GCSAA
Golf Course Superintendents Association of America

Best Management Practices for Pennsylvania Golf Courses

October 2020

BMP Best Management Practices

Best Management Practices Planning Guide & Template

In partnership with the PGA TOUR

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Pennsylvania Golf Course Superintendents Association

The PGCSA represents the seven regional chapters in the state and serves to unify and advance the golf turf management profession through communication, research & education, government relations, and industry advocacy within the Commonwealth of Pennsylvania.

Golf Course Superintendents Association of America

The Golf Course Superintendents Association of America (GCSAA) is the professional association for the men and women who manage and maintain the game's most valuable resource: the golf course. Today, GCSAA and its members are recognized by the golf industry as one of the key contributors in elevating the game and business to its current state.

Since 1926, GCSAA has been the top professional association for golf course management personnel in the United States and worldwide. From its headquarters in Lawrence, Kansas, the association provides education, information and representation to more than 17,000 members in more than 72 countries. GCSAA's mission is to serve its members, advance their profession and enhance the enjoyment, growth, and vitality of the game of golf.

Environmental Institute for Golf

The Environmental Institute for Golf (EIFG) fosters sustainability by providing funding for research grants, education programs, scholarships, and awareness of golf's environmental efforts and benefits. Founded in 1955 as the GCSAA's Scholarship & Research Fund, the EIFG serves as the association's philanthropic organization. The EIFG relies on the support of many individuals and organizations to fund programs to advance stewardship on golf courses in the areas of research, scholarships, education, and advocacy. The results from these activities, conducted by GCSAA, are used to position golf courses as properly managed landscapes that contribute to the greater good of their communities. Supporters of the EIFG know they are fostering programs and initiatives that will benefit the game and its environment for years to come.

United States Golf Association

The United States Golf Association (USGA) provides governance for the game of golf, conducts the U.S. Open, U.S. Women's Open, and U.S. Senior Open, as well as 10 national amateur championships, two state team championships, and international matches, and celebrates the history of the game of golf. The USGA establishes equipment standards, administers the Rules of Golf and Rules of Amateur Status, maintains the USGA Handicap System and Course Rating System, and is one of the world's foremost authorities on research, development, and support of sustainable golf course management practices.

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Acronyms

ABW	annual bluegrass weevil
AST	above ground storage tank
BMP	best management practice
Ca	calcium
CCE	calcium carbonate equivalent
CWA	Clean Water Act
DEP	Pennsylvania Department of Environmental Protection
DO	dissolved oxygen
DU	distribution uniformity
DWQ	Division of Water Quality
EC	electrical conductivity
EIFG	Environmental Institute For Golf
ET	evapotranspiration
FE	iron
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRAC	Fungicide Resistance Action Committee
GCSAA	Golf Course Superintendents Association of America
HRAC	Herbicide Resistance Action Committee
IPM	integrated pest management
IRAC	Insecticide Resistance Action Committee
K	potassium
K_2O	potash
Mg	magnesium
mg/L	milligrams per liter
MLSN	Minimum Level of Sustainable Nutrients
Mn	manganese
N	nitrogen
NPIRS	National Pesticide Information Retrieval Service
NPDES	National Pollutant Discharge Elimination System
NTEP	National Turfgrass Evaluation Program
OSHA	Occupational Safety and Health Administration
P	phosphorus
P_2O_5	phosphate
PCSM	Post-Construction Stormwater Management
PFBC	Pennsylvania Boat and Fish Commission
PGR	plant growth regulator
PNDI	Pennsylvania Natural Diversity Inventory
PPE	personal protective equipment
RUP	restricted use pesticide
S	sulfur
SDS	Safety Data Sheet
TDS	total dissolved solids
TMDL	Total Maximum Daily Load

USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGA	United States Golf Association
UST	underground storage tank

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Photos

Introduction

The golf industry in Pennsylvania contributes to the economic health of the state while providing recreational opportunities and valuable open space in developed areas. Often located within large population centers such as Philadelphia and its suburbs, golf courses provide advantages over other types of development. These advantages include absorption of stormwater and its potential pollutants and habitat for birds, pollinators, and other wildlife.

As managers of the land associated with golf courses, the state's golf course superintendents and golf course industry professionals are dedicated to protecting the natural resources and environmental functions of golf courses. As a demonstration of this commitment, golf course superintendents have partnered with Pennsylvania State University scientists to develop and document best management practices (BMPs) for golf courses. These research-based, voluntary guidelines have been developed specifically for the state's golf courses. These guidelines not only protect natural resources, they also afford the opportunity for superintendents to be recognized as environmental stewards by club members, the community at large, and state officials.

Best Management Practices

BMPs are methods or techniques found to be the most effective and practical means of achieving an objective, such as preventing water quality impacts or reducing pesticide usage. The BMPs contained within this document primarily protect water resources.

Pollution Prevention

Pennsylvania boasts over 86,000 miles of streams, borders Lake Erie, contains an abundance of surface lakes and ponds, and possesses a variety of groundwater aquifer types. Many BMPs protect these water resources by reducing nonpoint source pollution (such as nutrients, pesticides, and sediments in stormwater runoff), stormwater volume, and peak flow. Through retention, infiltration, filtering, and biological and chemical actions, any negative effects of golf courses on surface and groundwater resources can be prevented or minimized. In fact, several studies have shown that implementing BMPs can actually improve water quality as it traverses golf course properties. For example, bare ground is much more likely to erode than turfgrass. Therefore, following grow-in BMPs during course construction or renovation to quickly establish dense turfgrass ground cover helps minimize erosion potential. Maintaining vegetated areas, such as filter strips and buffers, to slow down stormwater or excess irrigation, allows infiltration and uptake and is another key BMP. Pesticide BMPs help superintendents follow state and federal regulations related to the storage, handling, transport, and use of pesticides, preventing point source pollution and minimizing the potential for nonpoint source pollution from these chemicals.

Water Conservation

Many BMPs can also be used to conserve water and to prepare for water use restrictions that may be imposed in times of drought. Water is a fundamental element for physiological processes in turfgrass such as photosynthesis, transpiration, and cooling, as well as for the diffusion and transport of nutrients. Turfgrass quality and performance depend on an adequate supply of water through either precipitation or supplemental irrigation. Too little water induces drought stress and weakens plants, while too much causes anaerobic conditions that stunt plant growth and promote disease. Excessive water can also lead to runoff or leaching of nutrients and pesticides into groundwater and surface water. Proper irrigation scheduling, careful selection of turfgrass species, and incorporation of cultural practices that increase the water holding capacity of soil are addressed through these BMPs, as well as considerations in the design, construction, and maintenance of irrigation systems.

Environmental Quality

In addition to water-related BMPs, this document includes a number of opportunities to increase the environmental quality of golf courses. For example, out-of-play areas can assist in the restoration and conservation of native grass areas, create habitat for wildlife, and provide critical habitat for declining species, such as monarch butterflies.

Creating a Facility BMP

To adapt BMPs to an individual facility, superintendents should assess their individual site, consider their available resources (such as budget), and understand that implementing BMPs is an ongoing process. Examples of information that can be added to the facility plan can include current efficiency and conservation plans, short-term and long-term improvement plans, and other related environmental plans (such as drought plans, integrated pest management plans, etc.). In addition, superintendents should understand that implementing BMPs can be undertaken over time and that multiple approaches can successfully protect natural resources.

Besides contributing to natural resources stewardship, incentives for golf courses in Pennsylvania to create a facility BMP plan and to implement BMPs include the following:

- Potential for more efficiently allocating resources by identifying management zones.
- Cost savings associated with applying less fertilizer and pesticide and conserving water.
- Improved community relations.
- Recognition by the golfing public and the community at large for environmental stewardship.

Because of limitations, such as budget, staff, clientele expectations, and management decisions, not all golf courses can achieve all of the best practices. However, planning for improvements over time and making even small changes that meet the goals of BMPs can be achieved. For

example, while a sophisticated washwater recycling system may be too expensive for many facilities, blowing clippings off mowers onto a grass surface is easily achieved and markedly reduces the amount of nitrogen and phosphorus in clippings that end up in washwater.

1 Planning, Design and Construction

The construction phase of any industry's infrastructure poses the greatest risk of ecosystem alteration. With proper planning and design, golf facilities can be constructed and maintained with minimal impact on water quality and other natural resources. Additional information about incorporating water quality protections into the planning and design phase is found in the "Surface Water Management" and "Maintenance Operations" chapters.

Regulatory Issues

Regulations are in place at the local, state, and national levels that impact planning, design, and construction activities on Pennsylvania's golf courses. These laws protect and conserve the environment both during and after construction. Before beginning golf course construction or renovation, consultation with the appropriate regulatory agencies is recommended. Communication between developers, designers, owners, the public, and regulatory agencies should occur early and often. In addition, if new wells must be installed, experts should be consulted for proper siting in the design plan, and all setback and other regulatory requirements.

State Regulations

Stormwater

The United States Environmental Protection Agency (USEPA) protects streams, rivers, and lakes from construction pollution under the Clean Water Act (CWA). Under the CWA, the National Pollutant Discharge Elimination System (NPDES) permit program helps address water pollution by regulating point sources that discharge pollutants to waters of the United States. The state of Pennsylvania has assumed the authority to administer the NPDES program in Pennsylvania. The Pennsylvania Department of Environmental Protection (DEP) Waterways and Wetlands Program, in DEP's regional offices, and DEP Regional Permit Coordination Office administer the NPDES permits for Discharges Associated with Construction Activity. These permits are required for any earth disturbance activity that is one acre or greater in size. If eligible, a project can apply for coverage under the PAG-02 NPDES General Permit, using the Notice of Intent Form, which are typically authorized by DEP's partnering County Conservation Districts. If ineligible for coverage under a general permit, the project may apply for an Individual NPDES Permit, using the Application Form, which are issued by the Regional Waterways and Wetlands Programs."

Structural BMPs must be integrated within the design plan to effectively manage stormwater. Detailed information on structural stormwater BMPs, including post-construction stormwater management requirements can be found in the DEP publication Pennsylvania Stormwater Best Management Practices Manual. In accordance with 25 PA Code Chapter 102, post-construction stormwater management should be planned and conducted to prevent an increase in the rate of stormwater runoff, minimize the increase in stormwater runoff volume, minimize impervious areas, maximize the protection of existing drainage features and vegetation and to minimize land

clearing, grading and soil compaction. In addition to a Post-Construction Stormwater Management (PCSM) Plan, the development of an Erosion and Sediment Control (E&S) Plan that address stormwater runoff issues during and after the earth disturbance activity are required for NPDES permits. These Plans must be kept on site and available for inspection. More information on E&S and PCSM Plans can be found at DEP's Construction Stormwater webpage.

Wetlands

Conserving the state's wetlands protects water quality and biodiversity, while reducing the potential for flooding and soil erosion. Wetlands are considered "Waters of the Commonwealth," and are regulated under Chapter 105 Waterway Engineering and Wetlands Management regulations and sections 404 and 401 of the federal CWA. The Water Obstructions and Encroachments Section of the Division of Wetlands, Encroachments and Training develops and coordinates regulation, policy, program guidance and procedure for the regional implementation of the Chapter 105 program, including coordination with Federal CWA, Section 404 requirements. Section 401 WQC may be issued out of the DEP Division of Wetlands Encroachment and Training as well as DEP Regional Permit Coordination Offices. More information about the regulations and policies related to wetland encroachment can be found on the DEP's Encroachment web page. Contacting DEP during the design phase of any construction activities expected to impact wetlands will assist in understanding the permitting process.

