move downward through the soil profile in water (leach) often varies among pesticides, as well as mineral nutrients.

Turfgrasses maintained on golf courses grow in a variety of soils and may be injured by high or low temperatures, drought, and traffic. Golf course superintendents in Tennessee manage turfgrass stresses as well as turfgrasses. Turfgrass management programs developed with water quality protection in mind incorporate sound agronomic principles with biological and chemical pest control strategies.

Management practices and guiding principles for developing and maintaining turfgrass while protecting water quality are listed below. They are based on a list developed by Balogh, et al. (1992d). To minimize the adverse impacts of pesticide use, the following practices and principles should be followed:

1. Only pesticides specifically labeled for application should be used, and all applications should be made by properly registered, certified, and trained personnel.
2. Selection criteria for pesticides should be based on target species, pesticide characteristics, and site characteristics. Properties that influence the fate of pesticides are efficacy, solubility, formulation, degradation rate, volatility, and adsorptivity. Soil texture, pH, organic matter content, depth to groundwater, and geology are site specific parameters that must be considered.

3. Reducing the frequency of pesticide application is one of the most effective practices for reducing the potential adverse effects from pesticides.
4. Less toxic, less mobile, and less persistent pesticides or alternative control strategies should be selected. Important properties of pesticides are given in **Section 3.5.3.1, Diseases; Section 3.5.3.2, Insects; Section 3.5.3.4, Weeds; and Section 3.5.4, Pesticide Selection and Leaching Potential.**
5. The timing and amount of pesticide applied should be adjusted according to local environmental conditions. Application of pesticide prior to anticipated rainfall events should be restricted. During periods of high wildlife population, less toxic pesticides should be used.
6. Pesticide use should be based on pest pressure, with action levels based on thresholds that prevent the application of pesticides when they are not needed.
7. Application methods should be chosen that minimize the potential for off-target losses. Pesticides intended for the soil should be incorporated or watered in with the proper amount of irrigation water. Spray application should be avoided when wind speeds are high enough to cause drift. Sprayers should be operated within the manufacturer's recommended pressure range for the appropriate nozzle and product. Operating at higher than recommended pressures can cause small drops that are more likely to drift or volatilize. When possible, spot applications should be used in place of blanket applications. Systems with onboard pesticide injection should be considered since they allow the operator to spot spray for weeds while making a blanket treatment with either a fertilizer and/or another herbicide.
8. Equipment used for pesticide application should be properly maintained and calibrated to deliver an accurate amount of pesticide and carrier.

BMPs related to the proper disposal of used containers and pesticide residues were discussed in **Section 3.1, Material Management**. BMPs and principles for minimizing the adverse effects of fertilizer use are as follows:

1. Minimal rates of nitrogen and phosphorus that will maintain nutrient levels and sustain turfgrass quality should be used.
2. Improved fertilizer efficiency can be achieved by selecting realistic goals for turfgrass quality, selecting application rates to meet quality goals, using tissue and soil tests to determine proper application rates, and using credits for previously applied nutrients.
3. Application of nutrients should be timed according to growth requirements.
4. Traffic patterns on the golf course should be managed to prevent compaction and reductions in turfgrass density. These conditions can increase the potential for surface runoff and can exacerbate fertility and pest problems which may subsequently lead to more frequent fertilizer and pesticide applications.
5. Application methods should be used that reduce the potential for loss by runoff; e.g., incorporation into the soil or frequent applications with reduced amounts of fertilizer (spoon feeding).
6. Fertilizer source and formulation should be chosen to minimize the potential for loss by leaching or runoff. In course-textured soils, time-released sources of nitrogen are recommended to reduce the potential for loss by leaching. Important physical and chemical properties of fertilizers are provided in **Section 3.5.1.2, Fertilization and Liming**.
7. Spreaders and sprayers should be properly maintained and calibrated to ensure the uniform and accurate application of nutrients.
8. Irrigation and drainage should be managed to minimize nutrient loss by leaching and runoff. Excessive irrigation, particularly in shallow, sandy soils, can cause accumulated nitrates to

be leached. On sloped areas, irrigating at rates exceeding the infiltration capacity of the soil can lead to loss of soluble fertilizers by runoff.

9. Application of fertilizers in areas with karst topography should be done with care to prevent the movement of nutrients into sinkholes, fractures, and other routes of entry to groundwater.
10. Maintaining good growing conditions for turf will reduce the potential for nutrient loss. This is done by maintaining optimum pH for plant growth, providing good soil tilth for root development, maintaining adequate soil moisture, and preventing damage from pests. Healthy turf is second to mature forest in preventing the loss of nutrients to surface and groundwater.

These aforementioned management practices are applicable to all turf management systems. In the following sections, environmentally sound methods for developing and maintaining turfgrass in Tennessee are discussed in more detail.

3.5.1 Primary Turfgrass Maintenance Practices

3.5.1.1 Mowing

Cutting height and frequency are influenced by turfgrass species (Table 2) and variety, air, and soil temperature (Figure 7), light intensity and quality (the photosynthetically active radiation reaching turfgrasses), soil fertility and texture, available moisture, and intended use (e.g., greens, tees, fairways, roughs, limited care areas). The rate of vertical growth of turfgrasses and the cutting height dictate mowing frequency. For highest quality turf, no more than 1/3 of the green tissue should be removed as the turf is mowed. As cutting height is lowered, the intensity level of maintenance must usually increase. Creeping bentgrass and hybrid bermudagrass greens maintained at a cutting height from 1/8 to 7/32 inch are routinely mowed once each day during favorable weather. Clippings are caught and removed. Similarly, bermudagrass, Kentucky bluegrass, perennial ryegrass, and *Zoysia* tees may be mowed daily, however, at a higher cutting height. Well-maintained fairways are mowed as often as five times each week, while fairways receiving ordinary care often require three mowings each week. Actively growing turfgrasses in roughs may be mowed twice each week; limited care areas, less than once each week. Turf is severely weakened when clippings are twice as long as the height of cut. Higher cutting heights favor root and rhizome development. Repeatedly scalping overgrown turfgrasses most often results in weak, weedy, and shallow-rooted turf. Maintaining a turfgrass species below its optimum cutting height range shortens both leaves and roots resulting in mechanically dwarfed turf.

Whenever possible, clippings should be returned to turf. Clippings are removed when they interfere with the game of golf (e.g., surface uniformity and ball roll). Each day greens are mowed, clippings are removed, and the direction of mowing may be changed. The perimeter of the greens surface (clean up lap) may be mowed every other day to reduce wear injury on this difficult to manage area. Mowing patterns are changed to prevent grain (leaf blades oriented in the same direction) and distribute soil compaction. Clipping removal, along with other maintenance practices, may help reduce annual bluegrass populations on fairways. Alternating mowing patterns usually creates aesthetically pleasing striping.

Several types of mowers are used to maintain turf on a golf course (Table 3). Reel mowers generally produce the highest quality cut and require less horsepower per foot of cut than high-cycle rotary mowers, flail mowers, and rotary cutters. Reel diameter and blade number required depend on the intended cutting height, turfgrass species, and features of the site. Greens mowers are equipped with smaller diameter reels with more blades than reels used to maintain turf at a higher cutting height. Reel blades and bedknives must be ground when they are nicked or when cutting edges are rounded and worn. Blades are back lapped frequently to keep them sharp between grindings.

When blades are sharp and decks are properly adjusted, high-cycle rotary mowers deliver an acceptable cutting quality in a variety of turfs. These mowers have a relatively low horsepower requirement (e.g., 2 horsepower per foot of cut) and may be mounted underneath or behind (3-point hitch) the operator. Although the cut may not be as sharp as one from the scissor-type action of a reel mower, rotary mowers are more versatile than reel mowers. They generally work well in tall vegetation and when weeds and seed stalks are present.

Flail mowers, like rotary mowers, cut on impact. Small, free-swinging knives hinged to a horizontal shaft are held out by centrifugal force as the shaft rotates. Since the knives fold back when they strike obstructions, there is less danger from projectiles compared to a rotary mower. They are especially effective when maintaining utility turf.

Single-spindle rotary cutters engineered for utility turf maintenance are powered by tractor power take off (e.g., requiring 540 PTO speed). Although cutting quality is relatively low and horsepower requirement is high (~5 horsepower per foot of cut), these mowers may cut tree seedlings up to 1.5 inches in diameter.

Table 2.
Optimum Cutting Height of Selected Turfgrass Species
During Favorable Growing Conditions

Species	Cutting Height (inches)
Cool Season	
Creeping bentgrass	0.125 to 0.8
Fine fescues	0.5 to 2.0
Kentucky bluegrass	1.5 to 2.25[a]
Perennial ryegrass	1.5 to 2.0[b]
Tall fescue	2.0 to 3.0
Warm Season	
Bermudagrass	0.25 to 1.5[c]
Zoysia	0.5 to 2.0[d]

[a] Turfgrass breeding efforts are underway to develop Kentucky bluegrasses for fairway use (e.g., 0.5-inch cutting height) in Tennessee.
[b] Perennial ryegrass in overseeded hybrid bermudagrass greens is often mowed at a cutting height as low as 0.25 inch during winter.
[c] Bermudagrasses (e.g. Champion, Tifdwarf, Tifeagle and Tifton 328) on golf greens are often maintained at a cutting height of $\leq$ 0.25 inch. In fairways, the cutting height of Tifsport, Tifton 419, Quickstand, and Vamont bermudagrasses often ranges from 0.5 to 1.5 inch depending on the time of year. The cutting height of common bermudagrass fairways is most often slightly higher than that of the hybrid bermudagrasses.
[d] *Zoysia* fairways are often mowed at 0.5 inch during summer. The height of cut is usually elevated in late summer and early fall to provide greater insulation against cold fall and winter temperatures.

Table 3.
Example Mower Inventory - 18-hole Golf Course

Number	Description	Use
2	Triplex reel mower	Greens
4	Power, walk-behind reel mower	Greens
2	Self-propelled, riding reel mower	Tees
3	Triplex reel mower with catcher	Fairways
1	7-gang reel mower	Fairways
1	5-gang reel mower	Roughs
1	Rotary mower (e.g., 6-foot cutting width) w/leaf mulcher	Roughs/Utility
2	Power edger/trimmer	Roughs/Utility
2	Riding rotary mower (e.g., 30-inch cutting width)	Utility
2	Walk-behind rotary mower (e.g., 24-inch cutting width)	Utility

Figure 7a.
Relative Growth Rate of Bermudagrass and *Zoysia* in Tennessee by Month

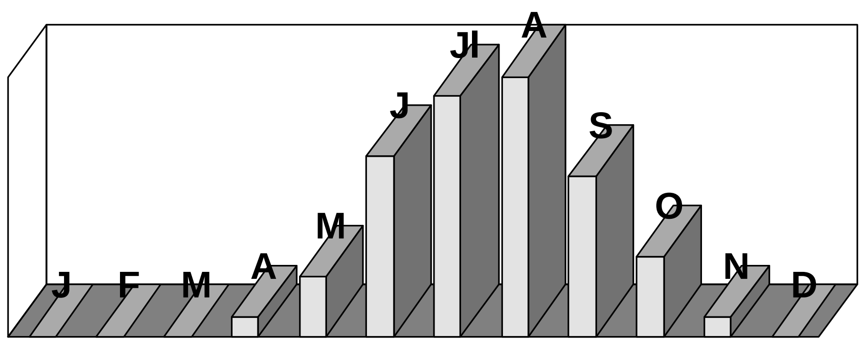
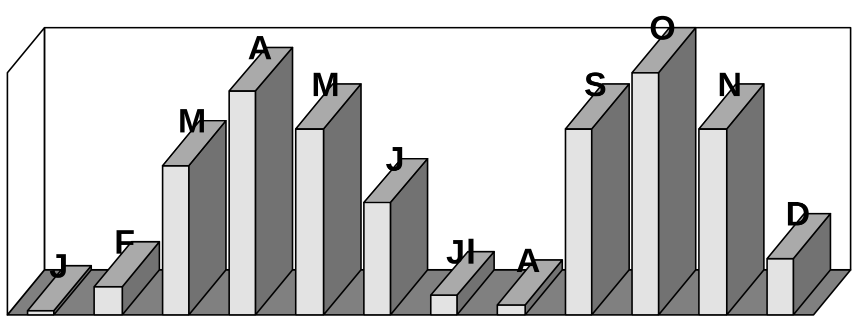


Figure 7b.
Relative Growth Rate of Creeping Bentgrass, Kentucky Bluegrass, Perennial Ryegrass, and Tall Fescue in Tennessee by Month



3.5.1.2 Fertilization and Liming

Actively growing turfgrasses usually contain 75 to 85 percent water. Collectively, carbon, hydrogen, and oxygen make up a major portion of the remaining dry matter. The rate of photosynthesis, the conversion of water and carbon dioxide to carbohydrates in the presence of light, is highest in young, fully expanded turfgrass leaves. Thirteen essential mineral elements are directly involved in plant nutrition (Table 4) and must be available to turfgrasses as they grow and mature. Healthy turfgrass roots are ideally suited for the uptake of these nutrients from soils. Root systems are most often fibrous, extensive, and have a very large surface area. Once taken into roots from the solution surrounding them, many nutrients are transported to other plant parts.

<u>Primary nutrients</u>

Nitrogen, phosphorus, and potassium are classified as primary nutrients based on the large amounts required by turfgrasses. These are the nutrients most often applied to turf. Turfgrasses require more nitrogen than phosphorus and potassium, and more potassium than phosphorus. Although mobility in soils varies among the three nutrients, all are mobile inside plants.

Nitrogen may be translocated from roots to turfgrass leaves within a matter of hours (e.g., 15 hours). It is found in amino acids, chlorophyll, enzymes and proteins. Turfgrasses usually contain from three to five percent nitrogen on a dry-weight basis, except where severe deficiencies exist. Although the atmosphere contains about 78 percent nitrogen gas (N_2), turfgrasses commonly obtain nitrogen from the soil.

The amount of nitrogen available in soil is often influenced by the amounts of organic matter, sand, silt, and clay. Nitrogen is primarily absorbed from the soil solution in the nitrate (NO_3^-) form, but turfgrasses can also absorb ammonium (NH_4^+). Certain soil-bourne bacteria gain energy as they convert nitrogen-containing ammonium and nitrite in soil to nitrate (Figure 8). Nitrate, the anionic (negatively charged) form of nitrogen preferred by turfgrasses, can leach from soils, especially soils containing a large amount of sand. By using extended-release nitrogen sources on turfs maintained on sandy soils, superintendents can control the amount of nitrogen in soil solution and reduce the potential for nitrogen loss from these soils due to leaching.

Soils rarely supply enough nitrogen to support high-quality, wear-resistant turf. The amount of nitrogen required by turfgrasses often varies among species (Table 5). For example, bermudagrass, creeping bentgrass, and Kentucky bluegrass usually require more nitrogen each “growing month” than either tall fescue or *Zoysia*. Excessive nitrogen fertilization results in poor turfgrass rooting, low energy reserves, and more disease. Succulent plants high in nitrogen are less tolerant of heat, cold, drought, and traffic. Turfs low in nitrogen are most often weak, weedy, and lack color. Turfgrasses deficient in nitrogen often appear stunted, with short leaves and very few tillers. Older leaves may first turn pale green in color, then yellow, as deficiency symptoms progress toward the base of the blade.

Much of the nitrogen in today’s fertilizers probably came from the atmosphere. Nitrogen gas in the atmosphere is converted to ammonia as it reacts with natural gas (e.g., methane, CH_4) under controlled conditions. Quickly available nitrogen sources may be manufactured from this ammonia (NH_3) (Figure 9). Quickly available sources of nitrogen are very soluble in water. About 11 pounds of ammonium nitrate, 5 3/4 pounds of ammonium sulfate, or 6 1/4 pounds of urea can be dissolved in one gallon of cold water (Table 6) (Turgeon, 1985). These nitrogen sources usually produce a more rapid, shorter-lived turfgrass response and are less expensive than slowly available sources. In addition, some sources provide phosphorus; others, potassium. Depending on the source, the application of nitrogen may increase soil acidity.