To protect this natural resource, wetlands should be identified in the field by qualified wetland specialists during the design phase and before the permitting process is initiated. Course design should minimize any impact to wetlands and streams tied to activities such as filling, dredging, flooding, crossings, or converting areas from one habitat type to another. In addition, natural buffers should be retained around wetlands (as with other waterbodies) to protect water quality and provide habitat.

Floodplains

Golf course development is often compatible with floodplains, particularly when compared with other uses such as residential or commercial development. Information about Pennsylvania floodplains can be found at the Pennsylvania Emergency Management Agency website, including floodplain maps. Minimizing encroachment into floodplains to the extent possible is prudent and is regulated under Pennsylvania's Chapter 105 regulations and Chapter 106, Floodplain Management regulations.

Any substantial disturbance to a floodplain, including clearing and grading, generally requires an engineering analysis to demonstrate minimal impact on the base flood elevation in accordance with local ordinances. Depending on the complexity of the encroachment, this analysis may be as simple as a comparison of cut and fill quantities within the floodplain or as complex as a detailed floodplain model of the entire watershed. A complex analysis may require a Federal Emergency Management Agency (FEMA) review along with potential revision to the floodplain mapping.

Key course components (such as greens and tees) should be designed above the 100-year flood elevation whenever possible to avoid loss of golf play due to periodic flooding. Any effects on the floodplain and floodway should be considered, and the required offsetting adjustments should be made in grades or vegetative treatment.

Dams

DEP's Division of Dam Safety monitors and regulates private dams in Pennsylvania under Chapter 105 regulations. The staff of the DEP assures proper planning, design review, construction review, maintenance monitoring and supervision of dams and reservoirs. Before constructing, maintaining, abandoning, or enlarging a reservoir, a permit must be issued by the agency. More information on permitting requirements and permit applications can be found on the Division's Dam Safety web page.

Listed Species

DEP requires applicants for most permits throughout Pennsylvania to utilize the Pennsylvania Natural Heritage Program's Pennsylvania Natural Diversity Inventory (PNDI) database. DEP uses PNDI as the primary source of information during the permit review process for the protection of threatened and endangered or species of special concern. PNDI information is accessible through the online Conservation Explorer. Additional information related to how the PNDI is incorporated into the permitting through DEP can be found in DEP's Policy for PNDI Coordination during Permit Review and Evaluation."

Noxious and Invasive Weeds

The Pennsylvania Department of Agriculture (PDA) administers the Noxious Weed Control Law and Noxious Weed Control List via the Noxious, Invasive and Poisonous Plant Program. PDA implements federal and state eradication and control programs when a noxious weed of limited distribution in the commonwealth is targeted by federal or state funding for suppression, control, or eradication. More information on these species and methods for their control can be found on the Noxious, Invasive and Poisonous Plant Program web page.

Planning

Principles

- Proper planning minimizes expenses resulting from unforeseen construction requirements.
- Good planning provides opportunities to maximize/integrate environmentally favorable characteristics into the property. This often requires the involvement of a team of experts, including golf course architects, superintendents, engineers, soil scientists, agronomists, biologists, etc.
- Any professional consultant engaged in planning should be familiar with Pennsylvania's regulations and permitting process.

Best Management Practices

- Assemble a qualified team with expertise in golf development and environmental permitting, including:
  - Golf course architect
  - Golf course superintendent
  - Clubhouse architect
  - Irrigation engineer
  - Environmental engineer
  - Energy analyst
  - Economic consultant
  - Civil engineer
  - Soil scientist
  - Geologist
  - Golf course builder
  - Legal team
- Determine objectives.
- Complete a feasibility study of the project that addresses the following topics:
  - Financial
  - Environmental
  - Water
  - Energy
  - Labor
  - Materials
  - Governmental regulatory requirements/restrictions
- Select an appropriate site that meets the needs of stakeholders.
- Identify strengths and weaknesses of the selected site.
- Have a qualified specialist accurately identify wetland boundaries.
- Identify any listed species or critical habitat present on the site.

Design

Principle

- Proper design meets the needs of the stakeholders, protects the site's environmental resources, and is economically sustainable.

Best Management Practices

- Retain a qualified golf course superintendent/project manager at the beginning of the design process to incorporate sustainable maintenance practices in the development, maintenance, and operation of the course.

- Minimize the need to alter or remove existing native landscapes and identify opportunities for restoration.
- Retain as much natural vegetation as possible. Where appropriate, enhance existing vegetation through the supplemental planting of native vegetation next to long fairways, in out-of-play areas, and along water sources supporting aquatic habitat.
- Remove nuisance, invasive, and exotic plants and replace with site-adapted native species.
- Plant only certified turfgrass.
- Define play and non-play maintenance boundaries.
- Greens:
    - Select a location that has adequate sunlight to meet plant needs and provides sufficient drainage.
    - Choose a green size and sufficient number of hole locations large enough to accommodate traffic and play damage, but not so large that it is not sustainable with your resources.
    - Select an appropriate root-zone material as designated by the USGA.
    - Consider the number of bunkers as it relates to resources available for daily maintenance.
    - Select a turfgrass species/variety that meets the needs of the stakeholders while adhering to the principle of "right plant, right place."
- Bunkers:
    - Decide whether bunkers will contain drainage.
    - Consider bunker entry and exit points and wear patterns, creating adequate space for ingress/egress points on greens, tees, fairways, and bunkers.
    - Select the proper color, size, and shape of bunker sand that meets your needs.

Construction

Principle

- Construction should be completed with care to minimize environmental impact and financial ramifications caused by poor construction techniques.

Best Management Practices

- Conduct a pre-construction conference with stakeholders.
- Attend a pre-construction meeting, as required under the NPDES permit, unless waived by DEP or the county conservation district.
- Schedule construction to maximize turfgrass establishment and site drainage.
- Use environmentally sound construction techniques.
- Follow the approved E&S Plan to ensure that the potential for accelerated erosion and sedimentation has been minimized.
- Maintain a construction progress report and communicate the report to permitting agencies.
- Use only qualified contractors experienced in the special requirements of golf course construction.
- Build temporary construction compounds to minimize environmental impacts.

Erosion and Sediment Control

Figure 1. Erosion and sediment control is a critical aspect of all construction activities when soil is disturbed.

Principles

- Soil carried by wind and water transports contaminants with it. Contaminants can dislodge, especially upon entering water bodies, where they can cause impacts to water quality.
- Because of the increased potential for accelerated erosion when soil is exposed, erosion and sediment control is a critical component of construction and grow-in of a golf course.

Best Management Practices

- Develop and implement strategies to effectively control sediment, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife and plant communities.
- Hydro-seeding or hydro-mulching offers soil stabilization.

Figure 2. Hydroseeding.

Grow-in

Principles

- Turfgrass establishment is a unique phase in turfgrass growth and requires greater quantities of water and nutrients than maintaining established turfgrasses.
- The establishment phase should be considered carefully to minimize environmental risk.

Best Management Practices

- ➢ Properly prepare and clear pests from the area to be established.
- ➢ Ensure erosion and sediment control devices are in place and properly maintained.
- ➢ To minimize environmental risk, apply nutrients – in either foliar or granular formulations – to the turfgrass surface and not the root zone, which does not speed establishment.
- ➢ Knife-in sprigs and roll to hasten root establishment.
- ➢ When using sprigs, application rates for nitrogen (N), phosphorous (P), and potassium (K) should correspond to percent ground cover (i.e., increasing rate as ground coverage increases).
- ➢ When using sod, topdress soil to fill in the gaps between sod pieces to hasten establishment and provide a smoother surface and delay nutrient applications until sod has sufficiently rooted.
- ➢ When establishing by seed, use appropriate seeding methods for your conditions.
- ➢ Use slow-release N or light, frequent soluble-N sources during grow-in.
- ➢ Mow as soon as the sod has knitted-down, when sprigs have rooted at the second to third internode, or seedlings have reached a height of one-third greater than intended height-of-cut.

Wetlands

Principles

- Wetlands act both as filters for pollutant removal and as nurseries for many species of birds, insects, fish, and other aquatic organisms. The biological activity of plants, fish, animals, insects, and especially bacteria and fungi in a healthy, diverse wetland is the recycling factory of our ecosystem.
- When incorporated into a golf course design, natural wetlands should be maintained as preserves and separated from managed turfgrass areas with native vegetation or structural buffers.
- Constructed wetlands are shallow marsh systems planted with emergent vegetation designed to treat stormwater runoff. While they are one of the best BMPs for pollutant removal, constructed wetlands can also mitigate peak rates of stormwater flow and even reduce runoff volume to a certain degree. They can also provide considerable aesthetic and wildlife benefits. Constructed wetlands use a relatively large amount of space and require an adequate source of inflow to maintain the permanent water surface.

Best Management Practices

- ➢ Delineate wetlands accurately before working in and around any wetlands.
- ➢ Ensure that proper permits have been obtained before working within any wetland boundaries.

Stream Restoration

Principles

- Vertical and lateral stream migration causing unstable banks, flooding, and reductions in groundwater recharge.
- Reestablishment of natural water systems helps mitigate flooding and control stormwater and can be used to address high sediment and nutrient loads to waterways.
- Land use decisions and engineering standards must be based on the latest research science available.

Best Management Practices

- ➢ Install stream buffers to restore natural water flows and flooding controls.
- ➢ Install buffers in play areas to stabilize and restore natural areas that will attract wildlife species.

Drainage

Principles

- Adequate drainage is necessary for growing healthy grass.
- A high-quality BMP plan for drainage addresses the containment of stormwater runoff, adequate buffer zones, and filtration techniques in the design and construction process to achieve acceptable water quality.
- Drainage of golf course features is only as good as the system's integrity. Damaged, improperly installed, or poorly maintained drainage systems result in inferior performance that negatively impacts play and increases risks to water quality.

Best Management Practices

- When constructing drainage systems, pay close attention to engineering details such as subsoil preparation, the placement of gravel, slopes, and backfilling.
- Internal golf course drains should not drain directly into an open waterbody. Instead, they should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- Stormwater should discharge through proper drainage and stormwater management devices, for example, vegetative buffers, swales, etc.
- The drainage system should be routinely inspected to ensure proper function.

Wildlife Considerations

Principles

- Golf courses occupy large land areas, generally in urban areas, providing critical links between urban and rural/natural environments.
- Maintaining wildlife habitat on golf courses better maintains biological diversity, which is especially important in the urban environment.
- Most golfers enjoy observing non-threatening wildlife as they play the game.

Best Management Practices

- Identify the different types of existing habitat.
- Identify the habitat requirements (food, water, cover, space) for identified wildlife species.
- Identify species considered threatened or endangered by the federal or state government, including species the state deems "of special concern."
- Preserve critical habitat.
- Identify and preserve regional wildlife and migration corridors.
- Design and locate cart paths to minimize environmental impacts. Construct the paths of permeable materials, if possible.
- Avoid or minimize crossings of wildlife corridors. Design unavoidable crossings to accommodate wildlife movement.
- Remove exotic/invasive plants and replace them with native species adapted to the site.
- Maintain clearance between the ground and the lowest portion of a fence or wall to allow wildlife to pass, except in areas where feral animals need to be excluded.
- Retain dead tree snags for nesting and feeding sites, provided they pose no danger to people or property.
- Construct and place birdhouses, bat houses, and nesting sites in out-of-play areas.
- Plant butterfly gardens around the clubhouse and out-of-play areas.
- Retain riparian buffers along waterways to protect water quality and provide food, nesting sites, and cover for wildlife.
- Minimize stream or river crossings to protect water quality and preserve stream banks.

- Retain riparian buffers along waterways to protect water quality, provide food, nesting sites, and cover for wildlife.

Figure 3. Installing a duck nesting box.

External Certification Programs

Principles

- Golf-centric environmental management programs or environmental management systems can help golf courses protect the environment and preserve the natural heritage of the game.

- These programs help people enhance natural areas and wildlife habitats, can improve efficiency, and minimize potentially harmful impacts of golf course operations.
- Golf courses can gain valuable recognition for their environmental education and certification efforts.

Best Management Practices

- Obtain and review materials to ascertain whether the facility should seek certification.
- Work with staff to establish facility goals that lead to certification.
- Establish goals to educate members about the certification program.

Figure 4. Audubon International certification can provide recognition for environmental education and natural resource protection efforts.

2 Surface Water Management

Whether natural or manmade, surface water in the form of lakes, ponds, and streams has long been associated with golf courses. Natural lakes and ponds are usually associated with existing water sources, such as wetland areas. Irrigation impoundments (lakes, ponds, and constructed wetlands) can be incorporated into the design of a course and be used both to manage stormwater and function as a source for irrigation.

Overall, surface water management incorporates not only the information contained in this chapter, but many of the issues discussed in this document, including fertilization strategies near surface waters, pesticide usage, water quality monitoring, and design considerations such as the use of vegetated buffers.

Regulatory Considerations

Course owners and superintendents should investigate regulatory requirements that apply to the golf facility to protect water quality, including watershed-based regulations.

Water Quality

DEP's Division of Water Quality (DWQ) includes several programs to protect and manage clean water and public health in Pennsylvania. The water quality program implements portions of the Pennsylvania Clean Streams Law and the federal CWA. Water quality standards are used to assess whether Pennsylvania's rivers and lakes are clean and pure enough to support fish and other aquatic life; recreation; water supply for drinking, agriculture, and industry; and other protected uses. In addition, the water standards are implemented by other Bureau of Clean Water programs as regulatory tools to prevent pollution of the Commonwealth's waters.

The CWA requires states to prepare a list of impaired surface waters every other year. Impaired waters are those that do not meet the state water quality standards. From this list of impaired waters, states prepare Total Maximum Daily Loads (TMDLs) that include pollution control goals and strategies necessary to improve the quality of impaired waters and remove the identified impairments. TMDLs can include goals for nutrient loading (e.g. N or P). The TDML Development Section is responsible for the statewide establishment of Total Maximum Daily Loads in Pennsylvania.

In addition to developing TMDLs, DEP is required to provide Congress with surface water quality reports every two years that describe the status and trends of existing quality of all waters in the state. The report also provides information about the extent to which designated uses are supported. DEP combines this report with the impaired waters report into one integrated report, which is published on the Integrated Water Quality Report web page.

Aquatic Pesticides

Persons wishing to use herbicides, algicides or fish control chemicals in surface waters within Pennsylvania must submit a permit application to DEP for each body of water to be treated. A copy of the application must be submitted to Pennsylvania Fish and Boat Commission (PFBC) if free flowing waters (i.e., not lakes or ponds) will be treated or if surface waters will be treated to control fish populations. If there are planned changes during the permit term to the water bodies to be treated, to the amount of pesticides to be applied, or to the pesticides to be used, then a new application must be submitted to DEP and, when necessary, PFBC. The new permit must be issued prior to implementing the changes. There are no thresholds for this program; anyone applying any amount of herbicides, algicides or fish control chemicals to surface waters must receive a permit.

Grass Carp

Grass carp are also known as Asian carp. Diploid grass carp are banned from stocking in Pennsylvania, but triploid (sterile) grass carp are allowed to be stocked in lakes and ponds with a PFBC-approved permit.

Stormwater Management

When golf courses are designed and built, their drainage capability concept is guided by an average rainfall event of a given frequency. For example, a golf course drainage system is typically designed to detain a two- or five-year rain event. In other words, when that rain event happens, the golf course will be able to be reasonably drained in a matter of hours, as excess water not absorbed by the soil flows through the drainage system, is temporarily held, and finally leaves the property. In some instances, golf courses and other recreational facilities are mandated to be designed to handle a 20-, 50- or 100-year rain event, which means the golf course must detain more water for perhaps a longer period of time. The ability to retain large amounts of water requires accurate engineering and extensive construction of structural BMPs to prevent physical or financial damage to the facility.

Stormwater BMPs are intended to prolong the retention process as long as practical, harvest as much of the stormwater in surface or underground storage as reasonable, and to improve the quality of water leaving the property when possible. Post-construction stormwater management should be planned and conducted to prevent an increase in the rate of stormwater runoff, minimize the increase in stormwater runoff volume, minimize impervious areas, maximize the protection of existing drainage features and vegetation and to minimize land clearing, grading and soil compaction. Detailed information on structural stormwater BMPs, including post-construction stormwater management requirements (in accordance with 25 PAA Code Chapter 102) can be found in the DEP publication Pennsylvania Stormwater Best Management Practices Manual.

In accordance with 25 PA Code Chapter 102, post-construction stormwater management should be planned and conducted to prevent an increase in the rate of stormwater runoff, minimize the increase in stormwater runoff volume, minimize impervious areas, maximize the protection of existing drainage features and vegetation and to minimize land clearing, grading and soil compaction.

Principles

- Stormwater treatment is best accomplished by a "treatment train" approach in which water moves from one treatment to another by conveyances that themselves contribute to the treatment.
- Source controls are the first car of the BMP treatment train. They help to prevent the introduction of pollutants into stormwater. For example, using integrated pest management (IPM) methods to reduce pesticide usage decreases the possibility of pesticide contamination in stormwater runoff.

Best Management Practices

- Design stormwater treatment trains that use multiple structural and non-structural controls to treat stormwater. For example, direct stormwater across vegetated filter strips (such as turfgrass), through a swale into a wet detention pond, and then out through another swale to a constructed wetland system.
- Institute buffer zones around surface water edges to reduce the amount of nutrients and other potential contaminants from reaching surface waters.
- Use management zones to protect surface waters, with the zone closest to shorelines getting low to no management.
- Ensure that no discharges from pipes go directly to surface water bodies.
- Eliminate or minimize directly connected impervious areas as much as possible.
- Use depressed landscape islands in parking lots to catch and filter, allowing it to infiltrate into the ground, instead of letting it run off. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediments, while allowing the overflow to drain away.
- Maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass. Special high-permeability concrete is available for cart paths or parking lots.
- Divert flow generated by gutters and roof drains from impervious areas onto permeable surfaces.

Stormwater Capture

Principles

- Capture systems should be considered part of the overall treatment of stormwater.

- Stormwater capture is desirable where the lowest quality of water is needed to conserve potable water, maintain hydrologic balance, and improve water treatment.
- This practice uses natural systems to cleanse and improve water treatment.
- Ponds often have the primary purpose of drainage and stormwater management and are also often a source of irrigation water.
- When the golf course is properly designed, rain and runoff captured in water hazards and stormwater ponds may provide most or all of the supplemental water necessary under normal conditions, though backup sources may be needed during times of drought.

Best Management Practices

- Install berms and swells to capture pollutants and sediments from runoff before it enters irrigation storage ponds.
- Monitor pond water level for water loss (seepage) to underground systems. If seepage is occurring, it may be necessary to line or seal irrigation ponds or install pumps to relocate water.
- Install water-intake systems that use horizontal wells placed in the subsoil below the storage basin. Use a post pump to filter particulate matter.
- A backup source of water should be incorporated into the management plan.
- Inspect irrigation pumps, filtration systems, conveyances, and control devices to prevent or correct system issues.
- Remove excess sediments to reduce irrigation system failures.

Buffers

Principles

- Buffers around the shore of surface waters, wetlands, or other sensitive areas filter runoff as it passes across. Buffers are the last line of defense to keep sediment out of streams and to filter out fertilizers and pesticides that might otherwise reach waterways.
- Depending upon site-specific conditions, including the amount of available space and in-play versus out-of-play considerations, a range of buffer widths can be considered. Buffer widths as narrow as 10 feet have been shown to be effective. In most cases, a buffer of at least 100 feet is necessary to fully protect aquatic resources. Smaller buffers (toward the lower end of this range) still afford some level of protection to the surface waters and are preferable to no buffer at all. Protection of the biological components of wetlands and streams typically requires greater buffer widths.
- For vegetated buffer zones, ornamental grasses, wetland plants, or emergent vegetation around the perimeter and edges of surface waters serve as a buffer and wildlife habitat for many aquatic organisms and can be aesthetically pleasing. Use native plants for these plantings whenever possible. See the “Landscaping” chapter for more guidance on plant selection and the benefits of utilizing native plants.

- Riparian buffers along streams and rivers can be up to three different plant assemblages, progressing from sedges and rushes along the water's edge to upland species. Riparian buffers of sufficient width intercept sediment, nutrients, and pesticides in surface runoff and reduce nutrients and other contaminants in shallow subsurface water flow. Woody vegetation in buffers provides food and cover for wildlife, stabilizes stream banks, and slows out-of-bank flood flows.

Best Management Practices

- Maintain healthy turfgrass cover adjacent to surface waters to slow sediment accretion and reduce runoff flow rates.
- Vary the width, height, and type of vegetation to meet the specific functions of the buffer and growing conditions at the specific location.
- Encourage clumps of native emergent vegetation at shorelines.
- Plant shrubs and trees far enough from water edges so that leaves stay out of the water.
- Mow buffers on in-play areas in riparian areas to heights up to 4 inches.
- When mowing near buffer areas, return clippings away from the water or collect them (such as for composting in a designated area) so that runoff does not carry vegetation into the water.
- Keep all chemical applications 10 to 15 feet away from the water's edge when using rotary spreaders and/or boom sprayer applications.
- In buffer areas, spot treat weeds, use drop spreaders, shielded rotary spreaders, or boom sprayers to minimize the potential for direct deposit of chemicals into the water.

Figure 5. BMPs protect the water quality of surface waters.

Lake and Pond Management

Principles

- Phytoplankton, including algae, provide the base for the food chain in ponds. Tiny animals called zooplankton use phytoplankton as a food source.
- Large aquatic plants (aquatic macrophytes) can grow rooted to the bottom and supported by the water (submersed plants), rooted to the bottom or shoreline and extended above the water surface (emersed plants), rooted to the bottom with their leaves floating on the water surface (floating-leaved plants), or free-floating on the water surface (floating plants). Floating aquatic plants suppress phytoplankton because they absorb nutrients from the water and create shade.
- Plant life growing on littoral shelves may help protect receiving waters from the pollutants present in surface water runoff. A littoral shelf is often required in permitted surface water-retention ponds.
- Locate littoral shelves at the pond's inlets and outlets to reduce problems with the playability and maintainability of a water hazard.
- An aquatic plant management strategy should address the intended uses of the waterbody to maintain water quality. Successful pond management should include a clear statement of goals and priorities to guide the development of the BMP necessary to meet those goals. Some of the challenges facing superintendents in maintaining the quality of golf course ponds are as follows:
    - Low dissolved oxygen (DO)
    - Sedimentation
    - Changes in plant populations
    - Nuisance vegetation
    - Maintenance of littoral shelves
    - Vegetation on the lakeshore
- Surface water sources can present problems with algal and bacteria growth. Algal cells and organic residues of algae can pass through irrigation system filters and form aggregates that may plug emitters.
- Only licensed pesticide applicators should be allowed to select and apply aquatic pesticides.

Best Management Practices

- ➢ Maintain a narrow band of open water at the pond edge.
- ➢ Maintain no-fertilization buffers along water edges.
- ➢ Do not allow irrigation to directly strike or run off to waterbodies.