Slowly available sources of nitrogen are categorized as slowly soluble, slow-release, and natural organic (Table 7). The release of nitrogen from slowly available sources may depend on water action (hydrolysis), temperature, and the activity of microorganisms in soil. Isobutylidene diurea (IBDU), methylene ureas, and urea formaldehyde (UF) are slowly soluble, synthetic organic nitrogen carriers. The solubilization of IBDU-nitrogen is primarily dependent on fertilizer particle size and moisture and is only slightly influenced by soil temperature. Nitrogen contained in UF is classified according to its solubility. Cold-water (77^oF) soluble nitrogen is immediately available to turfgrasses. The amount of cold-water insoluble nitrogen (CWIN) and hot-water insoluble nitrogen (HWIN) contained in UF influences the fertilizers' activity index, the percentage of cold-water insoluble nitrogen that is soluble in hot water. Much of the nitrogen in UF with an activity index of 40 percent or greater is solubilized within one year following application. Solubilization of HWIN and CWIN usually occurs as a result of microorganism activity in soil and is often accelerated by warm, moist climatic conditions. Polymer-coated urea and sulfur-coated urea are sources of slow-release nitrogen. The release of nitrogen from sulfur-coated urea is influenced by both hydrolysis and microbial activity. Nitrogen from polymer-coated urea is released as the polymer reacts with water in the soil. Nitrogen in activated sewage sludge, seed and bone meals, manures, and other natural organic sources is released as soil microorganisms decompose them. The activity of these microorganisms often decreases in cold, wet, and acidic soils. Slowly available nitrogen sources most often have less burn potential and are more expensive than quickly available sources.

Table 4.
Essential Mineral Elements In Turfgrass Nutrition

Classification/ Quantity Required	Element	Symbol	Ionic form(s) absorbed by turfgrasses[b]	Relative mobility in plants
Primary/Largest	Nitrogen	N	NO_3^-, NH_4^+	Mobile
	Phosphorus	P	HPO_4^{--}, $H_2PO_4^-$	Mobile
	Potassium	K	K^+	Mobile
Secondary/Medium	Calcium	Ca	Ca^{++}	Immobile
	Magnesium	Mg	Mg^{++}	Mobile
	Sulfur	S	SO_4^{--}	Mobile
Minor/Smallest[a]	Boron	B	$H_2BO_3^-$	Immobile
	Chlorine	Cl	Cl^-	Probably does not become a structural part of organic molecules in turfgrasses
	Copper	Cu	Cu^{++}	Content highest in actively growing tissue
	Iron	Fe	Fe^{++}, Fe^{+++}	Immobile
	Manganese	Mn	Mn^{++}	Immobile
	Molybdenum	Mo	MoO_4^{--}	Concentration highest in the leaf blade; tends to accumulate as plants reach maturity
	Zinc	Zn	Zn^{++}	Immobile

[a] Nickel, in addition to the seven minor nutrients listed here, has also been recognized as being essential.
[b] Since the surface of clay minerals and organic matter is negatively charged, soils containing clay and organic matter have an affinity for mineral nutrients in cationic (positively charged) form. Organic matter and the amount and type of clay in a soil contribute to the soils total cation exchange capacity or CEC. For example, organic matter, with a CEC of 200, has the ability to adsorb the sum total of 200 milliequivalents of exchangeable nutrient cations per 100 grams of oven-dry soil. Cation exchange capacities of common clay minerals are: montmorillonite, ~100; illite, ~30; and kaolinite, ~8. The contribution of sand and silt to the total CEC of soil is very small. A fairway soil with three percent organic matter and 24 percent clay may have a CEC of 18, compared to a sand-based green containing 85 percent sand and 15 percent peat moss, with a CEC of 3 or less.

Figure 8.
Bacterial Action in Soils is Responsible for The Conversion of Ammonium to Nitrate

Ammonium NH_4	+	Oxygen O_2	+	*Nitrosomonas*	→	Nitrite NO_2	+	Hydrogen H^+	+	Water H_2O	+	Energy

Nitrite NO_2	+	Oxygen O_2	+	*Nitrobacter*	→	Nitrate NO_3	+	Energy

Table 5.
Nitrogen Fertility Response Range of Several Turfgrasses

Needs	Warm Season	Lb(s) Per 1,000 sq ft Per Growing Month	Cool Season
Very Low	Centipedegrass	$\leq$ 0.4	
Low Medium	 *Zoysia*	0.2 to 0.6 0.4 to 1.0	Fine fescues Tall fescue Annual ryegrass Perennial ryegrass
High	Bermudagrass	0.5 to 1.5	Creeping bentgrass Kentucky bluegrass

Figure 9.
The Creation of Quickly Available Nitrogen Sources from Ammonia

Ammonia NH_3	+	Carbon Dioxide CO_2	=	Urea $CO(NH_2)_2$
		Nitric Acid HNO_3		Ammonium Nitrate NH_4NH_3
		Sulfuric Acid H2SO4		Ammonium Sulfate $(NH_4)_2SO_4$
		Phosphoric Acid H_3PO_4		Ammonium Phosphates $(NH4)_XH_YPO_4$

Table 6.
Sources of Quickly Available Nitrogen in Turfgrass Fertilizers

Source	~ Content (%)[a]			Salt Index per Unit[b]	Acidifying Effect[c]	Cold-Water Solubility (lb./gal)	Comments
	N	P_2O_5	K_2O				
Ammonium nitrate	33	0	0	3.2 H	62	11	Contains both ammonium ions that are adsorbed by soil colloids and nitrate ions, that may be mobile in soils.
Ammonium sulfate	21	0	0	3.3 H	110	5.7	Contains 24 percent sulfur and has the greatest acidifying effect of materials listed.
Calcium nitrate	15	0	0	---	---	---	Contains 19 percent calcium in addition to nitrogen; absorbs moisture very rapidly.
Diammonium phosphate	18	46	0	1.7 M	75	3.4	Provides both nitrogen and phosphorus; very soluble phosphate source.
Monoammonium phosphate	11	48	0	2.7 H	58	1.9	Although less soluble than DAP, MAP has a greater salt index per unit.
Potassium nitrate	13	0	44	5.3 H	(-23)	1.0	May slightly increase soil pH as it rapidly releases nitrogen.
Urea	45	0	0	1.7M	71	6.2	This highly water-soluble nitrogen source contains the highest nitrogen concentration of any granular fertilizer.

[a] To calculate the phosphorus content (percent) of each fertilizer, multiply percent P_2O_5 by 0.44; to calculate the potassium content (percent), multiply percent K_2O by 0.83.
[b] Partial salt index expressed as the relative salinity of mineral salts per unit of nutrient compared to sodium nitrate (6.3). High = 2.6 or greater; moderate = 1.0 to 2.5; and low = less than 1.0.
[c] Units of $CaCO_3$ required to neutralize 100 units of fertilizer (by weight).

Table 7.
Sources of Slowly Available Nitrogen in Turfgrass Fertilizers[a]

Source	Formula	~ Content (%)			Salt Index per Unit[a]	Cold-Water Solubility[b]	Comments
		N	P_2O_5	K_2O			
IBDU (isobutylidene diurea)	$[CO(NH_2)_2]_2C_4H_8$	31	0	0	0.2 L	SS	Two urea molecules are linked by a carbon group resulting in a source of nitrogen dependent on hydrolysis for release.
Milorganite	organic - N complex	6	4	0	0.7 L	SS	Nitrogen in this activated sewage sludge is released by microbial activity.
Polymer/ Resin-Coated Urea	$CO(NH_2)_2$ + polymer or resin	38	0	0	---	SR	Nitrogen release is dependent on soil temperature and, to a much lesser degree, hydrolysis.
SCU (sulfur-coated urea)	$CO(NH_2)_2$ + sulfur	32	0	0	0.7 L	SR	Permeable sulfur (molten) coating allows water to slowly move through the barrier dissolving the enclosed urea; nitrogen release is dependent on microbial activity and hydrolysis.
UF (urea formaldehyde or methylene ureas)	$[CO(NH_2)CH_2]_n$ $CO(NH_2)_2$	38	0	0	0.3L	SS	Nitrogen is released from these various-size, chain-like polymers of urea as a result of soil microorganism activity.

[a] Partial salt index expressed as the relative salinity of mineral salts per unit of nutrient compared to sodium nitrate (6.3). High = 2.6 or greater; moderate = 1.0 to 2.5; and low = less than 1.0.
[b] SS = slowly soluble; SR = slow release.

When a fertilizer applied to turf enters the soil, the concentration of mineral salts in solution surrounding turfgrass roots may increase. The osmotic pressure of this solution may also increase. A high external salt concentration resulting from the application of an excessive amount of fertilizer can cause a decrease in the amount of water available to turfgrass roots. The turfgrasses, unable to access water, experience a physiological drought. Similarly, the contact of water-soluble nutrient salts with turfgrass stems and leaves can result in a second type of physiological drought, sometimes called foliar burn. The aerial shoot tissue appears to burn or fire as it dehydrates. The potential to cause physiological drought varies among the nitrogen-containing fertilizer sources. In addition to a reduced leaching potential, slowly available nitrogen sources most often have a low salt index per unit nitrogen compared to quickly available, water-soluble sources of nitrogen (Tables 6 and 7).

Fertilizer technologies continue to change along with the needs and expectations of golf course superintendents. A new classification, aminoureaformaldehyde, has recently been accepted by the Slow-Release Task Force of the American Association of Plant Food Control Officials. An assortment of fertilizer analyses and combinations of both quick-release and slowly available nitrogen are marketed in a variety of particle sizes and granule densities.

Phosphorus is critically important in the transfer and storage of energy within turfgrasses, and phosphorus-containing compounds affect the transfer of genetic information. It is also found in DNA and plant cell membranes. The role of phosphorus in turfgrass rooting is well-documented. Phosphorus is relatively immobile in most soils and is less likely to move into soil solution and leach than nitrogen. For this reason, starter fertilizers broadcast prior to planting may contain more phosphate (P_2O_5) than nitrogen or potash (K_2O). Newly developing plants with limited root systems need access to phosphorus. As plants mature and develop extensive root systems, they become very efficient in obtaining the mineral nutrient from soil.

Phosphorus use in turf can pose a threat to the quality of surface water if phosphorus-containing fertilizers are not applied properly in the appropriate location. Research indicates it is very unlikely that phosphorus moves from the surface of well-established turf (even from sloped areas following heavy rainfall). However, problems arise if during turf establishment on slopes adjacent to surface water soil containing phosphorus and other nutrients is washed into the water. Sodding, mulching, or the use of temporary turf covers is often recommended when establishing turf in these sensitive areas. If fertilizer spreaders are operated too close to shorelines or stream banks, a portion of the fertilizer material may be broadcast directly over the water surface. Similarly, if fertilizer is spread into streets and over sidewalks it may be washed into storm sewers, eventually reaching lakes and streams. When phosphorus is introduced into a freshwater environment containing several aquatic plant species, algae and certain weeds usually grow very rapidly reducing overall quality and balance of the valued water resource.

Potassium is involved with several processes within turfgrasses. It is not found in amino acids, proteins, carbohydrates, sugars or plant cell walls, yet it activates enzymes, is involved in photosynthesis, and is very important in the regulation of small openings (stomates) on the exterior tissue of turfgrasses responsible for water release from the plant to the atmosphere. Turfgrasses deficient in potassium are not very tolerant of environmental stresses including high and low temperatures and drought.

Although potassium, a cation (positively charged), is held by the negatively charged surfaces of clay and organic matter in soil, the nutrient may have to be routinely applied to turfgrasses maintained in well-drained soil amended with large amounts of sand (e.g., sand-based greens).

The nutrient concentration, solubility, and burn potential varies among both phosphorus and potassium sources (Table 8).

Table 8.
Sources of Phosphorus and Potassium in Turfgrass Fertilizers

Source	Formula	~ Content (%)[a]			Salt Index per Unit[b]	Acid Effect[d]	Cold-Water Solubility (lb./gal)	Comments
		N	P_2O_5	K_2O				
Diammonium phosphate	Please refer to Table 6							
Monoammonium phosphate	Please refer to Table 6							
Muriate of potash	KCl	0	0	60	1.9 M	0	2.8	Very common source of potassium
Potassium magnesium sulfate	$K_2SO_4 \cdot 2\ MgSO_4$	0	0	22	---	--	---	Releases nutrients rapidly; also contains about 18 percent magnesium and 23 percent sulfur
Potassium nitrate	Please refer to Table 6							
Sulfate of potash	K_2SO_4	0	0	50	0.9 L	0	0.9	Often used in place of muriate of potash, sulfate of potash has a low salt index and contains 18 percent sulfur
Superphosphate	$Ca_n(H_nPO_4)_2 + CaSO_4$	0	20	0	0.4 L	0	0.2	Decreases soil acidity; contains calcium and sulfur in the gypsum ($CaSO_4$)component which acts as a drying (dehydrating) agent
Treble superphosphate	$Ca_n(H_nPO_4)_2 \cdot H_2O$	0	44	0	0.2 L	0	0.3	Concentrated source of phosphorus

[a] To calculate the phosphorus content (percent) of each fertilizer, multiply percent P_2O_5 by 0.44; to calculate the potassium content (percent), multiply percent K_2O by 0.83.
[b] Expressed as the relative salinity of mineral salts per unit of nutrient compared to sodium nitrate (6.3). High = 2.6 or greater; moderate = 1.0 to 2.5; and low = less than 1.0.
[c] Units of $CaCO_3$ required to neutralize 100 units of fertilizer (by weight).

Secondary nutrients

Secondary nutrients, calcium, magnesium, and sulfur, are no more or less essential than primary or minor nutrients. The amount of each of the secondary nutrients required by turfgrasses is considered intermediate between the primary and minor nutrients.

Calcium, like potassium, may reach deficient levels in acidic, sandy soils. Calcium and magnesium are held more tightly by clay and organic matter in soil than potassium, and the application of too much of either of the two nutrients may displace potassium, increasing its concentration in soil solution and the potential for potassium loss by leaching. The application of excessive amounts of nitrogen-containing ammonium can produce a similar result.

Most soils in Tennessee contain adequate levels of sulfur to support turfgrass growth and maturity. However, sulfur may leach from light, porous soils with little organic matter (e.g., sand-based greens) and from alkaline soils.

The roles of calcium, magnesium, and sulfur in turfgrasses are presented in Table 9 and fertilizer sources, in Table 10.

Minor nutrients

Minor nutrients, sometimes referred to as micronutrients or trace elements, often serve as catalysts in reactions regulated by enzymes in turfgrasses. Because they are required in such small amounts, the indiscriminate application of minor nutrients without benefit of soil or tissue test, may result in toxic accumulations in plant tissue, causing severe turf injury. Deficiencies are more likely to occur in turfs maintained in organic soils or soils amended with large amounts of sand. Heavily irrigated turf and turfgrasses in compacted soils may also be deficient in one or more of the minor nutrients.

In native soils in Tennessee, a deficiency of iron, the minor nutrient most often deficient in turf, may be the result of an insolubility problem rather than absence from soil. The availability of nutrients in soils is enhanced by maintaining an appropriate level of acidity (Figure 10). Most turfgrasses perform best when soils are slightly acid. Routine testing is recommended to monitor pH, a measure of soil acidity (hydrogen ion activity) or alkalinity, and to determine the soils nutrient status. Ground agricultural limestone or pelletized lime is used to neutralize soil acids, increasing pH. The application of sulfur increases soil acidity, resulting in a decrease in pH. Due, in part, to variations in resistance to changes in pH (buffering capacity) among soils, applications of sulfur or lime should always be based on soil test recommendations. As a general rule, no more than 50 pounds of lime per 1000 square feet should be applied to established turf at one time.

Granular fertilizers and lime can be washed from aerial shoots of turfgrass by irrigating immediately after application. Care must be taken to avoid runoff.

Table 9.
The Role of the Secondary Essential Nutrients in Turfgrasses

Nutrient	Function
Calcium	A structural component of cell walls necessary for plant cells to divide and the formation of flowers; influences potassium and magnesium absorption.
Magnesium	Found in chlorophyll; necessary for the formation of proteins; involved in many plant reactions regulated by a variety of enzymes; enhances the absorption of phosphorus from soils.
Sulfur	Contained in some amino acids required for the production of several proteins and a component of several plant vitamins.