- Accommodate natural lake processes in the construction of lakes and ponds. Include native herbaceous and woody vegetation and emergent and submergent shoreline plants to reduce operational costs.
- Use IPM strategies to control excessive aquatic plant growth.
- When chemical control is needed, select appropriate herbicides that will not harm other aquatic life and apply so as to minimize damage to non-target littoral plantings.
- In ponds with littoral plantings, problem plants should be selectively controlled without damaging littoral shelves.
- Frequently remove filamentous algae by hand and/or frequently spot treat small areas with algaecide.
- When chemical control of algae is needed, select algaecides containing hydrogen peroxide instead of copper or endothall when possible.
- If using copper containing algaecides, apply per label instructions to reduce the risk of impairing water quality and causing negative biological impacts, such as depleted DO levels.

Dissolved Oxygen

Principles

- Dissolved oxygen is the amount of oxygen present in water and is measured in milligrams per liter (mg/L).
- Adequate DO levels are required to sustain life in aquatic organisms and vary by species, the organism's life stage, and water temperature.
- The amount of DO that water can hold depends on the physical conditions of the body of water (water temperature, rate of flow, oxygen mixing, etc.), photosynthetic activity, time of day, and season.
- In ponds with excessive plant and algae growth, several cloudy days in a row during warm weather increases the potential for fish kills due to low DO. Limiting the amount of nutrients that contribute to excessive aquatic plant and algae growth helps to maintain DO levels.

Best Management Practices

- To reduce the potential for algal blooms, reduce the amount of nutrients (especially P) that enters the pond in runoff by preventing overthrowing of fertilizer into ponds, collecting clippings near the pond, and using buffer strips along the shorelines.
- Maintain DO levels above 3 mg/L to reduce stress on fish and to prevent fish kills.
- Manipulate water levels to prevent low levels that result in warmer temperatures and lower DO levels.
- Use artificial aeration (diffusers) to increase DO levels.
- Aerate shallow lakes less than 6 feet in depth to maintain acceptable DO levels.
- Spot-treat filamentous algae or frequently remove algae by hand t.
- Use dyes to maintain appropriate light levels.

Pond Water-Level Monitoring

Principle

- Evaporation losses are higher in some regions than others and vary from year to year and within the year. However, evaporative losses can approach 6 inches per month during the summer. Aquatic plants are more difficult to control in shallow water.

Best Management Practices

- A pond should hold surplus storage of at least 10 percent of full storage.
- Provide an alternative source for ponds that may require supplemental recharge from another water source such as a well during high-demand periods.
- Estimated losses from evaporation and seepage should be added to the recommended depth of the pond.

3 Irrigation

Regulatory Considerations

In compliance with the Water Resources Planning Act, DEP has implemented a statewide water withdrawal and use registration and reporting program to collect, process, and distribute information on water resources. Facilities withdrawing more than an average rate of 10,000 gallons per day in any 30-day period must register and report water usage information to DEP. Superintendents should ensure that required reports are submitted on time as required. Registrants must annually report their water usage and other information and retain records for at least five years. More information and links to permit application forms are available on DEP's Chapter 110 – Requirements for Water Withdrawal Registration & Reporting web page.

In addition to withdrawal reporting requirements, Chapter 105 permitting requirements regulates the construction, operation, and maintenance of intake and outfall structures in, along, across or projecting into the regulated waters of the Commonwealth. For more information, see the GP-4 Intake and Outfall Structures web page on the DEP website.

Irrigation Water Sources and Water Quality

Principle

- Studies of water supplies are recommended for irrigation systems, as are studies of waterbodies or flows on, near, and under the property. These maybe helpful to properly design a course's stormwater systems and water features and to protect water resources.

Best Management Practices

- ➢ Identify appropriate water supply sources, including alternative water supplies/sources, that meet seasonal and bulk water allocations for grow-in and routine maintenance needs.
- ➢ Design and/or maintain a system to meet a site's peak water requirements under normal conditions and also be flexible enough to adapt to various water demands and local restrictions.

Alternative Irrigation Water Sources and Suitability

Principles

- Golf course designers and managers should endeavor to identify and use alternative supply sources to conserve freshwater drinking supplies, promote plant health, and protect the environment.
- The routine use of potable water is not a preferred practice. Therefore, municipal drinking water should be considered only when no alternative exists.

Best Management Practices

- Reclaimed, effluent, and other non-potable water supply mains must have a thorough cross-connection and backflow prevention device in place that operates correctly.
- Post signs in accordance with local utility and state requirements when reclaimed water is in use.
- Monitor reclaimed water test results regularly for dissolved salt content.
- Amend sodic water systems appropriately (with gypsum or an appropriate ion) to minimize sodium buildup in soil.
- Use salt-tolerant varieties of turfgrass and plants to mitigate saline conditions resulting from an alternative water supply or source, if necessary.
- Monitor sodium and bicarbonate buildup in the soil using salinity sensors.
- Flush with freshwater or use amending materials regularly to move salts out of the root zone and/or pump brackish water to keep salts moving out of the root zone.
- Account for the nutrients in effluent (reuse/reclaimed) water when making fertilizer calculations.

Wellhead Protection

Principles

- Wellhead protection is the establishment of protection zones and safe land-use practices around water supply wells in order to protect aquifers from accidental contamination. It also includes protecting wellheads from physical impacts, keeping them secure, and sampling wells according to the monitoring schedule required by the regulating authority, which is often a local health department or state department of environmental quality.
- When installing new wells, contact the local regulating authority to determine the permitting and construction requirements and the required isolation distances from potential sources of contamination.
- Locate new wells up-gradient as far as possible from likely pollutant sources, such as petroleum storage tanks, septic tanks, chemical mixing areas, or fertilizer storage facilities.
- Licensed water-well contractors are required to drill new wells to meet state requirements, local government code, and water management districts' well-construction permit requirements.

Best Management Practices

- Use backflow-prevention devices at the wellhead, on hoses, and at the pesticide mix/load station to prevent contamination of the water source.
- Properly plug abandoned or flowing wells.
- Surround new wells with bollards or a physical barrier to prevent impacts to the wellhead.

- Inspect wellheads and the well casing at least annually for leaks or cracks. Make repairs as needed.
- Maintain records of new well construction and modifications to existing wells.
- Obtain a copy of the well log for each well to determine the local geology and the well's depth. These factors will have a bearing on how vulnerable the well is to contamination.
- Sample wells for contaminants according to the schedule and protocol required by the regulating authority.
- Follow pesticide labels for setback distance requirements (typically a minimum of 50 feet).
- Develop a written Wellhead Protection Plan that minimizes environmental risk and potential contamination.

Irrigation System Design and Installation

Principles

- Irrigation systems should be properly designed and installed to improve water use efficiency.
- A well-designed irrigation system should operate at peak efficiency to reduce energy, labor, and natural resources.
- An efficient irrigation system maximizes water use efficiency, reduces operational cost, conserves supply, and protects water resources.

Desirable Control System Features Available in an Irrigation System

- The ability to control the functions of a central computer from a phone or tablet.
- The ability that multiple staff members (up to 12) can be simultaneously accessing and operating the control function of the central computer such as running sprinklers, starting and stopping programs.
- The ability to use a Google map and the GPS on a phone or tablet to view, select, and operate sprinklers via a map of the facility.
- The ability to set watering times based on precipitation rates and have the software automatically calculate the needed run times based on sprinkler nozzle sizes, pressure settings, spacings and arcs for the user (to the nearest second).
- The ability to use evapotranspiration (ET) rates to automatically adjust program and sprinkler run times. The evaporation data can be automated from a weather station or manually entered.
- The ability to set sprinkler run times with cycle and soak periods to allow better infiltration on poor soil conditions, achieving to get the water to a targeted area preventing runoff.
- The ability to quickly adjust each sprinkler’s run time by percentage. Percentages can permanently assign or temporarily assign with user defined number of days, followed by a user defined percentage when completed.

- The ability to assign sprinklers to moisture sensors and have the software visually indicate if a sprinkler's run time is above or below a user defined moisture threshold.
- The ability to detect and display on an interactive map of the course sprinklers that are running, did not run, are on hold, or have a communication issue.
- The ability to monitor the amperage draw of each sprinkler and automatically shut it down when it is outside of a determined pre-set tolerance.
- The ability to run extensive diagnostics from the central to test field controllers, field hubs, or 2-wire modules for communication and solenoid operation.
- The ability to relay information such as flows, pressures, and temperatures from devices (such as satellites, hubs, and modules) to the central software and then act on the information based on user defined thresholds and parameters.
- The ability to set up and send automate alerts, actions, and issues to individuals or groups via text and email messaging in a user configured 7-day / 24-hour schedules.
- The ability to overlay actual pump station flows over theoretical flows on a projected flow screen to aide users in identifying programming, pump station, or system issues.
- The ability to monitor and autonomously respond to a pump system reduced flow event by recalculating based on the reduced flow and continue irrigating at a reduced capacity.
- The ability to autonomously monitor and respond to rainfall by:
    - Performing a system shutdown when a user-determined amount of rain is received over a user-determined period of time.
    - Live monitoring and autonomous response of active rainfall with an accuracy of .01 of an inch. When rainfall reaches a user determined amount in a user-determined time, the system will perform a system wide rain reflow to deduct the rainfall received from the run times of sprinklers that have not yet run. The system will keep the end time of the nightly irrigation event the same and calculate a new start time based on the shortened run times. The central will not start back up watering immediately if rainfall continues. The central will trigger more reflows, reducing runtimes and pushing out start times again and again, until the rain fall stops or matches the irrigation runtimes. Once rainfall matches the run times all irrigation stays off.
    - Assigning individual areas or holes of the course to specific rain tip buckets. The central software will reduce the run times on sprinkler heads (to the second) on the specific areas and/or holes by the amount of rainfall received in the last 24-hours for each tip bucket assigned for the respective area or hole.
- The ability to send updated software from the central to field satellites, hubs and sprinkler head modules from the central via digital radio and 2-way wire paths.
- The ability to have integrated soil sensors that are 100% wireless and relay information on moisture, salinity and temperature every 10 seconds.
- The ability to have a flow managed program resident in an interface device such as a satellite or hub that allows for flow managed irrigation even in the event of a central failure.

Desirable Sprinkler Head Features Available in an Irrigation System

- The ability to view the sprinkler head's communications, operation and the 2-wire path's voltage and amperage integrity via sequencing LED lights from the top of each sprinkler (2-wire systems only).
- The ability to access all components from the top of the sprinkler without the need to dig alongside the head to access them.
- The ability of having one sprinkler that can be easily adjusted from a full circle to a part circle arc.
- The ability to adjust the right stop and the left stop of a sprinkler without tools, and without having to dismantle the sprinkler.
- The ability to change pressure regulation settings, remove/replace the pilot valve assembly, remove the solenoid (or activating module in 2-wire systems) from a sprinkler head without the head turning on, or having to find a shut off valve to turn the water off.
- The ability to add back nozzles, plug nozzles, and install combinations of specialty nozzles by simply threading them in and without dismantling the sprinkler head's riser.
- The ability to raise and lower the main nozzle's throw to compensate for wind or obstructions.
- The ability to raise the lid and body of the sprinkler up over time, without needing to dig up and reset the sprinkler.
- The ability to grab on and turn or hold the nozzle base while it is operating without damaging the sprinkler gear drive.
- The ability to add a specialty lid to the top of the sprinkler so that a golf ball will not bounce irregularly off the top of the sprinkler.
- The ability to put yardage markers on the top of the sprinkler that are large and legible to golfers.
- The ability to have a consistent rotation speed of each sprinkler across the course regardless of elevation and pressure fluctuations (within +/- 10 seconds per rotation).

Best Management Practices

- ➢ Design should account for optimal distribution efficiency and effective root-zone moisture coverage. Target 80% or better distribution uniformity (DU).
- ➢ Design should allow the putting surface, slopes, and surrounds to be watered independently.
- ➢ The design package should include a general irrigation schedule with recommendations and instructions on modifying the schedule for local climatic soil and growing conditions. It should include the base ET rate for the particular location.
- ➢ The application rate must not exceed the infiltration rate, or the ability of the soil to absorb and retain the water applied during any one application. Conduct saturated hydraulic conductivity tests periodically.

- The design operating pressure must not be greater than the available source pressure.
- The design operating pressure must account for peak-use times and supply line pressures at the final buildout for the entire system.
- The system should be flexible enough to meet a site's peak water requirements and allow for operating modifications to meet seasonal irrigation changes or local restrictions.
- Turfgrass and landscape areas should be zoned separately, such as zones for greens, tees, primary roughs, secondary roughs, fairways, native areas, trees, shrubs, etc.
- Only qualified specialists should install the irrigation system.
- Construction must be consistent with the design.
- The designer must approve any design changes before construction.
- Construction and materials must meet existing standards and criteria.
- Prior to construction, all underground cables, pipes, and other obstacles must be identified and their locations flagged.
- Permanent irrigation sprinklers and other distribution devices should be spaced according to the manufacturer's recommendations.
- Space should be based on average wind conditions during irrigation.
- For variable wind directions, triangular spacing is more uniform than square spacing.
- Distribution devices and pipe sizes should be designed for optimal uniform coverage.
- The first and last distribution device should have no more than a 10% difference in flow rate. This usually corresponds to about a 20% difference in pressure.
- Distribution equipment (such as sprinklers, rotors, and micro-irrigation devices) in a given zone must have the same precipitation rate.
- Heads for turfgrass areas should be spaced for head-to-head coverage.
- Water supply systems (e.g. wells, and pipelines) should be designed for varying control devices, rain shut-off devices, and backflow prevention.
- Water conveyance systems should be designed with thrust blocks and air-release valves.
- Flow velocity must be 5 feet per second or less.
- Pipelines should be designed to provide the system with the appropriate pressure required for maximum irrigation uniformity.
- Pressure-regulating or compensating equipment must be used where the system pressure exceeds the manufacturer's recommendations.
- An irrigation system should also have high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- Equipment with check valves must be used in low areas to prevent low head drainage.
- Install isolation valves in a manner that allows critical areas to remain functional.
- Manual quick-coupler valves should be installed near greens, tees, and bunkers so these can be hand-watered during severe droughts.
- Install part-circle heads along lakes, ponds, and wetlands margins.
- Use part-circle or adjustable heads to minimize overspray of impervious areas such as roadways and sidewalks.
- Update multi-row sprinklers with single head control to conserve water and to enhance efficiency.
- Incorporate multiple nozzle configurations to add flexibility and enhance efficiency/ distribution.
- Ensure heads are set at level ground and not on slopes.

System Maintenance

Principles

- Irrigation system maintenance on a golf course involves four major efforts: calibration or auditing, preventive maintenance, corrective maintenance, and record keeping.
- Good system management starts with preventive maintenance and recordkeeping. Maintaining a system is more than just fixing heads.
- Routine maintenance of irrigation systems ensures the efficient and responsible use of water.
- Collecting information on the cost of maintenance as part of an overall system evaluation allows for planning necessary upgrades and replacements and for making comparisons after changes are made.
- Corrective maintenance is simply the act of fixing what is broken. It may be as simple as cleaning a clogged orifice or as complex as a complete renovation of the irrigation system.
- Renovating a golf course irrigation system can improve system efficiencies, conserve water, improve playability, and lower operating costs.

Best Management Practices – General Maintenance

- System checks and routine maintenance should include pumps, valves, programs, fittings, and sprinklers and should follow manufacturer's recommendations.
- To ensure that it is performing as intended, an irrigation system should be calibrated regularly by conducting periodic irrigation audits to check actual water delivery and nozzle efficiency.
- A visual inspection should first be conducted to identify necessary repairs or corrective actions. It is essential to make repairs before carrying out other levels of evaluation.
- Pressure and flow should be evaluated to determine that the correct nozzles are being used and that the heads are performing according to the manufacturer's specifications.
- Pressure and flow rates should be checked at each head to determine the average application rate in an area.
- Catch-can tests should be performed to determine the uniformity of coverage, accurately determine irrigation run times and ensure that the system is operating at its highest efficiency.
- Trained technicians should conduct an annual irrigation audit to facilitate a high-quality maintenance and scheduling program for the irrigation system.
- Inspect for interference with water distribution.
- Inspect for broken and misaligned heads.
- Check that the rain sensor is present and functioning.
- Inspect the backflow device to determine that it is in place and in good repair.
- Examine turfgrass quality and plant health for indications of irrigation malfunction or a need for scheduling adjustments.

- Make adjustments and repairs on items diagnosed during the visual inspection before conducting pressure and flow procedures.
- Flush irrigation lines regularly to minimize emitter clogging as part of a regular maintenance schedule. If fertigating, prevent microbial growth by flushing all fertilizer from the lateral lines before shutting down the irrigation system.
- Clean and maintain filtration equipment.
- Check filter operations frequently. An unusual increase in the amount of debris may indicate problems with the water source. Even under routine conditions, keeping filters operating properly prolongs the life of an existing system and reduces pumping costs.
- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.
- Document equipment run-time hours.
- Monitor pump station power consumption. Monthly bills should be monitored over time to detect a possible increase in power usage. Compare the power used with the amount of water pumped. Requiring more power to pump the same amount of water may indicate a problem with the pump motor(s), control valves, or distribution system. Quarterly checks of amperage by qualified pump personnel may more accurately indicate increased power usage and thus potential problems.
- Monitor and record the amount of water being applied, including system usage and rainfall. By tracking this information, you can identify areas where minor adjustments can improve performance. Not only is this information essential in identifying places that would benefit from a renovation, but it is also needed to compute current operating costs and compare possible future costs after a renovation.
- Document and periodically review the condition of infrastructure such as pipes, wires, and fittings.
- Check computer logs and visually inspect the pump station, remote controllers, and irrigation heads daily. A visual inspection should be carried out for leaks, misaligned or inoperable heads, and chronic wet or dry spots so that adjustments can be made.
- Observe systems in operation at least weekly. This can be done during maintenance programs such as fertilizer or chemical applications where irrigation is required, or the heads can be brought on-line for a few seconds and observed for proper operation. This process detects controller or communications failures, stuck or misaligned heads, and clogged or broken nozzles.

Best Management Practices – Preventative Maintenance

- In older systems, inspect irrigation pipes and look for fitting breaks caused by surges in the system.
- Install thrust blocks to support conveyances.
- Maintain air-relief and vacuum-breaker valves.
- Qualified pump personnel should perform quarterly checks of amperage to accurately identify increased power usage that indicates potential problems.
- Increase frequency of routine inspection/calibration of soil moisture sensors that may be operating in high-salinity soils.

- Ensure that all lubrication, overhauls, and other preventive maintenance are completed according to the manufacturer's schedule.
- Gather all of the documentation collected as part of the preventive maintenance program, along with corrective maintenance records for analysis. Correctly identifying problems and their costs helps to determine if renovations are appropriate.

Best Management Practices – Corrective Maintenance

- Replace or repair all broken or worn components before the next scheduled irrigation.
- Ensure that replacement parts have the same characteristics as the original components.
- Record keeping is an essential practice. Document all corrective actions.

Best Management Practices – Renovation

- Correctly identify problems and their cost to determine which renovations are appropriate.
- Determine the age of the system to establish a starting point for renovation.
- Identify ways to improve system performance by maximizing the efficient use of the current system.
- Routinely document system performance to maximize the effectiveness of the renovation.
- Evaluate cost of renovation and its return on benefits, both financial and management.

Figure 6. Irrigation system maintenance.

Winterization and Spring Start Up

Principle

- Winterization of the irrigation system protects the system and reduces equipment failures resulting from freezing.

Best Management Practices

- Visually inspect irrigation system: inspect for mainline breaks, low pressure at the pump, and head-to-head spacing.
- Flush and drain above-ground irrigation system components that could hold water.
- Remove water from all conveyances and supply and distribution devices that may freeze by using compressed air or by opening drain plugs at the lowest point on the system.
- Clean filters, screens, and housing. Remove drain plugs and empty water out of the system.
- Secure the system and close and lock covers/compartment doors to protect the system from potential acts of vandalism and from animals seeking refuge.
- Remove drain plugs and drain above-ground pump casings.
- Record metering data before closing the system.
- Perform pump and engine servicing and repairs before winterizing.
- Recharge irrigation in the spring with water and inspect for corrective maintenance issues.

Water Conservation and Efficient Use Planning

Principles

- The supplemental use of water for course play and non-play areas is essential to supporting healthy turfgrass, landscape plant health, sustaining optimal course playability, aesthetics, marketability, and club membership participation.
- BMPs related to water use that conserve and protect water resources include those related to irrigation systems and components and irrigation management decision making. Benefits of adopting these BMPs include:
    - Conserving the water supply.
    - Protecting existing water quality.
    - Maintain optimal ball roll and playing conditions.
    - Saving water and electricity.
    - Increasing pump and equipment life longevity.
    - Demonstrating responsible environmental stewardship.
    - Increasing the knowledge and effectiveness of employees
- Documenting actual watering practices over time can show improvements in water conservation. These improvements can be communicated to golf course members and the public.

- Some courses are being designed using a "target golf" concept that minimizes the acreage of irrigated turfgrass. Existing golf courses can make an effort to convert out-of-play areas to naturally adapted native plants, grasses, or ground covers to reduce water use and augment the site's aesthetic appeal. Native plant species also provide wildlife with habitat and food sources.
- Rainfall may vary from location to location on a course. The proper use of rain gauges, rain shut-off devices, flow meters, soil moisture sensors, and other irrigation management devices should be incorporated into the site's irrigation plan.
- It is also important to measure the amount of water that is actually delivered through the irrigation system via a water meter or a calibrated flow-measurement device.
- Knowing the flow or volume helps in evaluating the irrigation system and schedule.

Best Management Practices

- Periodically calibrate equipment to compensate for wear in pumps, nozzles, and metering systems.
- Properly calibrate flow meters, soil moisture sensors, rain shut-off devices, and other automated methods.
- Flow meters should have a run of pipe that is straight enough – both downstream and upstream – to prevent turbulence and bad readings.
- Use flow meters to determine how much water is applied.

Irrigation System Program and Scheduling

Principles

- Irrigation scheduling must take plant water requirements and soil intake capacity into account to prevent excess water use that could lead to leaching and runoff.
- Plant water needs are determined by ET rates, recent rainfall, recent temperature extremes, and soil moisture.
- Irrigation should not occur on a calendar-based schedule. It should be based on ET rates and soil moisture replacement.
- An irrigation system should be operated only on the moisture needs of the turfgrass, or to water-in a fertilizer or chemicals as directed by the label.
- Responsible irrigation management conserves water and reduces the potential for off-site transport of nutrients and pesticides.
- Clock-controlled irrigation systems preceded computer-controlled systems, and many are still in use today. Electric/mechanical clocks cannot automatically adjust for changing ET rates. Frequent adjustment is necessary to compensate for the needs of individual turfgrass areas.