Figure 10.
How Acidity and Alkalinity Effect the Availability of Plant Nutrients in Soil

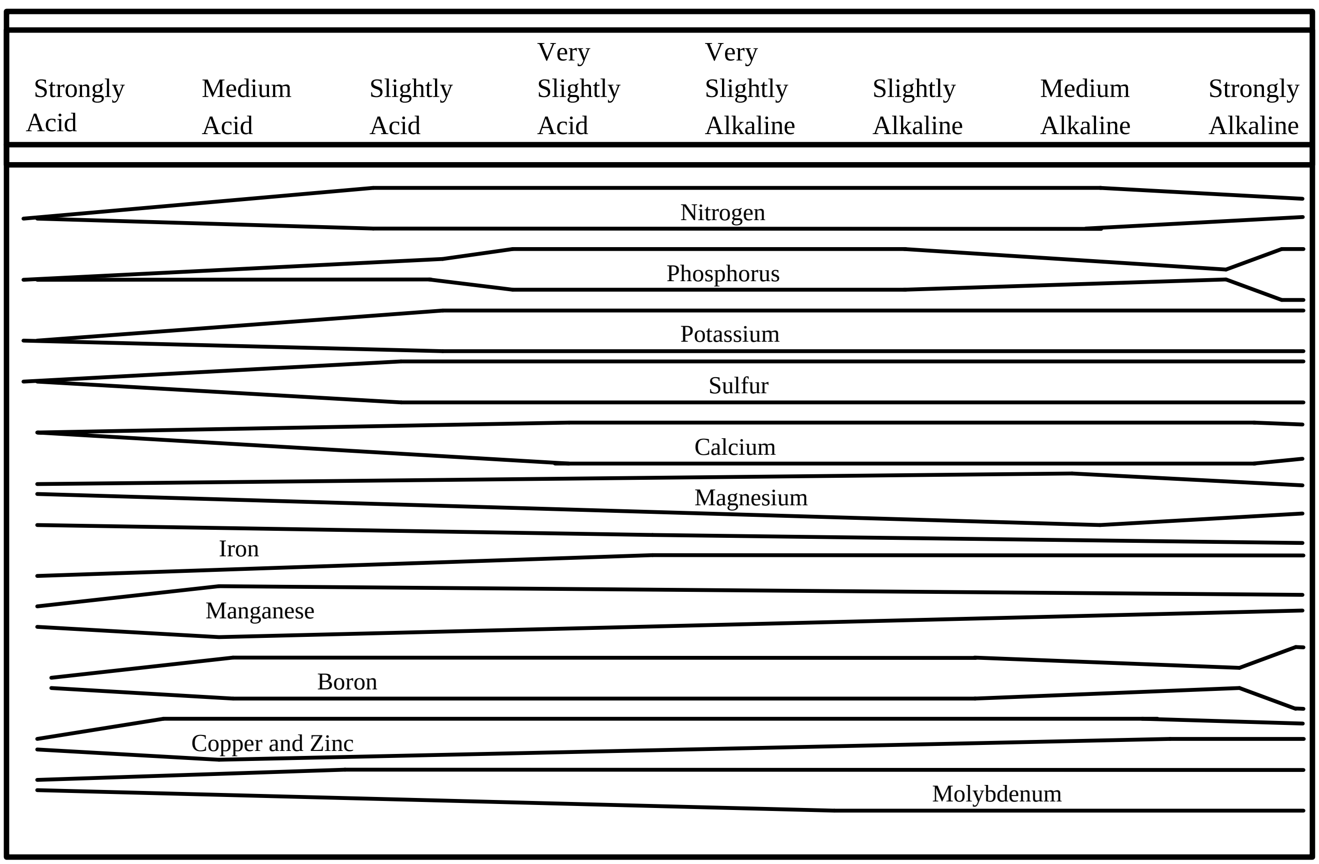


Table 10.
Sources of Calcium, Magnesium, and Sulfur in Turfgrass Fertilizers

Source	Formula	Neutralizing value %	~Calcium %	~Magnesium %	~Sulfur %
Ammonium sulfate	Please refer to Table 6				
Calcium carbonate	$CaCO_3$	100	32	0	0
Calcium hydroxide	$Ca(OH)_2$	136	46	1	0
Calcium metaphosphate	$Ca(PO_3)_2$	0	19	0	0
Calcium nitrate	$Ca(NO_3)_2$	0	19	2	0
Calcium oxide	CaO	179	52	0	0
Dolomitic limestone	$CaMg(CO_3)_2$	109	22	11	0
Ferrous ammonium sulfate	$(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$	0	0	0	16
Ferrous sulfate	$FeSO_4 \cdot 7H_2O$	0	0	0	18
Gypsum	$CaSO_4 \cdot 2H_20$	0	22	0	19
Magnesium carbonate (Magnesite)	$MgCO_3$	119	0	28	0
Magnesium hydroxide	$Mg(OH)_2$	172	0	40	0
Magnesium oxide	MgO	250	0	55	0
Magnesium sulfate	$MgSO_4$	0	0	10	14
Potassium magnesium sulfate	$K_2SO_4 \cdot 2MgSO_4$	0	0	11	22
Potassium sulfate	K_2SO_4	0	0	0	17
Sulfur, elemental	S	0	0	0	99
Superphosphate	$CaH_4(PO_4)_2$	0	21	0	12

3.5.1.3 Irrigation

Like the human body, actively growing turfgrasses contain more than 70 percent water. As mentioned previously, water, along with carbon dioxide, is a requirement for photosynthesis. In addition, turfgrasses rely on water for nutrient absorption and transport, turgidity, cooling, and protection from rapid changes in temperature. Many biochemical reactions take place in water inside turfgrass cells, and seeds must absorb water to germinate.

Water loss from turf occurs as plants grow and transpire. Warm season turfgrasses reportedly use about three times less water to produce a gram of dry matter by photosynthesis than cool season grasses. Water also evaporates from the soil surface. Although the rate of evapotranspiration (ET) varies among turfgrass species and varieties, most use from 0.1 to 0.3 inch of water daily.

The balance between water absorbed from the soil and water transpired impacts the internal moisture content of turfgrasses. When the amount of water transpired exceeds that absorbed from the soil, turfgrasses experience an internal water deficit or stress. Unfortunately, water deficits often occur when turfgrasses are recovering from wear injury resulting from extra-heavy play or are heat-stressed.

In Tennessee, it is virtually impossible to consistently maintain high-quality turf on heavily-trafficked areas of a golf course without irrigation. The annual distribution of rainfall does not generally meet the demand of turfgrasses for water (Table 11).

The amount and timing of irrigation may vary depending on turfgrass species and use, plant root mass and rooting depth, soil texture (proportions of sand, silt and clay, Table 12) and structure, exposure, and environmental conditions, such as temperature, humidity, wind, and shade.

Soils may have formed in place as a result of the weathering of parent rock material, or transported to (e.g., glacier, wind, or water) and deposited in their present location. Infiltration rate, water holding capacity, uniformity, and depth are very important aspects of soils that often influence irrigation practices. Soil texture and structure influence the rate that water moves into (water infiltration) and through (water percolation) a soil, as well as the volume of soil not occupied by soil particles (pore space). A loamy sand is coarse-textured and very often has less total pore space, more large diameter pores, and a faster water infiltration rate (if soil compaction is not a problem) than a fine-textured soil such as a silty clay (Table 13). Due in part to the large volume of small pores, the water infiltration and percolation rates of a moderately fine-textured soil, such as a clay loam, are most likely much slower than that of a deep, sandy loam soil.

During irrigation, water first moves into the soil by gravity. Then it moves either downward or laterally by capillary action and gravity. Water movement immediately after irrigation is most often variable. The rate of lateral and upward movement (e.g., back into the turfgrass root zone) of water in soils is usually slower than the movement of water downward. The movement of water in very moist soils is primarily through large pores. The arrangement of layers (horizons) from top to bottom in soil (profile) also influences the rate at which water moves downward through soil. For example, downward movement of water in a soil profile containing a coarse-textured surface soil overlaying a fine-textured soil may be restricted by the presence of the fine-textured soil.

Sprinkler systems permit a wide range of soils and turfgrass species to be irrigated. Sprinkler system design and components have changed through the years. Today's systems are engineered with flexibility and the conservation of water, energy, and labor in mind. They are automated to reduce the amount of labor required to operate the systems and to facilitate irrigation of turf during early morning hours, before golfers arrive. The pumping station is often centered on the golf course to limit pumping lift and friction loss. Whenever possible, low-pressure sprinklers and nozzles may be used to efficiently deliver and evenly distribute water over turf. Weather stations and soil moisture sensors are often used to provide local, precise, and instant data to computerized systems and golf course superintendents and staffs. Turfs are watered thoroughly and infrequently to promote turfgrass rooting during favorable weather and preserve turfgrass roots as plants become stressed.

Although the emphasis of this industry may change, a major objective of sprinkler irrigation remains the same--**to uniformly and efficiently apply an appropriate amount of water, at the appropriate time, to supplement natural rainfall, maximizing the performance of the turfgrass species/varieties with no surface water runoff.**

Table 11.
Rainfall Distribution and Evapotranspiration of Turfgrasses in Selected Areas in Tennessee[a]

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Chattanooga												
Rainfall[b]	4.82	4.77	5.02	3.94	3.70	3.76	5.33	4.09	2.93	2.67	3.33	4.32
Evapotranspiration[c]	0.51	0.67	1.51	3.00	4.96	6.48	7.21	6.51	4.68	2.70	1.10	0.57
Difference	4.31	4.10	3.51	0.94	-1.26	-2.72	-1.88	-2.42	-1.75	-0.03	2.23	3.75
Cookeville												
Rainfall	5.89	5.69	5.64	4.35	3.92	4.20	5.04	4.07	3.37	2.72	4.07	5.32
Evapotranspiration	0.47	0.63	1.44	2.89	4.80	6.27	6.98	6.32	4.54	2.62	1.09	0.57
Difference	5.42	5.06	4.20	1.46	-0.88	-2.07	-1.94	-2.25	-1.17	0.10	2.98	4.75
Nashville												
Rainfall	6.01	5.15	5.42	4.24	3.97	3.77	4.20	3.44	3.17	2.63	4.00	4.67
Evapotranspiration	0.51	0.72	1.61	3.15	5.15	6.88	7.64	6.91	4.87	2.83	1.20	0.64
Difference	5.50	4.43	3.81	1.09	-1.18	-3.11	-3.44	-3.47	-1.70	-0.20	2.80	4.03
Memphis												
Rainfall	5.96	4.65	5.28	4.42	4.16	3.96	4.04	3.05	3.30	2.85	4.27	4.47
Evapotranspiration	0.51	0.72	1.68	3.37	5.36	7.13	7.38	7.28	5.02	2.96	1.22	0.64
Difference	5.45	3.93	3.60	1.05	-1.20	-3.17	-3.84	-4.23	-1.72	-0.11	3.05	3.83

	Chattanooga	Cookeville	Nashville	Memphis
Rainfall (total annually)	48.68	54.28	50.67	50.41
Evapotranspiration (annually)	39.90	38.62	42.11	43.77
Difference	8.78	15.66	8.56	6.64

[a] Source: TORO Rainfall-Evapotranspiration Data / United States and Canada, The Toro Company, Minneapolis, Minnesota.
[b] Rainfall amounts are based on a 30 year average from 1930 through 1960.
[c] The modified Blaney-Criddle formula was used to determine potential evaporation. Consumptive coefficients for turfgrasses were developed by the Soil Conservation Service in 1960 and reported in “A Method for Estimating Irrigation Water Requirements of Lawns” by T. H. Quackenbush and J. T. Phelan, a paper presented during the 1963 Annual Meeting of the American Society of Agronomy, Denver, Colorado.

Table 12.
The Soil Separates[a]

Separate	Diameter (millimeters)	Number of particles per gram
Very coarse sand	1 to 2	90
Coarse sand	0.5 to 1	720
Medium sand	0.25 to 0.5	5700
Fine sand	0.10 to 0.25	46,000
Very fine sand	0.05 to 0.10	722,000
Silt	0.002 to 0.05	5,776,000
Clay	< 0.002	90,260,853,000

[a] United States Department of Agriculture classification.

Table 13.
General Description of Soils

Textural classification	Texture	Class
Sands	Coarse	Sandy soils
Loamy sand		
Sandy loam	Moderately coarse	Loamy soils
Sandy loam - fine		
Sandy loam - very fine	Medium	
Loam		
Silt loam		
Silt		
Clay loam	Moderately fine	
Sandy clay loam		
Silty clay loam		
Sandy clay	Fine	Clayey soils
Silty clay		
Clay		

3.5.2 Supplementary Turfgrass Maintenance Practices

Because golf courses generally receive a great deal of play and turfs are routinely trafficked, several management practices in addition to mowing, fertilization, and irrigation are usually needed. The surface (e.g., 2-inch depth) of soils supporting turfgrasses on greens, tees, and fairways often becomes heavily compacted, and the amount of internal, large (non-capillary) pore space can become limiting. Surface irregularities (e.g., ball marks, divots, depressions) may also develop as the game is played and turfs are maintained. Thatch, the layer of organic matter located above the soil surface and below the green tissue of the living turfgrass canopy, causes several problems as it accumulates.

3.5.2.1 Cultivation

Several machines are used to loosen soils and relieve compaction, reduce thatch, and/or groom the turf surface.

Core aerification is a very effective, selective cultivation technique to reduce both thatch and soil compaction. Hollow metal tines or open spoons are installed on vertical- or rotary-motion aerifiers to extract soil cores from the turf. Once on the surface, they are collected and transported from the turf (e.g., core harvester) or mixed with remaining thatch by dragging, irrigation, or vertical mowing. Fairways are often aerified two or more times each growing season using large, tractor-drawn, rotary-motion or drum-type equipment. Smaller, walk-behind or self-propelled vertical-motion core aerifiers are designed for use on greens, greens surrounds, and tees. Aeration tines are often available in a number of sizes and lengths. Spacing between tines may also be adjustable. Heavily compacted greens and tees may be cored as many as four or more times each year.

Subsurface compaction of soils (below standard coring depth) may be reduced by deep-tine or deep-drill aerification. Hollow or solid metal tines may be installed before using deep-tine aerifiers. Deep-drill aerifiers are engineered to bore large holes to a depth of eight or more inches, leaving loosened soil around each aeration channel. Both deep-tine and deep-drill aerifiers may be available for purchase or lease.

High-pressure (e.g., 1800 psi) streams of water are also used to reduce soil compaction, promote rooting, and increase the rate of water infiltration into soil. Like deep-tine aerification, water injection cultivation is a relatively new technology. Water is injected through small-diameter nozzles and into turf with very little disruption of the green or tee surface. Although it is not generally considered a substitute for routine core aerification of bentgrass and bermudagrass greens, this method has proven very effective during periods of climatic stress when core aerification with metal tines would cause too much damage.

Similarly, spiking and slicing are less aggressive cultivation methods than core, deep-tine, and deep-drill aerification. Spiking usually produces short, shallow cuts compared to slicing. The improved infiltration following spiking or slicing of bentgrass and hybrid bermudagrass greens during summer is usually very short-lived. Since no aeration core is removed, narrow openings at the soil surface often close very quickly.

Vertical mowing several times and in several directions each growing month may help promote upright plant growth, reducing grain on greens and tees. When set to scratch the soil surface, the same machines may effectively lift thatch and deposit much of this organic matter on the turf surface where it can be removed. Vertical mowing units designed for shallow dethatching may be interchanged with cutting reels of several triplex mowers.

Recently, several machines have been engineered for deep (e.g., 1 1/2 inches) vertical mowing. Depending on the distance between individual blades and the depth of soil penetration, they may expose more soil than conventional core aerification, providing an opportunity for the removal of large amounts of organic matter and the addition of more topdressing soil.

3.5.2.2 Topdressing

Light, frequent, and uniform applications of an appropriate soil over the surface of greens and tees can be very beneficial. Mature turf is topdressed to help control thatch, promote the recovery of turf from injury, smooth the surface, or change the composition of the soil base. Selection of topdressing material is perhaps one of the most critical decisions in turfgrass maintenance on the golf course. If the soil is favorable, soil used as topdressing must match that of the rootzone. Layering within the soil profile of a green or tee is commonly observed. Small differences in soil type among layers can cause problems including very poor internal drainage and turfgrass rooting. The infrequent application of too much topdressing material can result in alternate layers of soil and organic matter rather than mat, the desirable mixture of soil from topdressing and thatch. Several of today's topdressers are capable of delivering a uniform soil layer at an application rate of 0.2 cubic yards per 1000 square feet or less.

Topdressing immediately following core aerification will help fill aeration channels with soil, preventing them from being pinched at the surface. Older greens and tees established from unfavorable soil are often topdressed several times each year with more favorable soil (e.g., sand meeting United States Golf Association specifications for putting green construction, Table 14) in an effort to improve the physical composition of the turfgrass rootzone over time.