Best Management Practices

- The reliability of older clock-control station timing depends on the calibration of the timing devices. This should be done periodically, and at least once every season.
- An irrigation system should have rain sensors to shut off the system after 0.25 to 0.5 inch of rain falls. Computerized systems allow a superintendent to call in and cancel the program.
- Install control devices to allow for maximum system scheduling flexibility.
- In general, granular fertilizer applications should receive 0.25 inch of irrigation to move the particles off the leaves while minimizing runoff.
- Irrigation quantities should not exceed the available moisture storage in the root zone.
- Irrigation rates should not exceed the maximum ability of the soil to absorb and hold the water applied at any one time.
- The irrigation schedule should coincide with other cultural practices (e.g. application of nutrients, herbicides, or other chemicals).
- Irrigate in the early morning hours before air temperatures rise and relative humidity drops.
- Base plant water needs should be determined by ET rates, recent rainfall, recent temperature extremes, and soil moisture.
- Use mowing, verticutting, aeration, nutrition, and other cultural practices to control water loss and to encourage conservation and efficiency.
- Visually monitor for localized dry conditions or hot spots to identify poor irrigation efficiency or a failed system device.
- Use predictive models to estimate soil moisture and the best time to irrigate.
- Avoid use of a global setting. Make adjustments to watering times per head.
- Base water times on actual site conditions for each head and zone.
- Use computed daily ET rate to adjust run times to meet the turfgrass's moisture needs.
- Manually adjust automated ET data to reflect wet and dry areas on the course.
- Use soil moisture sensors to assist in scheduling or to create on-demand irrigation schedules.
- Reducing dry spots and soil compaction improves water infiltration, which in turn reduces water use and runoff in other areas.

Figure 7. Irrigating greens and fairways.

Non-Play and Landscape Areas

Principles

- Natural vegetation should be retained and enhanced for non-play areas to conserve water.
- The most efficient and effective watering method for non-turfgrass landscape is micro-irrigation.
- Older golf courses may have more irrigated and maintained acres than necessary. With the help of a golf course architect, golf professional, golf course superintendent, and other key personnel, the amount of functional turfgrass can be evaluated and transitioned into non-play areas.

Best Management Practices

- Designate 50% to 70% of the non-play area to remain in natural cover according to "right-plant, right-place," a principle of plant selection that favors limited supplemental irrigation and on-site cultural practices.
- Incorporate native vegetation in non-play areas.
- Use micro-irrigation and low-pressure emitters in non-play areas to supplement irrigation.
- Routinely inspect non-play irrigation systems for overall functionality and problems related to emitter clogging and filter defects.

Turfgrass Drought Response

Principles

- The presence of visual symptoms of moisture stress is a simple way to determine when irrigation is needed.
- Use a handheld soil moisture meter to determine moisture needs of greens and tees.
- Be prepared for extended drought/restrictions by developing a written drought management plan.

Best Management Practices

- Waiting until visual symptoms appear before irrigating is a method best used for low-maintenance areas, such as golf course roughs and, possibly, fairways.
- Irrigating too shallowly encourages shallow rooting, increases soil compaction, and favors pest outbreaks.
- For fairways and roughs, use infrequent, deep irrigation to supply sufficient water for plants and to encourage deep rooting.
- Create a drought management plan for the facility that identifies steps to reduce water use and protects critical areas.

- Select drought-tolerant varieties of turfgrasses to help maintain an attractive and high-quality playing surface while reducing irrigation needs.
- Plant non-play areas with drought-resistant native or other well-adapted, non-invasive plants that provide an attractive and low-maintenance landscape.
- The system should be operated to provide only the water that is actually needed by the plants or to meet occasional special needs such as salt removal.
- During a drought, closely monitor soil moisture levels. Whenever practical, irrigate at times when the least amount of evaporative loss will occur.
- Control invasive plants or plants that use excessive water.
- Use wetting agents (also referred to as soil surfactants) to improve the effectiveness of irrigation and reduce overall water usage.

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4 Water Quality Monitoring

Aligning golf course management practices with BMPs protects water quality on and downstream from the facility. A water quality monitoring program can confirm the effectiveness of a BMP-based program and provide important feedback on areas needing improvement. Golf course superintendents seeking to develop and implement a monitoring program to document water quality conditions should first review available baseline water quality data.

Baseline data can be assessed to determine the likely origin of contaminants, measure the extent of sedimentation and nutrient inputs, and estimate the potential impacts to surface water and groundwater. Following implementation of BMPs, routine monitoring can be used to measure water quality improvements and identify any areas where corrective actions should be taken. Water quality monitoring on golf courses is voluntary. However, monitoring results demonstrate a commitment to water quality and implementing BMPs that protect water resources downstream. Furthermore, providing monitoring information to local, regional, and state regulatory authorities and watershed groups can help foster positive relationships with these stakeholders.

In addition to monitoring water quality from golf course management operations, superintendents will want to regularly test irrigation water, such as that from retention ponds.

Monitoring Plan

Principles

- A water quality program begins with the development of a monitoring plan. The plan should identify specific conditions such as the presence of a watershed, stream flows, soil type, topography, drainage, and vegetation. In addition, the plan needs to document the hydrologic conditions and drainage, monitoring objectives, monitoring locations and frequency, and monitoring parameters. Use a handheld soil moisture meter to determine moisture needs of greens and tees.
- Baseline reference conditions can be established by collecting upstream water samples and comparing them with collection sites downstream of the areas influenced by golf course management practices.
- Surface water collection sites can include streams, rivers, ponds, wetlands, etc., with the number and location of collection sites dependent upon the monitoring objectives. The location of monitoring sites should remain consistent over time to establish trends in data.
- Groundwater monitoring from wells located at the hydrologic entrance and exit from the course may be the best way to evaluate a golf course's impact on water quality.
- Water quality monitoring of irrigation sources (particularly water supply wells and storage lakes) provides valuable agronomic information that can influence nutrient programs.

Best Management Practices

- Review existing sources of groundwater and surface water quality information.
- Develop a water quality monitoring program.
- Establish baseline quality levels for water.
- Identify appropriate sampling locations and sample at the same locations in the future.
- Conduct seasonal water quality sampling. The recommendation is four times per year.
- Partner with other groups or volunteer water quality monitoring programs if possible, to share data and monitoring costs.

Water Quality Sampling and Analysis

Principles

- A simple monitoring program can consist of the collection of DO data in surface waterbodies to ensure that these waterbodies can support aquatic life.
- A more comprehensive monitoring program for surface water should include both field measurements at the time of sampling (pH, temperature, specific conductance, and DO) and water sample analysis. Typical testing parameters include nutrients (such as nitrates and phosphorus), total dissolved solids, alkalinity, sediments, and selected pesticides used on the course. For more information on surface water monitoring programs and sampling procedures, see DEP's publication *Water Quality Monitoring Protocol for Streams and Rivers*; the *Environmental Stewardship Guidelines* also provides detailed guidance on water quality monitoring specific to golf courses..
- Golf courses should also consider sampling and identifying macroinvertebrates as surface water quality indicators. Partnering with a watershed organization, university professor, or other groups can assist in this effort. DEP's publication *Water Quality Monitoring Protocol for Streams and Rivers* provides information on macroinvertebrate sampling.
- Groundwater quality parameters can be limited to test only the ones directly influenced by course management, such as levels of pesticides and organic and inorganic N.
- Certified laboratories should be used for water sample analysis, even if the data is only for proprietary use and will not be reported to any regulatory agency.
- Sampling results should be analyzed to:
  - Compare subsequent water quality monitoring results to known benchmark levels.
  - Compare values following implementation of BMPs, such as IPM measures.
  - Evaluate any changes in water quality as water enters and leaves the site.
- Results should also be interpreted and compared with the state's water quality standards (Title 25, Chapter 93 Water Quality Standards) if water quality standards have been established for the parameter being evaluated. Data analysis can also be used to identify issues that may need corrective action.

Best Management Practices

- Visually monitor/assess any specific changes of surface waterbodies.
- Follow proper water sampling collection procedures.
- Use only certified laboratories for analyzing water samples.
- Visually monitor/assess any specific changes of surface waterbodies.
- Compare water quality monitoring results to benchmark quality standards.
- Review results and take corrective measures when necessary.

5 Nutrient Management

The goal of nutrient management programs is to apply the minimum necessary nutrients and maximize their uptake in order to achieve an acceptable playing surface and to maintain turfgrass density. Fertilizers containing N and P are a potential source of nutrients that can be transported in leaching and runoff events and contaminate water resources. Therefore, ensuring that a nutrient management program emphasizes proper fertilization and maintenance of turfgrass on golf courses reduces the potential for N and P losses to groundwater or surface water.

Regulatory Considerations

Pennsylvania does not currently have nutrient management regulations. However, legislation has been introduced to restrict the use of P on turf; if enacted, this legislation will allow P when establishing or repairing a turfgrass area or if a soil test indicates P deficiency and a site-specific plan is developed to address the deficiency.

Soil Testing

Principles

- The purpose of a soil test is to provide the grower with a prediction of a plant's response to an applied nutrient.
- Soil testing may or may not provide the appropriate answers to your nutrient management questions. Penn State's Agricultural Analytical Services Laboratory conducts soil tests and maintains a soil fertility lab and publishes information on recommendations for golf turfgrass on its Soil Test Recommendations for Turf web page.
- To manage certain nutrients, proper soil testing / sampling, laboratory analysis, interpretation of results and recommendations and recordkeeping can be used to manage nutrients more efficiently.

Best Management Practices

- Sample accurately and consistently to maximize usefulness of soil test information over time.
- Divide the course into logical components such as greens, fairways, tees, roughs, etc., for each hole.
- Ten to 15 soil samples should be collected in a regular grid pattern from each section; these sections could represent areas with the same soil type. The soils samples should be blended together to provide a representative, uniform soil sample.
- Each soil sample should be taken from the same depth.
- Use an extractant appropriate for your soils. The same extractant must be used for each test in order to compare soil test results over time.
- If your location has correlation data between a given nutrient applied to soil and a response to that nutrient by turfgrass, then recommendations may provide expected results. If your location does not have correlation data, soil test recommendations may be of little value.

Figure 8. Accurate and consistent soil sampling provides useful information to predict plant response to applied nutrients.

Soil pH

Principles

- Identifying pH levels may be the most important soil test result for turfgrass managers. In most cases, a pH of 6.3 is ideal because it provides the greatest probability of micronutrient availability.
- If the soil pH is below the pH goal, limestone recommendations will be provided based on the amount of exchangeable acidity measured by the Mehlich Buffer soil test.
- Penn State offers Limestone Recommendations – Turf, which provides recommendations as pounds of calcium carbonate equivalent (CCE) per 1000 ft^2. If the limestone to be used is significantly different from 100% CCE, the recommendation must be adjusted for this difference.

Best Management Practices

- ➢ To increase soil pH, apply a liming material (calcium carbonate, calcium oxide, dolomitic limestone) that contains Ca^{2+} and neutralizes acidity.
- ➢ To lower soil pH, apply products containing elemental sulfur or ammonium sulfate.
- ➢ In some cases, acidifying agents injected into irrigation water can lower soil pH.

Plant Tissue Analysis

Principles

- Visible plant symptoms can offer helpful clues in diagnosing nutrient deficiencies, but can also be easily confused and misinterpreted, especially where micronutrients or sulfur compounds are involved. Tissue testing can help to adjust nutrient management programs:
  - to confirm a suspected nutrient element deficiency when visual symptoms are present
  - to monitor plant nutrient element status in order to determine whether each tested nutrient is in sufficient concentration for optimum performance
- Recent soil test results should be used to assist in the interpretation of the results of a plant tissue analysis. If none are available, a soil sample should be submitted along with the tissue sample.
- Through proper sampling, consistent intervals, and record keeping, tissue sampling may be used to measure changes in turfgrass health.

Best Management Practices

- Tissue samples may be collected during regular mowing.
- Do not collect tissue after any event that may alter the nutrient analysis. Events may include fertilization, topdressing, pesticide applications, etc.
- Place tissue in paper bags, not plastic.
- If possible, allow tissue samples to air-dry at your facility before mailing them.
- Poor-quality turfgrass that is of concern should be sampled separately from higher-quality turfgrass.
- When turfgrass begins to show signs of nutrient stress, a sample should be collected immediately.
- More frequent tissue sampling allows for a more accurate assessment of your turfgrass nutrient status changes over time.
- The quantity of tissue analysis you choose to use is entirely up to you and your needs. However, two to four tests per year are common on greens and one to two tests per year are common on tees and fairways.
- Use tissue test results from prior years to observe changes over time.
- Tissue testing can provide good evidence of the impact of your nutrient management plan.