3.5.2.3 Rolling

Planting beds are often rolled to firm seed, sprigs, plugs, and sod to soil. Bermudagrass and *Zoysia* sod production sites are often rolled before harvest to ensure uniform soil thickness. Turfgrasses lifted by freezing and thawing cycles during winter may also benefit from rolling. Excessively moist soils are very prone to soil compaction, while dry soils may prove resistant as turfgrasses are rolled. Minor surface irregularities on greens and tees can be corrected by rolling. Recent advancements in power rollers provide superintendents an opportunity to smooth and firm the surface of greens and increase putting speed in preparation for major events (e.g., televised tournament, club championship). Routine rolling of greens and tees may result in more soil compaction and the need for additional cultivation.

3.5.3 Turfgrass Pest Management

Several diseases, insects, and weeds reduce the quality of turfgrasses on golf courses in Tennessee each year. While summer patch diseases, including Rhizoctonia blight and Sclerotinia dollar spot, may appear more often on creeping bentgrass greens and collars than anthracnose (*Colletotrichum graminicola*), *Pythium* root disfunction, and take-all patch (a spring and fall patch disease caused by *Gaeumannomyces graminis* var. *avenea*; syn. *Ophiobolus graminis*); they are most often much easier to identify and less troublesome and costly to manage. Many insects found on golf courses are very beneficial. Some decompose thatch, while others are predators or parasites of certain turfgrass pests.

Most insect pests of turfgrasses begin as eggs that hatch into immature insects (nymphs). After a series of molts and increasing in size, the immature finally develop into adults. This developmental process, or metamorphosis, varies among insect species. Chinch bugs and grasshoppers experience incomplete or gradual metamorphosis. Although they have no wings, nymphs resemble adults and often compete with them for the same energy sources. The immature larvae of white grubs do not resemble adults and do not compete with them for the same energy sources. White grub larvae are transformed to adult beetles during the pupa stage of complete metamorphosis. The activity of several species of white grubs is often predictable in that they have only one generation per year, overwinter as larvae, and have optimum temperatures at which they develop most rapidly. However, since they feed below the soil surface, activity may go undetected until aerial shoots of turfgrasses appear injured. Although crabgrasses and goosegrass may be observed more frequently in golf course turf than dallisgrass and nimblewill, these summer annual weed grasses are usually very effectively managed by maintaining a healthy, dense turf and/or applying an appropriate herbicide before seeds germinate. The two perennial weed grasses, dallisgrass and nimblewill, often compete with nearby turfgrasses for light, water, space, and nutrients. They may be very difficult to control with one herbicide application and without injuring nearby, desirable turf.

Table 14.
United States Golf Association Recommendations for Greens Root Zone Mix[a]

Saturated Hydraulic Conductivity inches/hour	Porosity %			Gravel 2 mm %	Sand Fractions (% Retained)				
	Non-Capillary	Capillary	Total		Very Coarse 1 mm	Coarse 0.5 mm	Medium 0.25 mm	Fine 0.15 mm	Very Fine[1] 0.05 mm
Normal 6-12 Accelerated 12 - 24	15 - 30	15-25	35 - 55	< 10 % (< 3 % gravel)		60 % minimum		< 20 %	< 5 %

Silt[1] 0.002-0.05 mm %	Clay[1] < 0.002 mm %	[1] Note: The total of very fine sand + silt + clay should be less than 10 percent
<5	<3	

[a] Soil physical analysis determined at 30 cm tension, U. S. G. A. protocol ASTM F1815; particle size analysis, ASTM C136 and ASTM F1832.

3.5.3.1 Diseases

Poor nutrition, soil compaction, drought, high and low temperatures, and excessive rainfall may be responsible for a turfgrass disorder (an interaction of the turfgrass plant and environment). Turfgrasses are also injured by destructive physical occurrences including divots, hydraulic fluid leaks, shoe spikes, and wear from golf cart tires. Turfgrass disorders and injuries often resemble diseases. However, most turfgrass diseases are caused by fungal parasites or pathogens. Fungal pathogens lack chlorophyll and rely on living plant tissue for energy. In turf, fungal mycelium or a mycelial mass may be visible to the naked eye although individual hypha (filament) composing the mycelium are microscopic. Pathogens are often found in the thatch or turfgrass root zone along with other more beneficial organisms including saprophytes that only break down organic debris to obtain energy. Some fungi exist both as saprophytes on plants or in soil as well as disease-causing pathogens. Disease symptoms are often expressed as bleached leaves (e.g., red thread, *Laetisaria fruciformis*), discolored spots or lesions on leaves (e.g., *Helminthosporium* leaf spot and copper spot [*Gloeocerospora sorghi*]), or depressed, circular areas of blighted turfgrass (e.g., take-all patch, Table 15).

A pathogen, a susceptible turfgrass species, and a favorable environment are required for disease development (Tables 16 and 17). A major goal of most superintendents is to minimize fungicidal treatments by maximizing turfgrass health through culture. Generally, the lower the mowing height, the greater the turfgrass stress and the more likely diseases will develop. Turfgrasses receiving an insufficient amount of nitrogen are most often more susceptible to rust (*Puccinia* spp. and *Uromyces* spp.), red thread, and dollar spot. Too much nitrogen favors the rapid development of diseases including brown patch, pink snow mold (*Microdochium nivale* (syn. *Fusarium nivale*), and *Pythium* blight (*P. aphanidermatum, P. arrhenomanes, P. graminicola, P. myriotylum and P. ultimum*). Depending on air and soil temperatures, drought-stressed turfgrasses may be very susceptible to patch diseases and *Ascochyta* leaf blight. Turfs maintained on poorly drained soils may be especially prone to *Pythium* blight. Routine steam cleaning of maintenance equipment can help minimize the spread of this and other diseases to uninfected turf. The use of disease-resistant varieties whenever possible is also a recommended disease-management strategy.

The biological control of turfgrass diseases involves using other living organisms to prevent or suppress the growth of a pathogen in plants, thatch, and/or soils. Microorganisms may suppress disease by:

1. Occupying space, preventing a pathogen from contacting turfgrasses.
2. Reducing the availability of shared energy sources.
3. Producing toxins that restrict the pathogens' rate of growth.

Recently, a very limited number of biocontrol agents have been registered by the EPA for use in turf. The fungus *Trichoderma harzianum* (Biotrek) is marketed in a granular formulation and is intended to be broadcast over the turf surface. The bacterium *Pseudomonas aureofaceans* (BioJect) is applied in irrigation water.

Table 15.
Symptoms of Several Common Turfgrass Diseases

Disease	Symptoms / Signs
Anthracnose	Older turfgrass leaves may first turn yellow, then tan to brown. Discoloration often starts at the leaf tip and moves toward the leaf sheath; however, when plants experience severe high-temperature stress, the diseased leaf tissue may uniformly discolor. Under magnification, small, raised, spiny, and black fruiting bodies are visible on the surface of dead leaves.
Brown Patch	Brown patches up to 3 feet in diameter develop during warm, moist climatic conditions. Smoke rings composed of grayish mycelium and dying grass may develop at the margin of the patch. Large gray to tan lesions appear on infected leaves.
Curvularia Blight	Irregularly shaped patches of blighted turf first appear yellow and mottled, then brown. Individual leaves discolor (appearing flecked and yellow-green in color) from the tip, downward toward the leaf sheath. If environmental conditions favor continued disease development, leaf sheaths and crowns may eventually be colonized. When this occurs in creeping bentgrass greens, blighted, tan-colored patches from 2- to 4-inches in diameter may appear on the putting surface.
Dollar Spot	Small, round spots approximately 1 to 3 inches in diameter develop on closely mowed turfs. Larger patches of bleached grass develop in turf maintained at a higher cutting height. Infected leaves may display light tan lesions with a distinct dark margin at each edge. Short, fuzzy white mycelium may be visible on lesions when dew is present.
Fairy Rings	Symptoms vary from small to large circles of dark green grass, dead grass, mushrooms or puffballs, or as combinations of these symptoms. Soils in the rings are often difficult to wet during summer and fall.
Fusarium Patch	Circular patches of gray or light tan turfgrasses develop during cold, wet climatic conditions. Small, round patches may enlarge to about 2 feet in diameter with snow cover. Patches seldom exceed 6 inches in diameter without snow cover. Patches become pink to salmon in color when exposed to sunlight.
Helminthosporium Diseases	These fungi can affect turfgrass leaves, crowns or roots. *Helminthosporium* leaf spot diseases are characterized by small brown circular lesions which may eventually enlarge and girdle leaves causing turfgrasses to appear light brown or tan. When these diseases attack turfgrass roots and crowns, the turf may appear to fade-out and become thin. These fungi may also affect turfgrasses developing from seed.
Powdery Mildew	White to gray powdery mycelium appears on infected leaves. Lower leaves are often affected more than younger leaves. Leaves may eventually become yellow and die slowly.

Table 15.
Symptoms of Several Common Turfgrass Diseases (Continued)

Disease	Symptoms / Signs
Pythium Blight	Hot, wet weather and irrigation favor development of this blight which often spreads rapidly in streaks along surface drainage patterns. This disease usually occurs in the summer and first appears as small circular patches of wilted turfgrasses from 1 to 12 inches in diameter. Cottony-gray mycelium is often visible in affected areas. Several *Pythium* species are responsible for root-rot type diseases which may develop during either hot, wet or cold, wet climatic conditions.
Red Thread	Bleached or reddish patches may develop rapidly during cool and moist climatic conditions. Disease usually spreads from the leaf tip toward the leaf sheath. Eventually, reddish mycelium may cover affected leaves and small red "threads" may develop from the tip of dead leaves.
Rust	Small yellow flecks first appear on leaves and stems. Yellow spots on infected leaves usually increase in area and have raised centers. When these raised areas rupture, masses of yellow, orange, red or dark brown microscopic spores are exposed, which can infect more plant tissue. The color of the turf may eventually look like that of the spores.
Slime Molds	Extended periods of warm, moist climatic conditions favor the development of this disease. The fruiting bodies of these fungi are often small and vary in color (i.e., white, gray). Although these fungi may cover the surface of turfgrass leaves, they do not kill plant tissue and are not considered harmful.
Spring Dead Spot	Dead spots may appear in mature (i.e., 3 to 5 years old) bermudagrass as growth resumes after the winter dormancy period. Each spring, for the next 3 to 4 years, the spots appear in the same location and expand. After the second or third year of disease activity, rings of dead grass may appear. Bermudagrass may slowly cover these rings of dead grass during summer. The disease may disappear after 3 to 4 years.
Stripe Smut	Infected turfgrasses appear pale green to slightly yellow or brown in color. Plants are often stunted and have a limited root system. Leaves of infected turfgrasses are often very rigid, split, and curled. These plants often die during extended periods of drought.
Take-all Patch	Initially, dull to bright reddish-bronze, depressed circular areas (e.g., 2 to 3 inches in diameter) of blighted turfgrasses appear. Eventually, diseased areas may reach a diameter of 2 feet or more. These may take on a frog-eye appearance as resistant plants fill in the center of each patch. During the growing season, individual patches fade from reddish-bronze to tan in color and often coalesce forming large irregularly-shaped patches of dead turf. As the disease develops, dark brown streaks may be visible inside turfgrass roots and, as temperatures warm, infected roots may turn black and become very brittle.
White Patch	Bleached patches of tall fescue, 1 to 2 feet in diameter, are distinctly white in color. Small, white mushrooms develop on leaf blades. Leaf blades are usually killed first at the leaf tip and later down the leaf blade to the sheath.

Table 16.
Susceptibility of Turfgrasses to Diseases/Disorders and Factors Favoring Their Development

Disease	Hosts	Factors Favoring Disease Development
Anthracnose	Annual bluegrass Bentgrasses Perennial ryegrass Red fescue	This disorder (referred to as a senectopathic disorder) occurs in late winter, spring and summer and develops only after turfgrass leaves age or senesce. Leaf blight of annual bluegrass, creeping bentgrass, red fescue and perennial ryegrass most often appears when daytime air temperatures range from 85° to 95°F and leaves remain wet for several days. In bentgrass, scattered, grey-green patches 1/2 inch to 1 1/2 feet or more in diameter appear as sheaths of older leaves and crowns blacken. Basal rot may develop on annual bluegrass or creeping bentgrasses at air temperatures from 60° to 75°F and is, most often, less of a problem at higher temperatures.
Rhizoctonia Blight	Bentgrasses Ryegrasses Tall fescue Hybrid bermudagrass	Occurs in warm, wet weather; high nitrogen fertility level; common on bermudagrass during spring green-up; and often on tall fescue during May and June.
Curvularia Blight	Annual bluegrass Bermudagrass Kentucky bluegrass Bentgrasses Chewings fescue Red fescue Tall fescue *Zoysia*	Curvularia blight may develop in early spring on bermudagrass and *Zoysia* damaged by low temperature and drought during winter. The disease may also occur on turfgrasses in late summer or early fall if they have been injured by climatic stresses, nutritional imbalances, nematodes, and insect activity. The fungus typically enters bentgrass leaves through wounds (e.g., cut tips, worn tissue) and penetrates plant cells as leaves senesce during hot, wet weather.
Dollar Spot	Bentgrasses Ryegrasses Kentucky bluegrass Bermudagrass *Zoysia*	Occurs in wet weather, heavy dew, low nitrogen fertility level, warm days and cool nights.
Fairy Rings	All turfgrasses	Mushrooms often appear in wet weather and originate near tree stumps.
Fusarium Patch	Bentgrasses Kentucky bluegrass Fescues Ryegrasses	Snowfall on unfrozen soil, tree leaves remaining on the turf for an extended period of time, maximum air temperature below 60°F, restricted air movement, and poor soil drainage.

Table 16.
Susceptibility of Turfgrasses to Diseases/Disorders and Factors Favoring Their Development (Continued)

Disease	Hosts	Factors Favoring Disease Development
Helminthosporium Leaf Spot	Nearly all turfgrasses	Wet weather and high nitrogen fertility level.
Powdery Mildew	Kentucky bluegrass	Shade, poor air circulation, and cool, moist weather.
Pythium Blight	Bentgrasses Ryegrasses	Hot, wet weather, high nitrogen fertility level, poorly drained soils, and seedlings are often highly susceptible.
Red Thread	Bentgrasses Kentucky bluegrass Fescues Ryegrasses	Cool, wet weather, heavy dew, fog, and low nitrogen fertility.
Rust	Kentucky bluegrass Ryegrasses Tall fescue *Zoysia*	Humid weather, shade, and infrequently mowed turfs.
Slime Molds	Nearly all turfgrasses	Extended periods of warm, wet weather.
Spring Dead Spot	Bermudagrass	Cold weather, excessive thatch, and high nitrogen fertility.
Stripe Smut	Kentucky bluegrass Tall fescue	Cool, wet weather, low fertility level, and acid soil.
Take-all Patch	Bentgrasses Kentucky bluegrass Red fescue Tall fescue Perennial ryegrass	Moist soils and cool soil temperatures (e.g., 50° - 65°F) favor root infection, applications of excessive rates of urea and a soil pH of 6.5 or above (e.g., in the top 1 inch) favor disease development, maintaining adequate levels of phosphorus and potassium in soil may suppress disease development, and use of ammonium sulfate or ammonium chloride after infection may speed recovery.
White Patch	Tall fescue	Hot, humid weather, and most common in newly established turfs.

Table 17.
Turf Disease Activity Calendar

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Anthracnose[a]				X[b]	X	X	X	X	X	X		
Rhizoctonia Blight					X	X	X	X	X	X		
Curvularia Blight				X	X			X	X	X		
Dollar Spot					X	X	X	X	X			
Fairy Rings	X	X	X	X	X	X	X	X	X	X	X	X
Helminthosporium Leaf Spot					X	X	X	X	X	X		
Powdery Mildew			X	X	X	X	X	X	X			
Pythium Blight					X	X	X	X	X	X		
Rust					X	X	X	X	X			
Spring Dead Spot				X	X							
Stripe Smut			X	X					X	X	X	
Take-all Patch[c]				X	X	X					X	X

[a] Air temperatures of 60° to 75°F favor the development of basal rot of annual bluegrass and bentgrasses, while leaf blight of annual bluegrass, bentgrasses, perennial ryegrass, and red fescue is promoted when successive daytime temperatures range from 85° to 95°F and leaves remain wet for an extended period of time.
[b] X indicates that environmental conditions often favor disease development this month. Depending on the disease severity, application(s) of an appropriate fungicide may be required.
[c] Although take-all patch is initiated in the spring and late fall, severe damage may not appear until affected plants become stressed by hot, dry weather, and traffic.

Certain composts appear capable of suppressing some turfgrass diseases (e.g., dollar spot, Pythium blight, Pythium root rot, and red thread). However, not all composts suppress disease, and an individual compost does not generally suppress all pathogens. Much more research is needed to determine those organisms in a compost that suppress a turfgrass disease and develop reliable quality control techniques to ensure product viability and performance.

Testing and use of biologicals to manage certain diseases on golf courses will increase as microorganisms that antagonize specific pathogens are identified and cultured, and expertise regarding the establishment and maintenance of appropriate populations in thatch and soil improves.

Fungicides are an integral part of many turfgrass disease-control programs. They are used to suppress the growth of a fungal pathogen when the environment favors disease development, preventing the infection of sensitive turfgrasses. Fungicides are classified according to *biochemical* (the effects on internal metabolic processes of the pathogen) and *topical* (the location on or in turfgrasses where activity takes place) modes of action. Fungicides from different biochemical classes are often alternated and/or mixed to reduce the potential for the development of fungicide resistance within a population of troublesome pathogens.

Topical modes of action of fungicides are classified as either contact or penetrant (Table 18). Contact fungicides are active only in the area of placement or contact. Penetrant fungicides move from the plant surface into underlying tissue in amounts that are toxic to fungi. They are further categorized as localized, acropetal, or systemic. Localized penetrants move into underlying tissue and remain near the point of entry. Once inside turfgrasses, acropetal penetrants move upward in water-conducting tissue (xylem). Systemic fungicides move both upward, in xylem, and downward, in energy-conducting tissue (phloem).

3.5.3.2 Insects

Very few of the many insects living in golf course turf actually injure turfgrasses. Insects that do are classified as root-feeding, shoot-feeding, or burrowing. Mole crickets, several species of white grubs, and older billbug larvae feed on turfgrass roots. Sod webworms, armyworms, cutworms, leafhoppers, spittlebugs, chinch bugs, and billbug adults and young larvae feed on aerial shoots. Some insect pests are preferential feeders injuring a limited number of turfgrasses (Table 19). Others injure grasses as they feed on leaves, stems, or roots. Although ants, burrowing bees, and wasps may nest in turf and gain the attention of superintendents and golfers alike, they are not generally considered major turfgrass pests.

Most insect pests develop very rapidly when air and soil temperatures reach their temperature optimum and are often observed in Tennessee every year (Table 21). When air and soil temperatures are considerably higher or lower than optimum, the activity of the insect pest usually stops. White grubs, caterpillars, and mole crickets injure turfgrasses as they chew plant tissue. Injury symptoms associated with insects with chewing mouth parts (side-to-side movement) are severed leaves or roots and holes in leaf tissue. Chinch bugs use a needle-like structure to pierce turfgrass tissue and withdraw juices. Injured turfs usually appear blotchy before turning pale green, then yellow in color.

Promising biocontrol agents for the control of turfgrass insects include parasites, predators, pathogens, and endophytes. Although not yet commercially available, several small insects are known to parasitize some insect pests. For example, *Tiphia* spp. wasps feed on white grubs, the Winsom fly (*Hyperecteina aldrichi*) on Japanese beetle adults, and the red-eyed Brazilian fly (*Ormia depleta*) on mole crickets. Ground beetles seek out and attack small caterpillars. Similarly, a number of spiders are predators of more than one insect species. Several formulations of microorganisms capable of causing disease in target insect pests are commercially available (Table 22). These work in a number of ways. Entomopathogenic nematodes penetrate the bodies of targeted insects, releasing a bacteria that causes disease. Varieties (e.g., *israelensis*, *kurstaki,* and *japonensis [“buibui”*]) of the bacteria *Bacillus* *thurgiensis* (BT) are toxic to some species of annual white grubs, cutworms, mosquitos, and webworms. A toxin is produced in the gut of Japanese beetle grubs after ingesting the live bacteria *Bacillus popilliae* (BP). Chinch bugs and billbugs are attacked by the fungus *Beauvaria bassiana* (Naturalis T&O™ and others). Similarly, the fungus *Metarhizium anisopliae* attacks white grubs. Some insect growth regulators (IGRs) interfere with the ability of an insect pest to produce materials necessary to mature. Others are juvenile hormones signaling an insect that it is not yet time to molt. Fenoxycarb (Award™), halofenozide (MACH 2™), and hydramethylon (Amdro™, Siege™) are examples of commercially available IGRs. Some fungi (e.g., *Neotyphodium* spp.) living inside certain turfgrasses produce substances that are toxic to insects that feed at the turf surface. These endophytes may also improve turfgrass tolerance to diseases such as Sclerotinia dollar spot and summer patch. Endophytes are found in seeds of several turfgrasses; however, they do not exist in bentgrass, bermudagrass, or Kentucky bluegrass.

Insecticides continue to be very effective tools when managing pest populations in high-quality golf course turf. They should never be used indiscriminately. Many insecticides developed in recent years have relatively short residual activity. This magnifies the need to apply an appropriate product at an appropriate rate when the target insect pest is most vulnerable. To ensure success, a thorough understanding of both the life cycles of insect pests and available chemical controls is required (Table 23).

Table 18.
Biochemical Class, Topical Mode of Action, and Common Trade and Chemical Names of Selected Fungicides Used in Turf

Class	Topical Mode of Action[a]	Common Name	Example Trade Name and Formulation	Chemical Name
Acylalanine	ASx	metalaxyl	Subdue™ 2E Subdue +™ WSP Subdue MAXX™	N-(2,6-dimethylphenyl)-N-(methoxyacetyl)-alanine methyl ester
Aromatic hydrocarbon	C	chloroneb	Terramec SP™ 65 WP	1,4-dichloro-2,5-dimethoxybenzene
	C	ethazol/etridiazole	Koban™ 30 WP	5-ethoxy-3-trichloromethyl-1,2,4-thiadiazole
	C	PCNB/quintozene	Terrachlor™ Turfcide™	pentachloronitrobenzene
Benzamide	ASx	flutolanil	ProStar™ 50 WP	N-[3-(1-methylethoxy)phenyl]-2-(trifluoromethyl)benzamide
Benzeneacetic acid	APm	trifloxystrobin	Compass™ 50 WDG	(E,E)-alpha-(methoxyimino)-2-[[[[1-[3-trifluoromethyl)phenyl]ethylidene]amino]oxy]methyl]-, methyl ester
Benzimidazole	ASx	thiophanate-methyl	Cleary 3336™	dimethyl 4,4'-*o*-phenylenebis [3-thioallophanate]
Benzonitrile	C	chlorothalonil	Daconil Ultrex™ WDG Daconil Weather Stik™ F	tetrachloroisophthalonitrile
Carbamate	ASx	propamocarb	Banol™ 66.5 L	propyl (3-[dimethylamino] propyl) carbamate
Dicarboximide	LP	iprodione	Chipco 26019™ 50 WP	3-(3,5-dichlorophenyl)-N-(1-methylethyl) 2,4-dioxo-1-imidazolidinecarboxamide
	LP	vinclozolin	Curalan™ DF	3-(3,5-dichlorophenyl)-5-ethenyl-5-methyl-2,4-oxazolidinedione
Dimethylation Inhibitor	ASx	cyproconazole	Sentinel™ 40 WG	a-(4-chlorophenyl)-a-(1-cyclopropylethyl)-1H-1,2,4-triazole-1-ethanol

Table 18.
Biochemical Class, Topical Mode of Action, and Common Trade and Chemical Names of Selected Fungicides Used in Turf (Continued)

Class	Topical Mode of Action[a]	Common Name	Example Trade Name and Formulation	Chemical Name
Dimethylation Inhibitor DMIs, Triazoles and Sterol Inhibitors	ASx	fenarimol	Rubigan™ 1 AS	a-(2-chlorophenyl-a-(4-chlorophenyl) 5-pyrimidinemethanol
	ASx	myclobutanil	Eagle™ 40 WSP	a-butyl-a-(chlorophenyl)-1H-1,2,4-triazole-1-propanenitrile
	ASx	propiconazole	Banner Maxx™ L	1-{[2-(2,4-dichlorophenyl)4-propyl-1,3-dioxolan-2-yl]methyl}-1H-1,2,4-triazole
	ASx	triadimefon	Bayleton 50 T&O™ WSP	1-(4-cmhlorophenoxy)-3,3-dimethyl-1-(1H-1,2,4-triazol-1-yl)-2-butanone
	C	mancozeb	Dithane™ DF Fore™	coordination product of zinc ion and manganese ethylene bisdithiocarbamate
Dithiocarbamate	C	maneb	Manex™	manganese ethylene bisdithiocarbamate
	C	thiram	Spotrete™	tetramethylthiuram disulfide
Ethyl Phosphonate	Sp	fosetyl-Al	Aliette™	aluminum tris (O-ethyl phosphonate)
B-Methoxyacrylate	ASx	azoxystrobin	Heritage™	methyl(E)-2-{2-[6-(2-cyanophenoxy)pyrimidin-4-yloxy]phenyl}-3-methoxy-acrylate

[a] ASx =acropetal systemic: xylem; C = contact; LP = localized penetrant; APm = acropetal penetrant, also referred to as mesostemic (e.g., translaminar movement with little or no movement in turfgrass vascular system); and Sp = systemic: phloem.

Table 19.
Several Insect Pests and Preferred Turfgrass Hosts

Pest(s)	Preferred Host(s)	Comments
Ants	Tall fescue and many other grasses	Usually present, ants are generally not a pest. When populations are large, ants can dig up soil covering turfgrass plants. Mounds disrupt the uniformity of the soil surface.
Armyworms and cutworms[a]	Bentgrass Bermudagrass Tall fescue and many other grasses	Occasional pests, armyworm caterpillars measure approximately 1 1/2 inches long at maturity; cutworms, 1 1/2 to 2 inches in length. Armyworms have distinct stripes along the sides of their bodies. Cutworms and armyworms are larvae of night-flying moths. Several generations of each may occur in one growing season.
Bees and wasps	Tall fescue and many other grasses	Some species of bees and wasps burrow into the turf to form their nests. They are usually present in turfs but are generally not considered major turfgrass pests.
Billbugs	Bermudagrass Kentucky bluegrass *Zoysia*	Billbugs are considered occasional pests. Overwintering adults usually lay eggs in turfgrass stems. Larvae tunnel inside stems and eventually feed on the roots of turfgrasses.
Fall armyworm	Bermudagrass Bentgrass Kentucky bluegrass Ryegrasses Tall fescue	At home in Central America, tropical South America and the West Indies, many fall armyworm moths are moved by weather fronts into the United States each spring. Female moths most often deposit eggs in masses on light-colored objects (e.g., metal fences, flags on greens, gutters on buildings) adjacent to turf. Eggs usually hatch in 2 to 10 days. Larvae feed on eggshells before spinning down to the turf where they feed on aerial shoots of turfgrasses. After feeding for 2 or more weeks, mature larva burrow into the soil to pupate.
White grubs[b]	Tall fescue and many other grasses	Larvae of several Scarab beetles feed on turfgrass roots and are frequent pests of turfgrasses in Tennessee. These include green June beetle, Japanese beetle, black turfgrass ataenius and chafers. When large white grub populations exist, severely damaged turfgrasses can often be rolled back like a carpet.
Mole crickets	Bentgrass	These occasional pests feed on turfgrass roots. Plants may be uprooted as mole crickets burrow through soil.
Sod webworms[a]	Bentgrass Bermudagrass Kentucky bluegrass Tall fescue	A frequent pest of several turfgrasses, sod webworm larvae live in thatch during the day and feed on turfgrass leaves at night. Mature larvae are about 3/4 inch in length, tan colored, and spotted.

[a] To check for cutworms and sod webworms, prepare a soap solution by adding 2 teaspoons of liquid dishwashing detergent in a gallon of water. Pour this solution over a 4 square foot area of the turf. Treat with an appropriate insecticide when one or more cutworms, or four to six or more sod webworms, are found per 4 square foot area.
[b] Several insecticides effectively control white grubs. Insecticide treatment is recommended when the population reaches the economic "aesthetic" threshold for the problem grub species (Table 20). Sample several square foot sections of the turf to determine the white grub population. Use a shovel or spade to cut out a square foot section of the turf, lift the turf and count the number of grubs present.

Table 20.
Threshold Targets for White Grubs by Species[a]

Pest	Number of Grubs per Square Foot
Annual White Grubs (Japanese Beetle, Oriental Beetle, European Chafer and Asiatic Garden Beetle)	5 to 10
Masked Chafer (Annual White Grub)	15 to 20
Black Turfgrass Ataenius	30 to 50
May/June Beetles	3 to 8
Green June Beetle	6 to 8

[a] Assuming adequate growing conditions and no digging animals.

Table 21.
Turf Insect Activity Calendar

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Ant(s)			**X**[a]	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**
Armyworms, Cutworms					**X**	**X**	**X**	**X**	**X**	**X**	**X**	
Bees and Wasps						**X**	**X**	**X**	**X**	**X**		
Billbugs					**X**	**X**	**X**	**X**				
Chinch Bugs								**X**	**X**	**X**		
Fall Armyworm						**X**	**X**	**X**	**X**	**X**		
Green June Beetle Grubs			**X**	**X**				**X**	**X**	**X**		
Leafhoppers & Spittlebugs								**X**	**X**	**X**	**X**	
Mole Crickets					**X**	**X**	**X**		**X**	**X**	**X**	
Sod Webworm							**X**	**X**	**X**	**X**		
White Grubs			**X**	**X**	**X**			**X**	**X**	**X**	**X**	**X**

[a] X indicates that turfgrass pest activity is commonly observed this month. When damage is apparent, an insecticide application may be required.

3.5.3.3 Nematodes

Nematodes are microscopic round worms (unsegmented) usually ranging from 0.013 to 0.125 mm in length. They reproduce by eggs and molt four times (juvenile stages) before becoming adults. All soils contain nematodes. Most are harmless. As previously mentioned, some nematodes benefit turfgrasses by causing disease in troublesome insect pests. A limited number of nematodes parasitize turfgrasses at some time during their life cycle (Table 24). These use a hollow or grooved spear-like structure or stylet to puncture walls of plant cells and inject digestive enzymes. The nematodes then withdraw partially digested food through the same stylet.

Plant parasitic nematodes are classified according to feeding habit as ectoparasitic or endoparasitic. Ectoparasitic nematodes survive outside turfgrasses, feeding from the surface of turfgrasses. Endoparasitic nematodes are located inside roots and, depending on their mobility, are either migratory or sedentary.

Turfgrasses are more tolerant of some parasitic nematodes than others. Areas of damaged turf usually vary in size and are irregular in shape. Affected turfgrass plants may be stunted. The color of aerial shoots often changes from green to light-green, then yellow and eventually brown. Roots of turfgrasses under nematode attack may be very short with few, if any, root hairs. Brown or red lesions may be visible on some roots and root tips may appear swollen. Turfgrasses with root systems severely weakened by nematodes are not able to take up water and nutrients from the soil.

Although plant parasitic nematodes may be active, healthy turfgrasses growing in fertile, moist soil during favorable weather often persevere. However, turfgrasses usually begin showing signs of nematode injury as they experience other stresses including drought, high temperatures, low temperatures, and wear. When nematode activity is suspected, an assay of soils and turfgrass roots is recommended to determine the extent of the problem. The application of a nematicide on golf course turf should always be based on assay results.

Table 22.
Entomopathic Nematodes, Bacteria, and Fungi for Insect Pest Management

Biocontrol Agent	Example Trade Name(s)	Target Pest(s)
Nematode		
Steinernema carpocapsae	BioSafe™ and others	Cutworms, webworms
Steinernema glaseri	N/A[a]	White grubs
Steinernema scapterisci	Proactant™	Mole crickets
Heterorhabditis bacteriophora	Cruiser™	Billbugs, white grubs
Bacteria		
Bacillus thuringiensis var. *israelensis*	Bactimos,™ TeKnar,™ Vectobac™ and others	Mosquitos
Bacillus thuringiensis var. *kurstaki*	Dipel 2X,™ Javelin,™ Steward™ and others	Cutworms, webworms
Bacillus thuringiensis var. *japonensis ("buibui")*	N/A[a]	Some species of annual white grub
Bacillus popilliae	Milky Spore Powder (St. Gabriel Laboratories)	Japanese beetle grubs
Fungi		
Beauvaria bassiana	Naturalis T&O,™ BotaniGard ES™ and BotaniGard 22WP™	Billbugs, chinch bugs, cutworms, white grubs, and others
Metarhizium anisopliae	N/A[a]	White grubs

[a]Not yet developed or commercially available.