Fertilizers Used in Golf Course Management

Principles

Understanding the components of fertilizers, the fertilizer label, and the function of each element within the plant is essential in the development of an efficient nutrient management program.

Terminology

- Grade or analysis is the percent by weight of N, phosphate (P_2O_5) and potash (K_2O) that is guaranteed to be in the fertilizer.
- A complete fertilizer contains N, P_2O_5, and K_2O.

Label

- The label is intended to inform the user about the contents of the fertilizer which, if understood and followed, will result in little to no environmental risk.
- The fertilizer label may contain:
  - Brand
  - Grade
  - Manufacturer's name and address
  - Guaranteed analysis
  - "Derived from" statement
  - Net weight

Macronutrients

Macronutrients are required in greater quantities than micronutrients. Primary macronutrients include N, P, and K. Additional macronutrients include carbon, hydrogen, calcium, sulfur, and magnesium. Understanding the role of each macronutrient within the plant should provide you with a greater understanding of why these nutrients play such a key role in proper turfgrass management.

<u>The Role of Nitrogen</u>

Nitrogen is required by the plant in greater quantities than any other element except carbon, hydrogen, and oxygen. Nitrogen plays a role in numerous plant functions including as an essential component of amino acids, proteins and nucleic acids. The goal of all applied nutrients is to maximize plant uptake while minimizing nutrient losses. Understanding each process increases your ability to make sound management decisions and ultimately leads to an increase in course profitability and a reduction in environmental risk. The processes include:

- *Mineralization,* the microbial mediated conversion of organic N into plant-available NH_4.
- *Nitrification,* the microbial-mediated conversion of NH_4 to NO_3.
- *Denitrification*, the microbial mediated conversion of NO_3 to N gas. This primarily occurs in low-oxygen environments and is enhanced by high soil pH.
- *Volatilization*, the conversion of NH_4 to NH_3 gas.
- *Leaching,* the downward movement of an element below the rootzone.
- *Runoff,* the lateral movement of an element beyond the intended turfgrass location.

Nitrogen Sources

Understanding how certain N sources should be blended and applied is an essential component in an efficient nutrient management plan. In some cases, N sources are applied without regard to their release characteristics. This is an improper practice and increases the risk of negative environmental impact. Each N source (particularly slow-release forms) is unique and therefore should be managed accordingly. Applying a polymer-coated urea in the same manner one would apply a sulfur-coated urea greatly reduces the value of the polymer-coated urea. Similarly, applying 2 pounds of N from ammonium sulfate may cause burning, while applying 2 pounds of N from certain polymer-coated ureas may not provide the desired turfgrass response. Rate, application date, location, source, and turfgrass species should all be included in your nutrient application decision-making.

- *Soluble nitrogen sources:*
    - Urea (46-0-0)
    - Ammonium nitrate (34-0-0)
    - Ammonium sulfate (21-0-0)
    - Diammonium phosphate (18-46-0)
    - Monoammonium phosphate (11-52-0)
    - Calcium nitrate (15.5-0-0)
    - Potassium nitrate (13-0-44)

- *Slow-release nitrogen sources*

  A slow-release N source is any N-containing fertilizer where the release of N into the soil is delayed either by requiring microbial degradation of the N source, by coating the N substrate which delays the dissolution of N, or by reducing the water solubility of the N source. These include:

    - Sulfur-coated urea
    - Polymer/resin-coated
    - Isobutylidene diurea
    - Urea-formaldehyde/urea-formaldehyde reaction products
    - Natural organic

- *Urease and nitrification inhibitors*
    - Urease inhibitors reduce the activity of the urease enzyme resulting in a reduction of volatilization and an increase in plant-available N.
    - Nitrification inhibitors reduce the activity of *Nitrosomonas* bacteria, which are responsible for the conversion of NH_4 to NO_2. This reduced activity results in a reduction of N lost via denitrification and an increase in plant-available N.

The Role of Phosphorous

Phosphorus can be a growth-limiting factor for many unintended organisms and is a major contributor to eutrophication of water bodies. Thus, proper timing and rates should be implemented to reduce the risk of off-site movement of P.

Phosphorus forms high-energy compounds that are used to transfer energy within the plant. Phosphorus may remain in an inorganic form or may become incorporated into organic compounds. Phosphorous application rates should be based upon soil test results derived from documented correlations demonstrating a turfgrass response to soil test P levels.

- *P deficiency symptoms*
    - Initially, reduced shoot growth and dark green color may be observed
    - Later, lower leaves may turn reddish at the tips and then the color may progress down the blade

- *P sufficiency ranges*

See Penn State's Soil Test Recommendations for Turf for more information on sufficiency ranges.

- *P fertilizer sources*
    - Diammonium phosphate
    - Concentrated superphosphate
    - Monoammonium phosphate
    - Natural organics

The Role of Potassium

Potassium is of no environmental concern, but can be an economic concern, particularly when potassium is overutilized, which can be quite common. Generally, K concentrations in turfgrass tissue are about one-third to one-half that of N.

Potassium is not a component of any organic compound and moves readily within the plant. Potassium is key component of osmoregulation which has been documented to increase stress resistance.

- *K deficiency symptoms*

  Except under severe, documented deficiencies, K may not have an observable influence on turfgrass quality. Yellowing of older leaves followed by tip dieback and scorching of leaf margins have been reported.

- *K sufficiency ranges*

  See Penn State's Soil Test Recommendations for Turf for more information on sufficiency ranges.

  K fertilizer sources

  - Potassium sulfate
  - Potassium chloride
  - Potassium nitrate

Secondary Macronutrients

Secondary macronutrients are essential to plant function and are required in quantities less than the primary macronutrients N, P, and K, but more than micronutrients. These include calcium (Ca), magnesium (Mg), and sulfur (S). See Penn State's Soil Test Recommendations for Turf for more information on sufficiency ranges for secondary macronutrients..

The Role of Calcium

- Primarily a component of cell walls and structure.
- Found in gypsum, limestone, and calcium chloride.

The Role of Magnesium

- Central ion in the chlorophyll molecule and chlorophyll synthesis.
- Found in S-Po-Mg, dolomitic limestone, and magnesium sulfate.

The Role of Sulfur

- Metabolized into the amino acid cysteine, which is used in various proteins and enzymes.
- Found in ammonium sulfate, elemental sulfur, gypsum, and potassium sulfate.

Micronutrients

Understanding the role of each micronutrient within the plant provides a greater understanding of why these nutrients play such a key role in proper turfgrass management. Micronutrients are just as essential for proper turfgrass health as macronutrients, but they are required in very small quantities compared with macronutrients. Micronutrients include iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and Chlorine (Cl). See Penn State's Soil Test Recommendations for Turf for more information on sufficiency ranges of micronutrients.

The Role of Iron

- Part of the catalytic enzymes and is required for chlorophyll synthesis.
- Affects photosynthesis, N fixation, and respiration.

The Role of Manganese

- Involved in photosynthesis.
- Required as a cofactor for about 35 enzymes.
- Lignin biosynthesis depends on Mn.

The Role of Boron

- Found in the cell wall. Probably required for the structural integrity of the cell wall.

The Role of Copper

- Cu-protein plastocyanin is involved in photosynthesis.
- Cofactor for a variety of oxidative enzymes.

The Role of Zinc

- Structural component of enzymes.
- Protein synthesis requires Zn.
- Carbohydrate metabolism affected by Zn.

The Role of Molybdenum

- Primarily related to nitrogen metabolism.
- Responsible for structural and catalytical functions of enzymes.

The Role of Chlorine

- Required for the oxygen-evolving reactions of photosynthesis.
- Appears to be required for cell division in both leaves and shoots.

Nutrient Management

Principles

- The objective of all nutrient application is plant uptake and the corresponding desirable response.

- Proper nutrition, including the application of nutrients, allows turfgrass to recover from damage, increase its resistance to stress, and increase its playability. However, the increase in available nutrients also increases the potential risk of environmental impact. Nutrients may move beyond the turfgrass via leaching or runoff, which may impact water quality.
- Within Pennsylvania, environmental conditions may vary including differences among soils, topography, rainfall, and temperature. These differences require that a nutrient management plan be flexible enough to allow turfgrass managers to address their unique needs.
- It is important to understand the importance of fertilizer sources, fertilizer rates, application timing, species requirements, soil types, weather conditions, and location of application relative to environmentally sensitive areas for effective use of applied nutrients.
- To improve application efficiency, a spatial assessment of nutrient requirements that calibrate nutrient applications to plant growth can be performed. Using Minimal Levels of Sustainable Nutrition (MLSN) soil nutrient interpretation guidelines and the turfgrass growth potential model, nutrient needs can be predicted based on variable plant demand through the growing season. This approach ensures nutrients are applied in amounts and at times when plants are most capable of uptake and utilization and can effectively reduce costs in nutritional programs through reduced applications.
- The reduced height of cut and excessive traffic damage on putting greens results in an increased need for growth leading to an increase in the need for nutrition.
- Tees and landing areas often have higher fertility requirements than fairways and roughs because they suffer constant divot damage.
- Fairways and roughs often require less nutrient inputs than other locations because of their increased height of cut, less damage, and clipping return.
- Application timing is important to effectively apply nutrients without increasing the potential for runoff or leaching.

Best Management Practices

- Apply nutrients when turfgrass is actively growing.
- Because turfgrass is extremely responsive to soil N status, evaluate changes in clipping yield during the growing season to estimate N availability.
- Apply slow-release N fertilizer at the appropriate time of year to maximize a product's release characteristics. For example, an application of slow-release N to cool-season turfgrasses in late summer/early fall may be more desirable than early spring and mid-summer applications.
- Follow N application rate recommendations published in Soil Test Recommendations for Turf.
- N application rates from slow-release materials should take into consideration the release rate of the chosen material. If insufficient material is applied, the desired response may not be observed.
- Consult Soil Test Recommendations for Turf for the efficient N:K in your location.

- Exercise caution when making nutrient applications during turfgrass establishment as these applications are particularly susceptible to loss via leaching and runoff. Light irrigation after P application has been shown to reduce P runoff.
- Reduce N inputs on more mature turfgrass stands.
- Use N fertilizer to produce an even growth rate. This increases golf course playability and minimizes the risk to the environment, while excessive fertilization reduces playability and increases the risk of N loss.
- Monitor K and P by testing soil regularly.

Fertilizer Application

Principles

- Fertilizers must be applied using practices that prevent runoff and leaching, including removing any that are accidentally applied to impervious surfaces.
- Sandy soils often have a lower potential to fix P and are more likely to have a leaching problem than other soils.
- Fertilizer applications should be avoided whenever possible on steep slopes.
- Maintaining a vegetated buffer or filter strip around surface waterbodies significantly filters out any nutrients from fertilizers in surface runoff. Depending upon site-specific conditions, including the amount of available space and in-play versus out-of-play considerations, a range of buffer widths can be considered. Buffer widths from 10 to 656 feet have been shown to be effective. In most cases, a buffer of at least 100 feet is necessary to fully protect aquatic resources. Smaller buffers (toward the lower end of this range) still afford some level of protection to the surface waters and are preferable to no buffer at all. Full protection typically requires buffer widths toward the upper end of the range.
- Selection and calibration of application equipment is another important aspect of nutrient management.
- Be aware of the different types of spreaders (walk-behind rotary, drop spreader, bulk rotary, spray) and understand the advantages and disadvantages of each, choosing the appropriate spreader for a given fertilizer material.