Table 23.
Selected Insecticides/Nematicides for Use on Turf

Chemical Class	Common Name	Example Commercial Name(s)/Formulation(s)
Carbamate	bendiocarb	Turcam 76WP,™ Dycarb™
	carbaryl	Sevin Brand SL 4SL™
	methomyl	Lannate 2.4LV,™ Lannate 90SP™
Chloronicotinyl	imidacloprid	Merit 75 WSP,™ Merit 0.5G™
Diacylhydrazine	halofenozide	Mach 2.5G,™ Mach 22L,™ GrubEX 1.5G™
Organophosphate		
derivative: aliphatic	acephate	Orthene Turf, Tree & Ornamental Spray 75S, ™ Address 75SP™
	ethoprop (N)[b]	Mocap 10G - GC™
	trichlorfon	Dylox 80 80 SP,™ Dylox 6.2 G,™
derivative: phenyl	fenamiphos (N)[b]	Nemacur 10G,™ Nemacur 3EC™
Pyrethroid	beta-cyfluthrin	Astro 3.2EC™
	bifenthrin	Talstar GC™
	cyfluthrin	Tempo 20 WP GC™
	deltamethrin	DeltaGard™
	lambda-cyhalothrin	Scimitar GC™
	permethrin	Astro 3.2EC™
Spinosyn	spinosyn A + spinosyn B	Conserve SC 1 SC™
Phenyl pyrazole	fipronil	Chipco Choice™

[a](N) signifies a nematicide.

Table 24.
Some Common Parasitic Turfgrass Nematodes and Susceptible Turfgrasses

Genus	Common Name	Susceptible Turfgrass Species	
		Warm-Season	Cool-Season
Belonolaimus	Sting	ü	
Criconemella	Ring	ü Centipedegrass[a]	ü
Dolichodorus	Awl	ü	
Helicotylenchus	Spiral	ü	ü
Heterodera	Cyst	ü	ü
Hoplolaimus	Lance	ü	ü Bentgrass
Longidorus	Needle	ü	ü
Meloidogyne	Root-knot	ü *Zoysia*	ü Bentgrass
Paratrichodorus	Stubby root	ü	ü Kentucky bluegrass, Fescues
Paratylenchus	Pin		ü Kentucky bluegrass, Fescues
Pratylenchus	Lesion	ü	ü
Tylenchorhynchus	Stunt	ü	ü
Xiphinema	Dagger	ü *Zoysia*	ü Ryegrass

[a] ü indicates that the nematode has been found; ü followed by turfgrass species indicates that this species is especially susceptible to the nematode.

3.5.3.4 Weeds

The presence of many weeds on the golf course often indicates the need to adjust the overall turf care program.

Turfgrass weeds may develop from seeds or vegetative plant parts including bulbs, corms, rhizomes, stolons, and tubers. Unfortunately, many turfgrass weeds are prolific seed producers and are as tolerant of frequent mowing as the most well-adapted turfgrasses. These weed seeds may be transported by wind, water, maintenance equipment, and golfers. In addition to weed seeds, topsoil, and straw used to smooth and mulch soil surfaces, respectively, may contain plant segments capable of developing into a mature weed.

Turfgrass weeds are divided into two major groups based on plant form: weed grasses and broadleaf weeds. Weed grasses (including crabgrasses, dallisgrass, and goosegrass) are monocots emerging from seed with a single seedling leaf. Leaves of monocots have parallel veins. Dicots (such as white clover, dandelion, and broadleaf plantain) display two seedling leaves as they emerge from soil. The veins of leaves of these broadleaf weeds form a network-like pattern. Both monocots and dicots can be annuals, biennials, or perennials and are further subdivided by their season of growth (Table 25).

Summer Annual Weed Grasses. Each year, smooth crabgrass, large crabgrass, goosegrass, and foxtails germinate from seed and compete with turfgrasses for available moisture, nutrients, light, and space. These aggressive summer annual weed grasses begin emerging from seed in the spring, grow very fast during summer months, and complete their life cycle or die in late fall.

Winter Annual Weed Grasses. Seeds of winter annual weed grasses (e.g., annual bluegrass and annual ryegrass) germinate in late summer, fall, and winter. Plants usually complete their life cycle in the spring.

Summer Annual Broadleaf Weeds. Lespedeza, prostrate spurge, and prostrate knotweed are examples of low-growing, summer annual broadleaf weeds that begin emerging from seed in the spring and enter turf during summer months.

Winter Annual Broadleaf Weeds. Henbit, common chickweed, and speedwell are frequently observed growing in dormant bermudagrass, centipedegrass, and *Zoysia*. They also invade cool season turfgrasses. These winter annual broadleaf weeds complete their life cycle in spring.

Perennial Weeds. Perennial weed grasses and broadleaf weeds live for more than two years. Dallisgrass, nimblewill, and orchardgrass are difficult to control perennial weed grasses. Mouse-ear chickweed, white clover, ground ivy, and buttercup are persistent, creeping perennials.

Table 25.
Selected Annual, Biennial, and Perennial Turfgrass Weeds Found in Tennessee

Common Name	Scientific Name	Life Cycle[a]
Annual bluegrass	*Poa annua* L.	A (W), [P][b]
Barnyardgrass	*Echinochloa crusgalli* (L.) Beauv.	A (S)
Bermudagrass	*Cynodon* spp. Rich	P
Buttercup, creeping	*Ranunculus repens* L.	A (W)
Carpetweed	*Mollugo verticillata* L.	A (S)
Chickweed, common	*Stellaria media* (L.) Cyrillo	A (W)
Chickweed, mouse-ear	*Cerastium vulgatum* L.	A (W), [P]
Clover, white	*Trifolium repens* L.	P
Crabgrass, large	*Digitaria sanguinalis* (L). Scop.	A (S)
Crabgrass, smooth	*Digitaria ischaemum* (Schreb.) Muhl.	A (S)
Dallisgrass	*Paspalum dilatatum* Poir.	P
Dandelion	*Taraxacum officinale* Weber	P
Deadnettle, red	*Lamium purpureum* L.	A (W)
Dock, curly	*Rumex crispus* L.	P
Foxtail, green	*Setaria viridis* (L.) Beauv.	A (S)
Foxtail, yellow	*Setaria glauca* (L.) Beauv.	A (S)
Garlic, wild	*Allium vinale* L.	P
Geranium, Carolina	*Geranium carolinianum* L.	A (W), [P]
Goosegrass	*Eleusine indica* (L.) Gaertn.	A (S)
Ground ivy	*Galechoma hederacea* L.	P
Henbit	*Lamium amplexicaule* L.	A (W)
Knotweed, prostrate	*Polygonum aviculare* L.	A (W)
Mallow, common	*Malva neglecta* Wallr.	A (S, W), [B]
Medic, black	*Medicago lupulina* L.	A (S), [B]
Nimblewill	*Muhlenbergia schreberi* Gmel.	P
Nutsedge, yellow	*Cyperus esculentus* L.	P
Nutsedge, purple	*Cyrerus rotundus* L.	P
Onion, wild	*Allium canadense* L.	P
Orchardgrass	*Dactylis glomerata* L.	P
Panicum, fall	*Panicum dichotomiflorum* Michx.	A (S)
Plantain, broadleaf	*Plantego major* L.	P
Plantain, buckhorn	*Plantego lanceolata* L.	P
Purslane, common	*Portulaca oleracea* L.	A (S)
Shepherdspurse	*Capsella bursa-pastoris* (L.) Medic	B
Sorrel, red	*Rumex acetosella* L.	P
Spurge, prostrate	*Euphorbia supina* Raf.	A (S)
Violets	*Viola* spp.	P
Virginia buttonweed	*Diodia virginiana* L.	P
Witchgrass	*Panicum capillare* L.	A (S)
Woodsorrel, yellow	*Achilla millefolium* L.	P

[a] A (S) = summer annual, A (W) = winter annual, B = biennial, P = perennial.
[b] [P] indicates that there is also a perennial form; [B], that there is a biennial form.

Dandelion, broadleaf and buckhorn plantains, and curly dock are perennial broadleaf weeds that do not form above-ground or below-ground creeping stems. Wild garlic and wild onion, found throughout Tennessee, reproduce by both bulbs and seeds.

<u>Pre-emergence Herbicides and Summer Annual Weed Grasses</u>

Several herbicides are labeled for the pre-emergent control of crabgrasses, goosegrass, and foxtails in established turfs (Table 26). Most will not control emerging seedling weeds. Timing of the herbicide application is critically important for successful weed control. For best results, pre-emergence herbicides should be applied about one to two weeks before climatic conditions favor weed seed germination.

Crabgrass seeds require light to germinate. They usually begin germinating shortly after forsythia blooms. Generally, goosegrass seeds begin to germinate about one month after crabgrasses. For best control of summer annual weed grasses, pre-emergence herbicides should be applied in the spring when the temperature of the soil surface reaches 55°F (e.g., daytime air temperatures reach 65°F) for four or more days (Table 27).

The level of control often drops if pre-emergence herbicides are not activated by watering (1/2 inch) or rainfall within about seven days after treatment. Core aeration, slicing, or spiking should be completed before applying pre-emergence herbicides. Disturbing the soil surface after the application of a pre-emergence herbicide may reduce its effectiveness. Seeding, sprigging, plugging, or sodding may have to be delayed for several weeks or months after the herbicide application to avoid injury to turfgrasses.

<u>Pre-emergence Herbicides and Winter Annual Weed Grasses and Broadleaf Weeds</u>

Seeds of annual bluegrass and other aggressive winter annual weeds often begin to germinate in late summer. Germination of seeds and seedling emergence may continue through cool, moist periods in spring. Several herbicides are labeled for the pre-emergent control of winter annual weed grasses and broadleaf weeds (Table 26). These herbicides should be applied when temperatures drop below 60°F at night (Table 28). Sequential applications of pre-emergence herbicides may be necessary to extend the period of time winter annual weeds are controlled.

<u>Post-emergence Herbicides</u>

Post-emergence herbicide application(s) may be needed to control perennial weed grasses (e.g., dallisgrass, nimblewill, and orchardgrass) and broadleaf weeds (e.g., ground ivy, Virginia buttonweed, yellow woodsorrel, and wild violet) in golf course turf. Similarly, several herbicides are labeled for post-emergent control of annual weed grasses and broadleaf weeds. Post-emergence herbicides are usually most effective when uniformly applied to aerial shoots of susceptible, actively growing weed species within 30 days following their emergence from soil. Addition of a surfactant to the spray solution may improve product uptake and effectiveness. Chemical class, solubility, volatility, and use category vary among these herbicides (Table 29).

Table 26.
Characteristics of Several Herbicides Used for the Pre-emergent Control of Smooth and Large Crabgrass, Foxtails, Annual Bluegrass, and/or Other Annual Weed Grasses in Turf

Common Name	Example Trade Name	Herbicide Family	Water Solubility (ppm)	Vapor Pressure (mm mercury)	Half-life in Soils (days)	Use Class
atrazine	Atrazine™	triazine	33-70	2.9×10^{-7} @ 20-35°C	60	Restricted
benefin	Balan™	dinitroanaline	0.1-0.3	7.8×10^{-5} @ 25-30°C	40	General
bensulide	Betasan™ Bensumec™ PreSan™ Lescosan™	sulfonamide	25	8×10^{-7} @ 25-35°C	120	General
dithiopyr	Dimension™	pyridine[b]	1.4	4×10^{-6} @ 25-35°C	17	General
ethofumesate	Prograss™	unclassified	110	6.45×10^{-7} @ 25-35°C	35-98	General
isoxaben[c]	Gallery™	amide	1.0	<3.9×10^{-7} @ 25-35°C	34-146	General
siduron	Tupersan™	substituted urea	18	4×10^{-9} @ 20-35°C	90	General
metolachlor	Pennant™	acetanilide	488 @ 20 C	1.3×10^{-5} @ 20-35°C	15-25	General
metribuzin	Sencor Turf™	asymmetrical triazine	1100	1.2×10^{-7} @ 20-35°C	30-60	General
napropamide	Devrinol™	amide (acetamide)	73	4×10^{-6} @ 25-35°C	56-84	General
oryzalin	Surflan™	dinitroanaline	2.6	$1\text{-}2.5 \times 10^{-8}$ @ 25-30°C	20-128	General
oxadiazon	Chipco Ronstar G™ Regal Ronstar A.C.™ Ronstar™	oxadiazole	0.7	7.8×10^{-7} @ 20-35°C	60	General
pendimethalin	Pendulum™ Pre-M™ Weedgrass Control™	dinitroanaline	0.2-0.5	9.4×10^{-6} @ 25-30°C	44	General
prodiamine	Barricade™ Regelkade™	dinitroanaline	0.013	2.5×10^{-8} @ 25-30°C	70-120	General
quinclorac	Drive™	unclassified	62	<1×10^{-7} @ 25-35°C	not yet available	General
pronamide	Kerb WSP™	amide (acetamide)	15	8.5×10^{-5} @ 25-35°C	60	Restricted
simazine	Princep™ Simazine™	triazine	2-84	6.1×10^{-9} @ 20-35°C	60	General
trifluralin[d]	Treflan™	dinitroaniline	0.2-0.3	1.1×10^{-4} @ 25-30°C	45	General

[b] Dithiopyr offers control similar to that of the dinitroanilines.
[c] Isoxaben provides primarily pre-emergent broadleaf weed control.
[d] Trifluralin is a component of a pre-emergence herbicide combination along with benefin (trade name, Team™).

Table 27.
Pre-emergence Weed Control Calendar/Summer Annual Weed Grasses

J	F	M	A	M	J	Jl	A	S	O	N	D
	XXXXXX[a]			XXXX[b]							

[a] Depending on soil and air temperatures, pre-emergence herbicides should be applied between late February and early April for the control of crabgrasses, goosegrass, and foxtails.
[b] Sequential (split) applications of the pre-emergent herbicide may be required for extended (e.g., total of 200 days from initial herbicide application) weed control. Please read and follow label directions very carefully.

Table 28.
Pre-emergence Weed Control Calendar/Winter Annual Weeds

J	F	M	A	M	J	Jl	A	S	O	N	D
XXXX[b]							XXXXXX[a]		XXXX[b]		

[a] For pre-emergent control of winter annual weed grasses (i.e., annual bluegrass) and broadleaf weeds (henbit, common chickweed), herbicides should be applied in late summer or early fall before weed seeds germinate.
[b] Sequential applications of the pre-emergence herbicide may be required for extended weed control. Please read and follow label directions very carefully.

Table 29.
Characteristics of Several Herbicides Used to Control Emerged Broadleaf Weeds and/or Weed Grasses In Turf

Common Name	Example Trade Name	Herbicide Family	Water Solubility (ppm)	Vapor Pressure (mm mercury)	Half-life in Soils (days)	Use Class
AMA, ammonium methanearsenate	Super-Dal-E-Rad™	Organic Arsenical	256,000	nonvolatile	Inactivated by soil colloids	General
atrazine	Atrazine™	triazine	33-70	2.9×10^{-7} @ 20-35°C	60	Restricted
asulam	Asulox™	carbamate	534,000	1×10^{-7} @ 25-35°C	2 1/2-7	General
bentazon	Basagran T/O,™ Lescogran ™	unclassified	500	7.5×10^{-9} @ 25-35°C	20	General
bromoxynil	Buctril™	nitrile or substituted phenol	130	4.8×10^{-6} @ 20-30°C	7	General
chlorsulfuron	Corsair Selective™	sulfonyl urea	587 @ pH 5, 31,800 @ pH 7	2.3×10^{-11} @ 20-30°C	40	General
clopyralid[bc]	Lontrel Turf & Ornamental™	pyridine/ piclonic acid	1,000	1.3×10^{-6} @ 25-35°C	12-70	General
CMA, calcium methanearsenate	Super-Crab-E-Rad-Calar™	organic arsenical	256,000	nonvolatile	Inactivated by soil colloids	General
2,4-D[c]	Several	phenoxy	540-900	1.4×10^{-7} @ 20-30°C	10	General
2,4-DB[c]	Butyrac™	phenoxy	46	$< 1 \times 10^{-7}$ @ 20-30°C	5-10	General
2,4-DP[c] dichlorprop	Several	phenoxy	710	3×10^{-6} @ 20-30°C	10	General
dicamba[c]	Banvel™	benzoic acid	4,500	9.2×10^{-6} @ 25-30°C	< 14	General
diclofop[d]	Illoxan™	aryl-oxy phenoxy	3,000	3×10^{-7} @ 20-30°C	10 in sands 30 in clays	Restricted
diquat	Reward™	bipyridyllum	718,000	$< 10^{-8}$ @ 25-35°C	Bound to clays	General
DSMA, disodium methanearsenate	Crab-E-Rad,™ DSMA Liquid™ and others	organic arsenical	296,000	nonvolatile	Inactivated by soil colloids	General
ethofumesate	Prograss	unclassified	110	6.45×10^{-7} @ 25-35°C	35-98	General

Table 29.
Characteristics of Several Herbicides Used to Control Emerged Broadleaf Weeds and/or Weed Grasses In Turf (continued)

Common Name	Example Trade Name	Herbicide Family	Water Solubility (ppm)	Vapor Pressure (mm mercury)	Half-life in Soils (days)	Use Class
fenoxaprop	Acclaim Extra™	aryl-oxy phenoxy	1	1.4×10^{-7} @ 20-30°C	5-14	General
fluazifop	Fusilade II™	aryl-oxy phenoxy	2	2.5×10^{-7} @ 20-30°C	7-21	General
glufosonate	Finale™	unclassified	1,370,000	0	7	General
glyphosate	Roundup™	unclassified, amino acid derivative	15,700	1.9×10^{-7} @ 25-35°C	47	General
halosulfuron	Manage™	sulfonyl ures	15@pH 5, 1630 @ pH 7	2.8×10^{-2} @ 20-30°C	4-30	General
imazaquin	Image™	imidazolinone	60-120	< 2×10^{-8} @ 45°C	60	General
MCPA[c]	Several	phenoxy	825	1.5×10^{-6} @ 20-30°C	5-6	General
MCPP[c] mecoprop	Several	phenoxy	620	< 10^{-7} @ 20-30°C	21	General
metribuzin	Sencor Turf™	asymmetrical triazine	1,100	1.2×10^{-7} @ 20-35°C	30-60	General
metsulfuron	Manor Selective™	sulfonyl urea	550@pH 5, 2790 @ pH 7	2.5×10^{-12} @ 20-30°C	30	General
MSMA, monosodium methanearsenate	Daconate 6,™ Bueno 6™ and others	organic arsenical	1,040,000	nonvolatile	Inactivated by soil colloids	General
pronamide	Kerb WSP™	amide (acetamide)	15	8.5×10^{-5} @ 25-35°C	60	Restricted
quinclorac	Drive™	unclassified	62	< 1×10^{-7} @ 25-35°C	not available	General
saturated fatty acids	Sythe™	unclassified	emulsifiable in water	---	---	General
simazine	Princep™ Simazine™	triazine	2-84	6.1×10^{-9} @ 20-35°C	60	General
triclopyr[bc] w/ chlorpyralid	Confront™[b]	pyridine/ picolinic acid	430	1.26×10^{-6} @ 25-35°C	30	General

[b] Triclopyr formulated in combination with chlorpyralid is marketed as Confront.™
[c] Combination products including MCPA + MCPP + dicamba, MCPA + MCPP + 2,4-DP, MCPA + triclopyr + dicamba, 2,4-D + dicamba, 2,4-D + 2,4-DP, 2-4-D + MCPP, 2,4-D + MCPP + dicamba and 2,4-D + triclopyr are often very effective on many broadleaf weeds.
[d] In Tennessee, the use of diclofop (Illoxan™) is restricted to bermudagrass fairways for post-emergent control of goosegrass.

Table 30.
Post-emergence Weed Control Calendar/Summer Annual and Perennial Broadleaf Weeds

J	F	M	A	M	J	Jl	A	S	O	N	D
				XXXXXXXXXX[a]							

[a] For the control of some emerged annual summer and perennial broadleaf weeds and weed grasses, post-emergence herbicides should be applied from May 1 to July 15.

Table 31.
Post-emergence Weed Control Calendar/Winter Annual and Perennial Broadleaf Weeds

J	F	M	A	M	J	Jl	A	S	O	N	D
XXXXXXXXXXX[a]										XXXXXXXX	

[a] For post-emergent control of some annual winter and perennial broadleaf weeds, post-emergence herbicides should be applied from October 15 to March 1. Some (e.g., atrazine, diquat, and glyphosate) are intended for use during winter dormancy only.

In addition to the rate, timing, and uniformity of a pesticide application, the spray volume and pH of the spray solution can affect product performance (Couch, 1995). For example, some fungicides are very effective over a wide range of dilutions while others are dilution specific (Table 32). Several pesticides break down in solution if the water pH is not within a particular range (Table 33). The bonds of certain pesticide molecules may break down if the solution pH is >7. Insecticides appear to be more susceptible to this alkaline hydrolysis than fungicides or herbicides.

3.5.4 Pesticide Selection and Leaching Potential

Research indicates that the pollution of surface waters and groundwater reservoirs from pesticide applications to turfgrasses is uncommon. Recently, in an effort to help golf course superintendents select pesticides based on minimizing leaching potential, researchers R. L. Warren and J. B. Weber, North Carolina State University, developed a pesticide ranking system. This system, known as the Pesticide Leaching Potential (PLP) Index, estimates the potential leaching of individual pesticides by considering several of their characteristics. The index is based on a numeric scale from 0 to 100, where 0 indicates a very low leaching potential and 100, a very high likelihood for leaching (Table 34). A maximum recommended application rate (pounds active ingredient per acre) for each pesticide is also presented. The researchers note that, in addition to pesticides, other factors influence leaching potential. These include soil type and pH, volatilization, microbial decomposition, and photodecomposition. Several pesticides are more likely to leach in sandy soils with a pH $\geq$6.0 and very little organic matter than soils containing large amounts of clay.

Table 32.
Ideal Dilution Level of Selected Fungicides Applied at Label Dosage Rate[a]

Common Name	Example Trade Name	Ideal Dilution Per 1,000 Square Feet
chlorothalonil	Daconil 2787™	1.0 gallon
iprodione	Chipco 26019™	1/2 to 4 gallons
propiconazole	Banner™	2 gallons
triadimefon	Bayleton™	2 gallons
vinclozolin	Vorlan,™ Curalan™	1 to 2 gallons

[a]Couch, 1995

Table 33.
The pH Stability of Selected Fungicides, Insecticides, and Herbicides

Example Trade Name	Common Name	pH Stability
Fungicides		
Alliette™	fosetyl-AL	pH 5, 5 days; pH 8, 12 hours
Banner Maxx™	propiconazole	stable pH 5-9
Banol™	propamocarb	stable (no hydrolysis)
Bayleton™	triadimefon	stable at a wide pH range
Chipco 26019™	iprodione	pH 5, 90 days
Cleary's 3336™	thiophanate-methyl	pH 6-8, optimum
Daconil™	chlorothalonil	pH 9, 31 days
Dithane T/O™	mancozeb	decomposes at high acid or alkalinity levels
Rubigan™	fenarimol	stable at a wide pH range
Sentinel™	cyproconazole	stable from pH 1-9 for 35 days
Subdue™	metalaxyl	stable pH 5-9
Insecticides		
DeltaGard	deltamethrin	less stable in alkaline conditions
Orthene Turf, Tree & Ornamental Spray 75S ™	acephate	pH 5-7 optimum; pH 9, 3 days

Table 33.
The pH Stability of Selected Fungicides, Insecticides, and Herbicides (continued)

Example Trade Name	Common Name	pH Stability
Sevin Brand SL 4SL™	carbaryl	pH 7, 30 days; pH 8, 2-3 days
Talstar GC™	bifenthrin	stable pH 5-9
Tempo 20 WP GC™	cyfluthrin	stable pH 5-9
Herbicides		
Acclaim Extra™	fenoxaprop-P-ethyl	decomposes at alkaline pH
Balan™	benefin	stable at pH 5-9
Banvel™	dicamba	stable at pH 5-6
Basagran T/O™	bentazon	resistant to hydrolysis
Image™	imazaquin	stable at pH 5-9
Manage™	halosulfuron-methyl	pH 7 optimum solubility
Pendulum™	pendimethalin	pH 6-7 optimum
Pennant™	metolachlor	>200 days @ pH 2-10
Princep™	simazine	slowly decomposes at alkaline pH
Reward™	diquat	decomposes at alkaline pH
Roundup™	glyphosate	pH 3.5 to 6 optimum
Surflan™	oryzalin	pH 5-9 optimum

Table 34.
Pesticide Leaching Potential Index

Example Trade Name	Common Name	Index[a]	Rate[b]
Fungicides			
Curalan™	vinclozolin	20	2.7
Aliette™	fosetyl-AL	25	17.4
Cleary's 3336™	thiophanate methyl	31	2.7
Dyrene™	anilazine	31	5.4
Chipco™	iprodione	33	2.5
Fore™	mancozeb	36	8.7
Bayleton™	triadimefon	43	1.3
Banner™	propiconazole	45	1.5
Daconil™	chlorothalonil	46	19.6
Subdue™	metalaxyl	50	1.36
Banol™	propamocarb	51	7.24
Rubigan™	fenarimol	51	2.0
Terraneb™	chloroneb	51	7.0
Manzate™	maneb	56	13.0
Koban™	etridiazole	65	6.5
Insecticides or Nematicids			
Tempo™	cyfluthrin	0	0.09
Astro™	permethrin	12	0.9
Award™	fenoxycarb	19	1.5
Nemacur™	fenamiphos	36	10.0
Orthene™	acephate	36	3.0
Crusade™	fonofos	37	3.9
Insecticides or Nematicides			
Turcam™	bendiocarb	38	4.1
Sevin™	carbaryl	39	2.1
Oftanol™	isofenphos	44	1.9
Triumph™	isazofos	44	2.0
Proxol™	trichlorfon	52	8.16
Mocap™	ethoprop	55	4.9
Baygon™	propoxur	76	8.10
Herbicides			
Acclaim™	fenoxaprop	0	0.18
Barricade™	prodiamine	1	0.75
Illoxan™	diclofop-methyl	10	1.5
Pendulum™	pendimethalin	18	3.0
Dimension™	dithiopyr	20	0.5

Table 34.
Pesticide Leaching Potential Index (continued)

Example Trade Name	Common Name	Index[a]	Rate[b]
Herbicides			
Pennant™	metolachlor	22	4.0
MSMA™	MSMA	27	3.0
Treflan™	trifluralin	32	3.0
Kerb™	pronamide	34	1.5
Roundup™	glyphosate	36	4.0
Ronstar™	oxadiazon	36	3.0
Balan™	benefin	36	3.0
Basagran™	bentazon	36	2.0
Prograss™	ethofumesate	41	1.0
2,4-D™	2,4-D	41	0.75
Methar™	DSMA	41	5.0
Gallery™	isoxaben	44	1.0
Betasan™	bensulide	44	10.0
Surflan™	oryzalin	44	3.0
Devrinol™	napropamide	46	3.0
Asulox™	asulam	47	2.0
Sencor™	metribuzin	48	0.5
Aatrex™	atrazine	52	2.0
Princep™	simazine	54	2.0
Banvel™	dicamba	54	0.5
Image™	imazaquin	58	0.5
MCPP™	mecoprop	61	1.75
Tupersan™	siduron	64	10

[a] Pesticide Leaching Potential Index, scale 0 to 100, 0 = very low leaching potential and 100 = very high leaching potential. Rough guideline: pesticides with a PLP Index <40 have a low leaching potential compared to those with a PLP Index >70, indicating that potential leaching is a concern.
[b] The maximum recommended application rate expressed as pound(s) active ingredient per acre.

3.6 WILDLIFE HABITAT AND WATER QUALITY BUFFERS

3.6.1 Management of Aquatic and Terrestrial Wildlife

It is ideal when managing for wildlife to have a large piece of undisturbed land in which to achieve the greatest diversity of species in a given area. Within a golf course, there is usually a relatively small piece of land in a disturbed or inhabited area. This makes managing for wildlife more difficult. To maintain wildlife diversity it is an absolute necessity to preserve the habitat that already exists and improve upon it when needed. Since 18-hole golf courses generally cover an area of 133 acres, it is important to recognize the species which need to be managed. In most cases, these species will be small non-game and game (rabbit, squirrel); birds, aquatic species (amphibians, reptiles and fish), and insects. Such a diverse combination of wildlife will provide for a healthy system to manage.

Terrestrial and aquatic wildlife require basic welfare factors which include food, water, and cover.

Food: As mentioned above, the primary wildlife will probably be small mammals and birds. Recognition of the habitat should make it easy to determine the types of wildlife involved. Providing adequate food during the spring, summer, fall, and winter is important in establishing a healthy population. Since most species have different needs for food during different times of the year, it is important to provide food during all four seasons. Spring and summer foods can vary from various types of wild fruits, plants, herbs, seeds, and a large variety of insects (McConnell 1971).

These foods can be provided by planting trees, plants, and grass species or by maintaining them if they already exist. Examples of some spring and summer tree types are plum, black cherry, apple, pear, and persimmon. Fruits and seeds from these trees are often referred to as soft mast. All of these trees produce a very edible and desirable fruit for wildlife. Examples of plants and grasses that provide food for wildlife are clover, sunflower, blackberry, pokeweed and native warm season grasses such as blue stem. Some examples of fall and winter foods are trees such as dogwood, oaks, and hickories (hard mast). The plants and grasses include panic grass, clover, jewel weed, lespedeza, millet, and cowpeas. There are other types of food bearing plants; however, those mentioned here are some of the best for Tennessee.

Insects also play a large role in the management of wildlife. Many bird species thrive on the insects and it is important to maintain insect populations. Fortunately, insects flourish in most areas. One of the greatest threats to insects are chemicals applied to the course for maintenance. With the reduction in pesticide use needed for a wildlife-friendly course, insect populations should be adequate.

Food plots consisting of the above mentioned types of food should be located throughout the entire course. These will not only add to the diversity of the wildlife in the area but can be aesthetically pleasing and make the course more challenging. Information regarding food-plot sizes and localities can be obtained from the local wildlife management office or the state wildlife management agency, Tennessee Wildlife Resource Agency (TWRA).

Water: A good source of uncontaminated water is important to terrestrial species and imperative for aquatic species. Proper pesticide management and use of water quality buffers and riparian zones are important factors in keeping the water clean. Although some herbicides may be needed for greens and tee boxes, if applied correctly and according to labeled rates, herbicide use should not adversely impact water sources. The goal should be to reduce areas that require high rates of herbicides and irrigation water, thus allowing chemically sensitive species to thrive on the golf course (Conard, 1992). The potential for pesticides in runoff to enter surface water bodies can be reduced by use of buffer strips and riparian zones. Habitats like wetlands, wooded areas, and good roughs can serve as water quality buffers.

Altering a water source during construction as a means of flood control can destroy ponds and streams. Also, high sediment load due to poor erosion control and inadequate treatment of sewage can adversely impact the quality of surface waters. Channelization of streams to discourage flooding on the course should be avoided. This can increase flow velocities and sediment flow in the stream and cause flooding downstream. Also, species which require several microhabitats in the system would be destroyed due to a high flow. The building of communities around golf courses can increase runoff volumes. Methods for reducing the volume of runoff are discussed in the storm water management section.

Riparian protection (streamside vegetation) plays a vital role in the terrestrial/aquatic communities. Riparian areas serve as the transition zones between the aquatic and terrestrial environments (Wesche, 1993). Many important survival factors coexist here. Riparian zones serve as a place of cover, food, and also help maintain a healthy water source. Vegetation along the streambank can stabilize the surrounding soils (erosion control), help in flood control, and filter sediments and chemicals that are being transferred into the system.

Cover: Cover is an actual subset of habitat. Almost all welfare factors for wildlife can be placed within this one item. Cover is any physical or biological feature or arrangement of features that provide shelter from weather or concealment from or for predators (Robinson and Bolen, 1989). Brush piles, a stand of trees, snags, riparian areas, and even roughs are considered cover. Cover provides and promotes important areas in the course which are significant for all species. It furnishes nesting cover, loafing cover, feeding cover, roosting/denning cover, and concealment cover (predator/ prey). And, by adhering to the recommendation that 70 percent of the course area be left natural, providing cover for wildlife is easy to accomplish.

By preserving and maintaining the three basic welfare factors when developing a golf course, the habitats needed for wildlife to survive and remain healthy come naturally. Golf courses do have the ability to become a great refuge for wildlife and a crucial link in the habitat of the state as it becomes more urbanized. Wildlife protection and management can coincide with golf course management and humans, as well as wildlife, will reap the benefits.

3.6.2 Water Quality Buffers

Forest vegetation should be maintained along streams and wetlands to provide a natural buffer for minimizing impacts from golf course maintenance. Properly designed and managed water quality buffers have been shown to be highly effective for reducing and controlling sediment and nutrient transport to streams adjacent to agricultural disturbances (Lowrance et al., 1995).

Recent studies have also shown forested riparian buffer systems to be highly effective in preventing herbicide transport in overland flow exiting agricultural operations (Lowrance et al., 1997).

A three-zone concept for riparian buffers developed by the U.S Forest Service (Welch, 1991) provides an effective framework for designing and managing forested water quality buffers. This concept (illustrated in Figure 11) includes an undisturbed tree zone closest to the water to stabilize streambanks and protect aquatic habitat; a middle zone consisting of trees and shrubs managed to trap and remove nutrients, pesticides, and organics; and a grass zone that converts concentrated runoff to sheet flow to facilitate sediment trapping and infiltration.

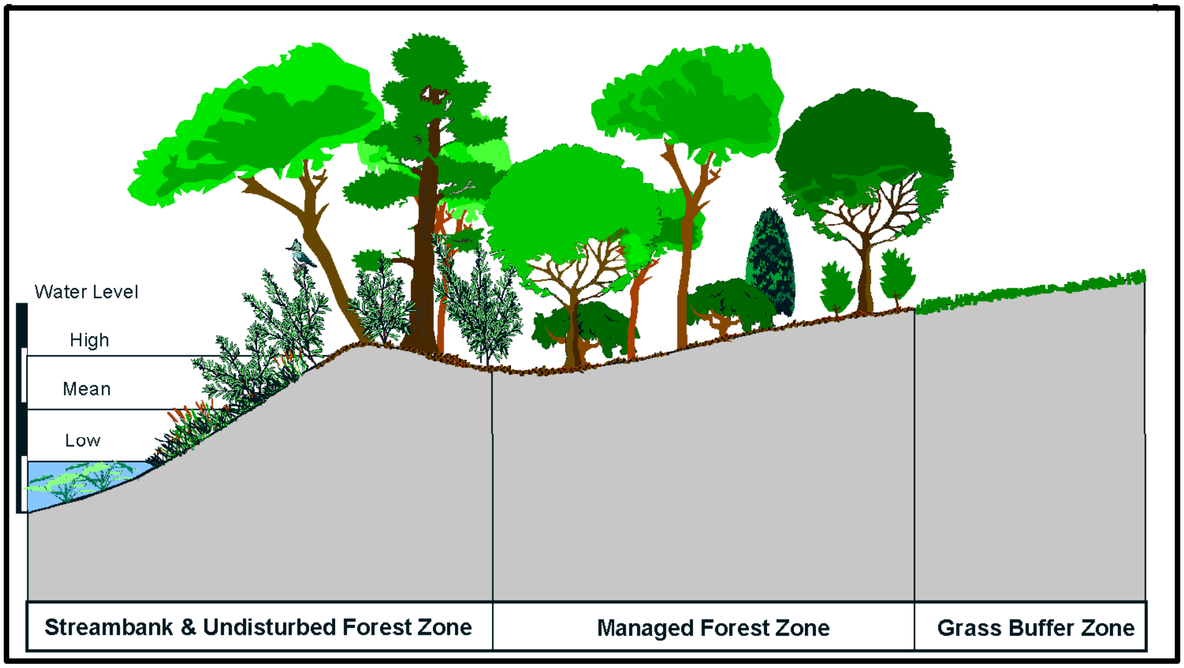


Figure 11: Three Zone Concept for Riparian Water Quality Buffers

The specific design of riparian water quality buffers will vary with soil type, permeability, slope, adjacent land-use impacts, and management objectives. Additional details on functions, benefits, design specifications, and maintenance guidelines for forested buffers were described by Welch (1991) and Herson-Jones et al. (1995).

Another critical factor in the design and management of water quality buffers and/or wildlife habitat is the selection of native plant species that are adapted to the geographic region and specific conditions. Plants that flourished in North America prior to occupation by European settlers are called native plants, and these should be the plants of choice for projects to control erosion, protect water quality, and enhance aquatic or terrestrial habitats. Native plants are strongly recommended over introduced or exotic plant species for several reasons. For one, native plants provide a natural source of food, shelter, and habitat for wildlife, and they tend to exist in balance with the natural diversity of the area. Because these plants have evolved under local conditions, they are tolerant of drought or extreme cold temperatures and have a natural resistance to insects and diseases. Consequently, native plants that become established in the appropriate site often require minimal cultural attention and maintenance. Native plants provide an extensive array of growth forms, foliage, flowers, and fruits making them suitable for a wide variety of applications. The use of native plants also helps to conserve and preserve our regional flora and fauna against eventual loss through habitat destruction or displacement by exotic or invasive species.

It is very important to select native plants that are adapted to the environmental conditions at any specific site. Surveys to determine the types of native plants that are thriving under similar conditions at nearby locations is an ideal way to identify species that will grow best at a specific location. Personal preferences can also be important considerations in the selection of plants. Particular attributes of different plants vary greatly and can offer some very interesting choices. These considerations may include growth form, texture, and ultimate height, appearance, and seasonal coloration of foliage. Selecting plants that bloom at different times will provide an attractive display of flowers throughout the growing season. Similarly, plants with attractive foliage, fruits, or fall colors can also be important elements in landscape design. Plants also differ widely in their inherent value to wildlife, and species can be selected to provide food, cover, or habitat for favored birds and other wildlife. The publications and Internet sites referenced below provide additional information on habitat requirements, environmental tolerances, management options, and sources of native plants.

- Bates, A.L., S.S. Harper, K.R. Kelley, and D.H. Webb. 1997*. Banks & Buffers - A guide to selecting native plants for streambanks and shorelines*. Tennessee Valley Authority. Knoxville, TN.

  This guide was produced by TVA, and it consists of a 14-page color publication and a compact disk (CD). The publication contains a description and printed copy of a database containing selected characteristics, environmental tolerances, and photographs of 117 species of native plants that can be used to restore riparian buffer systems, to stabilize streambanks and shorelines, or enhance aquatic, wetland, and riparian habitat in the Tennessee Valley. The CD contains a software application designed to guide users through the process of selecting plants. The software includes over 400 full-color photographs illustrating growth form, habitat, and selected features. Notes describe the natural habitat of each plant along with information on special uses or characteristics, commercial availability, and methods of establishment. Users can also browse a regional listing of more than 400 wholesale and state forestry nurseries. The guide is available for $25, plus handling and shipping. To order: call (423) 751-7338 or write TVA Water Management, 110 Market Street, TVA CST 17B, Chattanooga, TN 37402-2801.

- Midgley, Jan. 1993. *Nursery sources of native plants of the southeastern United States*. Wildflower Publishing. 234 Oak Tree Trail. Wilsonville, AL 35186.

  This compilation of nursery sources for native plants lists about 180 nurseries in 15 states, primarily in the southeast and mid-Atlantic regions of the United States. The publication provides specific sources for more than 1300 native species of ferns, grasses, herbaceous and woody plants, and vines.

- USDA, NRCS 1999. The PLANTS database. (http://plants.usda.gov/plants). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

  The PLANTS database is a source of standardized information about plants. It includes names, distributional data, plant growth data, plant materials information, plant links, and references.

- USEPA, GREEN ACRES: Green Landscaping with Native Plants (http://www.epa.gov/greenacres/)
  This Internet site provides a wide range of educational materials, case studies, and links to additional internet resources providing information about native plants or natural landscaping.

3.6.3 Wildlife-Related Problems

A few problems can result from creating a wildlife and environmentally sound golf course. Unwanted pest species may take up residence in and around the golf course. High grass in rough areas can cause the rodent population such as moles *(Scalopus aquaticus)* and other gnawing species to increase in the area. The area could also attract some common waterfowl to the course. Canadian geese *(Branta canadensis)* have been a problem on courses in the past. At some courses, geese have become an issue by straying onto fairways and leaving a trail of droppings behind them. Also, some courses and surrounding areas support wildlife such as the white-tail deer (*Odocoielus virginianus)* that can damage a course when feeding on it.

With the course properly managed for wildlife species, a balance should occur which prevents wildlife animals from becoming pests. In a wildlife-friendly course, rodents should be kept under control by raptors such as the red-shouldered hawk *(Buteo lineatus)* and the short-eared owl *(Asio flammeus)*. The Canadian geese should be enticed away from the fairways and greens by the high vegetation in the surrounding rough areas and by vegetation near the ponds (Terman, 1997). Keeping deer off golf courses can be a problem, particularly in areas where urbanization has fragmented their habitats. Methods for controlling dear populations include allocating hunting, repellents, relocation, and sterilization of the females in the herd. Wildlife-related problems on golf courses can be solved if wildlife is managed correctly.

Aside from wildlife, golfers are the most serious threat to the maintenance of golf courses. Persuading golfers to support and promote the wildlife-friendly course can be a challenge. Educating golfers will be the best way to accomplish this. The publication *Environmental Principles for Golf Courses in the United States* (USGA, 1996) provides the following list of what we as golfers can do.

1. Recognize that golf courses are managed land areas that should complement the natural environment.
2. Respect designated, environmentally sound areas within the course.
3. Accept the natural limitations and variations of turfgrass plants growing under conditions that protect environmental resources.
4. Support golf course management decisions that protect or enhance the environment and encourage development of environmental conservation plans.
5. Support maintenance practices that protect wildlife and natural habitat.
6. Encourage maintenance practices that promote the long-range health of the turf and support environmental objectives. Such practices include aeration, reduced fertilization, limited play on sensitive turf areas, and water conservation.
7. Commit to long-term conservation efforts (efficient water use and Integrated Plant Management) on the golf course.
8. Educate others about the benefits of environmentally responsible golf course management.
9. Support research and education programs that expand our understanding of the relationships between golf and the environment.

10. Take pride in our environmentally responsible courses.

Together with the help and support of the designers, golf organizations, and golfers we can develop and maintain environmentally and wildlife-friendly courses.

SECTION 4.0
REGULATORY CONTACTS

United States Environmental Protection Agency (EPA)
Web Site: http://www.epa.gov.region4

EPA Numbers

EPA National Response Center	(800) 424-8802
EPA Hazardous Waste Hotline	(800) 424-9346 (or Poison Control Center)
EPA Safe Drinking Water Hotline	(800) 426-4791
EPA Right-to-Know Hotline	(800) 535-0202
EPA Regional Offices: Atlanta	(404) 563-8357

Tennessee Department of Agriculture
Web Site: http://www.state.tn.us/agriculture/
Phone: (615) 837-5148

Tennessee Department of Environment and Conservation
Web Site: http://www.state.tn.us/environment.
Phone: (888) 891-8332

Tennessee Valley Authority
Web Site: http://tva.com/index.htm
Phone: (423) 632-2101

United States Army Corp of Engineers
Web Site: http://www.usace.army.mil/
Phone: (615) 736-5181

Tennessee Wildlife Resources Agency
Web Site: http://www.state.tn.us/twra/
Phone: (615) 781-6500

Additional Numbers

CHEMTREC Emergency Hotline	(800) 424-9300
Chemicals Referral Center	(800) 262-8200
American Crop Protection Association	(202) 296-1585
National Pesticides Telecommunications Network	(800) 858-7378

Information Organization: The information is categorized by the agencies that regulate the specific areas of responsibility such as, air, water, waste, land, pesticides, nutrients, forestry, and wildlife.

Air Pollution: (TDEC) - (888) 891-8332

Construction Permit: Constructing or modifying a source that emits pollutants into the air.

Operating Permit: Operating a source that emits pollutants into the air.

Title V Operating Permit: Emitting more than 100 tons/year of an air pollutant, 10 tons/year of hazardous air pollutant, and/or 25 tons/year of a combination of hazardous air pollutants.

Open Burning Permit: Open burning of any material other than wood waste.

Notification of Asbestos Demolition or Removal: Removing asbestos where quantities exceed 160 square feet or demolition of a regulated facility.

Archeology: (TDEC) - (888) 891-8332

Archaeological/Cemeteries/Grave Sites Division
Geologic Characteristics

Solid Waste: (TDEC) - (888) 891-8332

Hazardous Waste Generator Notification/EPA ID Number: Generating more than 100 kg of hazardous waste or 1 kg of acutely hazardous waste in any month of the calendar year requires notification. Generating, transporting, treating, storing, or disposing of hazardous waste requires an EPA ID number.

Hazardous Waste Permits: Treating, storing, or disposing of hazardous wastes.

Special Waste Approval: Disposing of special waste.

Permit-By-Rule for Non-hazardous Solid Waste: Operating solid waste processing, collection, and/or recycling facilities.

Landfill Permit: Operating a solid waste landfill to take household, industrial, land clearing, landscaping, and/or construction and demolition wastes.

Hazardous Waste Transporter Permit: Transporting hazardous wastes that originate or terminate in Tennessee

Solid Waste Transporter Permit: Hauling municipal solid waste.

Notification For Used Oil: Every used oil collection center, transporter, transfer facility, marketing, processing, refining, and off-specification burner site must file a notification with the state.

Water (TDEC) - (888) 891-8332

NPDES Discharge Permit for Industrial Activity: Point source discharge of storm water and wastewater runoff to the waters of the state.

NPDES General Permit For Industrial Storm water: Point source discharge of storm water runoff to the waters of the state.

Aquatic Resource Alteration Permit (ARAP)/Section 401 Certification: Physically altering waters (streams and wetlands) of the state, including water withdrawals that have the potential to affect the stream's ability to support classified uses.

State Operating Permit: Operating a closed-loop wastewater; irrigating wastewater to land, etc.

Surface Mining Permit: Surface disturbance and surface mining of specific minerals.

Water Supply – (TDEC) - (888) 891-8332

Wellhead Protection Program Approval: Public water supplies using groundwater as a source.

Certificate of Dam Approval and Safety: Constructing, altering, removing, or operating a dam that is a minimum of 20 feet high or impounding at least 30 acre-feet of water.

Groundwater availability: The availability of groundwater in a specific area.

Well Driller Licensing Requirements: Water well driller or installer license: The digging, drilling, or re-drilling of a water well, or anyone who installs or repairs water well pumps or filters and treatment devices.

Underground Injection Control Permit: Injection wells and injection activities with the exception of single-family domestic waste-disposal systems and injection of natural gas for the purpose of storage, which includes discharges into sinkholes.

Public Water System Construction: Constructing or modifying a public water system.

Subsurface Sewage Disposal Requirements

Division of Groundwater Protection - (888) 891-8332

Petroleum Underground Storage Tank (TDEC) - (888) 891-8332

Petroleum Underground Storage Tank Notification: Installing a petroleum underground storage tank and/or having an existing petroleum underground storage tank on-site.

Superfund

Consent Order Agreement - Voluntary Cleanup Oversight and Assistance Program (VOAP): Investigation and cleanup of Superfund sites under the VOAP.

Department of the Army Federal Permits - (615) 736-5181

Section 404 (Dredge or Fill Permit): Discharging dredged or fill material, excavating or mechanized land clearing in any waters of the United States, including wetlands.

Section 10 (Work Altering or Placing Objects in Navigable Waters): Discharging dredged or fill material, excavating, or mechanized land clearing in any waters of the United States, including lakes and streams

Tennessee Valley Authority - (423) 632-2101

Section 26a Permits: Constructing, operating, or maintaining a structure in the Tennessee River area or any of its tributaries that affect navigation, flood control, or public lands or reservations.

Pesticides, Nutrients, Seed, Fertilizer - (TDA) - (615) 837-5148

Certification, Licensing, and Pest Control Charters: Governs the custom application of pesticides is "The Tennessee Application of Pesticides Act" (TAPA), and there are published rules that coincide with the law.

Feed Seed Fertilizer Lime Law: Feed, Seeds, fertilizer, and lime are checked for purity and effectiveness, ensuring that the standards of quality expected by the customer are met.

Proper Pesticide Use - Application, selling, purchasing, registering

Proper Pesticide Storage - Storage and handling

Pesticide Waste - Proper disposal of unusable and unwanted pesticides

Forestry – (TDA) - (615) 837-5520

Forest Burning Permits (TDA) - (615) 837-5520 or your local forester or Tennessee Department of Agriculture Web page.

Forest Burning Permits - Burning permits focus attention on the safe use of fire.

Landowner Assistance- Assists landowners through education about forest stewardship, management, and environmental protection.

Tennessee Wildlife Resources Agency (TWRA) – (615) 781-6500
Fish kills, boating, fisheries, information & education, law enforcement, and wildlife.

SECTION 5.0
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