Best Management Practices

- Prevent fertilizers from being deposited onto impervious surfaces.
- Avoid applying fertilizer to soil at or near field capacity or following rain events that leave the soil wet.
- Do not apply fertilizer when heavy rains are likely.
- Do not apply fertilizers to dormant turfgrass or when ground is frozen.
- Maintain buffer areas around waterbodies. The buffer areas should not be fertilized.
- Choose the appropriate type of spreader for a given fertilizer.
- Calibrate application equipment regularly.

6 Cultural Practices

Dense, healthy turfgrass with adequate infiltration plays an important role in preventing runoff and erosion. Cultural practices promote both turfgrass density and health, in balance with providing a high-quality playing surface. These practices include cultivar selection, mowing, aeration, surface cultivation, topdressing, and rolling.

Turfgrass Selection

Principles

- The use of recommended cultivars usually results in a turfgrass stand of higher quality and density, greater stress tolerance, lower nutrient requirements, less water usage, and fewer pest problems.
- The use of recommended cultivars generally has the benefits of greater water infiltration, reduced need for pesticide applications, reduced water runoff, and the enhancement of the environmental benefits of properly managed turfgrass.
- The National Turfgrass Evaluation Program (NTEP) provides information on the testing and adaptation of the turfgrass cultivars, searchable by the state's two NTEP test locations.
- When selecting cultivars for a specific site, considerations include desired use, site and microclimate conditions, disease resistance, and spring transition traits.

Best Management Practices

- Select the most suitable turfgrass cultivar for existing conditions and one that adheres to design specifications.
- Avoid the use of turfgrass in heavy shade.
- Select shade-adapted grasses for areas receiving partial sun or shaded areas.

Mowing

Principles

- Mowing is the most basic yet most important cultural practice to consider when developing a management plan.
- The mowing practices implemented on a facility impacts turfgrass density, texture, color, root development, and wear tolerance.
- Mowing practices affect turfgrass growth. Frequent mowing increases shoot density and tillering. It also decreases root and rhizome growth as a result of plant stress associated with removal of leaf tissue.

- Infrequent mowing results in alternating cycles of vegetative growth followed by scalping, which further depletes food reserves of the plants.
- Proper mowing height is a function of the species/cultivar being managed and the intended use of the site. Other factors influencing mowing height include mowing frequency, shade, mowing equipment, time of year, root growth, and abiotic and biotic stress.
- Maintaining an optimal root-to-shoot ratio is critical. Turfgrass plants that are mowed too low require a substantial amount of time to provide the food needed to produce shoot tissue for future photosynthesis. If turfgrass is mowed too low in one event, an imbalance occurs between the remaining vegetative tissue and the root system, resulting in more roots being present than the plant needs physiologically. As a result, the plants will slough off the unneeded roots. Root growth is least affected when no more than 30% to 40% of leaf area is removed in a single mowing.
- Failure to mow properly results in weakened turfgrass with poor density and quality.

Best Management Practices

- Mowing frequency should increase during periods of rapid growth and decrease during dry, stressful periods.
- If turfgrass becomes too tall, it should not be mowed down to the desired height all at once. Such severe scalping reduces turfgrass density and can result in a dramatic reduction in root growth. Tall grass should be mowed frequently and height gradually decreased until desired height of cut is achieved.
- Shade affects turfgrass growth by filtering out photosynthetically active radiation. As a result, turfgrass plants respond by growing upright in an effort to capture more light to meet their photosynthetic needs. As a result, mowing height should be increased by at least 30% to improve the health of turfgrass grown in a shaded environment.
- The use of the plant growth regulator (PGR) trinexapac-ethyl has been shown to improve overall turfgrass health when used as a regular management tool for grasses growing in shaded environments.
- Environmental stresses such as prolonged cloudy weather or drought can have a significant impact on turfgrass health. Increase the mowing heights as much as use will allow in order to increase photosynthetic capacity and rooting depth of plants.
- Use proper mowing equipment.
- Reel mowers are ideally suited for maintaining turfgrass stands that require a height of cut below 1.5 inches. They produce the best quality when compared with other types of mowers.
- Rotary mowers, when sharp and properly adjusted, deliver acceptable cutting quality for turfgrass that is to be cut above 1 inch in height. Dull blades shred leaf tissue, increasing water loss and the potential for disease development.
- Flail mowers are most often used to maintain utility turfgrass areas that are mowed infrequently and do not have a high aesthetic requirement.
- Mowing patterns influence both the aesthetic and functional characteristics of a turfgrass surface.

- Turfgrass clippings are a source of nutrients, containing 2% to 4% nitrogen on a dry-weight basis, as well as significant amounts of phosphorus and potassium and therefore can be sources of pollution.
- Clippings should be returned unless the presence of grass clippings impact play or when the amount of clippings is so large that it could smother the underlying grass.
- Collected clippings should be disposed of properly to prevent undesirable odors near play areas and to prevent fire hazards that can occur when clippings accumulate. Consider composting clippings or dispersing them evenly in natural areas where they can decompose naturally without accumulating in piles.

Cultivation

Heavily used areas such as putting greens often deteriorate because of compacted soil, thatch accumulation, and excessive use. Soil problems from active use are usually limited to the top 3 inches of the soil profile and should be actively managed to enhance turfgrass health and improve nutrient and water uptake.

Principles

- Accumulation of excessive thatch and organic matter reduces root growth, encourages disease, and creates undesirable playing conditions.
- Cultivation involves disturbing the soil or thatch through the use of various implements to achieve important agronomic goals that include relief of soil compaction, thatch/organic matter reduction, and improved water and air exchange. Because it disturbs the playing surface, significant time for recovery following cultivation may be required.
- Frequency of cultivation should be based on traffic intensity and level of soil compaction.
- Core aerification involves removal of small cores or plugs from the soil profile. Cores are usually 0.25 to 0.75 inch in diameter. Core aerification is effective at managing soil compaction and aiding in improvement of soil drainage. Light and frequent applications of sand smooths the playing surface, controls thatch, and potentially changes the physical characteristics of the underlying soil when done in conjunction with core aerification.
- Solid tines cause less disturbance to the turfgrass surface and can be used to temporarily reduce compaction and soften surface hardness during months when the growth rate of grasses is lower.
- Deep-drill aerification creates deep holes in the soil profile through use of drill bits. Soil is brought to the surface and distributed into the canopy. Holes can be backfilled with new root-zone materials if a drill-and-fill machine is used. These machines allow replacement of heavier soils with sand or other materials in an effort to improve water infiltration into the soil profile.
- Slicing and spiking reduce surface compaction and promote water infiltration with minimal surface damage. Slicing is faster than core aerification but less effective. Slicing is best

accomplished on moist soils. A spiker can break up crusts on the soil surface, disrupt algae layers, and improve water infiltration.

- Vertical mowing, or verticutting, can be incorporated into a cultural management program to achieve a number of different goals. The grain of a putting green can be reduced by setting a verticutter to a depth that just nicks the surface of the turfgrass. Deeper penetration of knives stimulates new growth by cutting through stolons and rhizomes while removing accumulated thatch.
- Groomers, or miniature vertical mowers attached to the front of reels, are effective at improving management of grain and improving plant density through cutting of stolons.

Figure 9. Cultivation achieves important agronomic goals that include relief of soil compaction, thatch/organic matter reduction, and improved water and air exchange

Best Management Practices

- Annual core aerification programs should be designed to remove 15% to 20% of the surface area. High-traffic areas may require a minimum of two to four core aerifications annually.
- Core aerification should be conducted only when grasses are actively growing to aid in quick recovery of surface density.
- Vary depth of aerification events by incorporating different lengths of tines to prevent development of compacted layers in the soil profile as a result of cultivation.
- Verticutting depth for thatch removal should reach the bottom of the thatch layer and extend into the surface of the soil beneath the thatch.
- De-thatching with a verticutter is an aggressive practice that is not recommended on golf putting greens because of the damage that occurs and the extensive recovery time required.
- Initiate verticutting when thatch level reaches 0.25 to 0.5 inch in depth. Shallow verticutting should be completed at least monthly on putting greens to prevent excessive thatch accumulation.

Topdressing

Principles

- Sand topdressing programs dilute organic matter and produce smooth, firm putting surfaces while minimizing golfer and mower impact.
- Sand topdressing improves the soil structure and can relieve surface compaction, improve drainage, increase water and air infiltration, and protect turfgrass crowns.
- The important considerations for a sand topdressing program include sand selection, application rate, and application frequency.
- Topdress the playing surface with sand following core aerification and heavy vertical mowing to aid in recovery of turfgrass. Rates vary from 0.125 to 0.25 inch in depth and depend on the capacity of the turfgrass canopy to absorb the material without burying the plants.

Figure 10. Topdressing dilutes organic matter and improves soil structure.

- Light, frequent applications of topdressing sand on putting greens can smooth out minor surface irregularities, aiding in the management of thatch accumulation.

Best Management Practices

- Use light and frequent topdressing applications following aeration.
- Use sand particle size distribution similar to the existing soil to avoid layering.
- Know the sand source and ensure that the sand is free of weed seeds, uniform, and of appropriate quality.

Rolling

Principles

- Rolling can help smooth the putting surface and maintain speeds at higher height of cut. Even with a raised height of cut, rolling can increase ball roll by 10 percent.
- Lightweight rollers typically have little negative impact on soil compaction unless the practice is overutilized or is used on high silt and clay soils when saturated with water.
- Rolling can also be used to remove dew from the playing surface, which reduces the possibility of dollar spot.

Best Management Practices

- Roll putting surfaces following mowing to increase putting speeds and allow for improved ball roll without lowering height of cut.
- Avoid rolling on saturated soils to prevent compaction.
- Use lightweight rollers to minimize potential compaction.

Overseeding Warm Season Turfgrass

Principles

- Overseeding establishes a temporary cool-season grass into a warm-season base for improved color and playability during the fall and winter when the warm-season grass enters dormancy.
- Overseeding increases the need for irrigation and routine mowing and may result in significant thinning of the base grass during spring transition.
- Successful overseeding programs require year-long planning and incorporate all aspects of root-zone cultivation and weed control in an effort to maintain health of the warm-season turfgrass while allowing successful establishment of the overseeded cool-season grass species.

Best Management Practices

- Thatch depth greater than 0.5 inch in the warm-season turfgrass base prevents good seed-to-soil contact and will result in sporadic germination and establishment. Remove thatch as part of an active cultivation program before overseeding.
- Reduce or eliminate fertilization of the base grass three to four weeks before the planned seeding date to minimize growth and competition.
- Core-aerify the soil four to six weeks before the planned overseeding date to open turfgrass canopy and aid in uniform establishment of overseeded grass.
- Select grass species/cultivars that are adapted to the desired use, taking note of disease resistance and spring transition traits. Cultivars with improved heat tolerance can delay spring transition and create increased competition for water, nutrients, and light with the warm-season turfgrass base.
- Irrigate newly planted overseed to maintain constant moisture levels, not allowing the soil surface to dry out. Gradually reduce irrigation once the seedlings have been mowed.
- Do not fertilize with N immediately before or during establishment of overseed as the N may encourage warm-season turfgrass competition and increase disease potential.
- Move hole locations on putting greens daily during the establishment period to minimize damage to seedlings from foot traffic.
- Reduce fertilizer rates in spring to slow the growth of overseeded grass. Once warm-season turfgrass regrowth is apparent, restore fertilizer applications to stimulate growth of the warm-season turfgrass.
- Colorants (dyes and pigments) can be used to provide color to dormant grasses.
- Overseeding practices can generate significant dust that may require dust control measures.

Shade and Tree Management

Principle

- Excessive shade reduces photosynthesis and air circulation, thus increasing the susceptibility of the turfgrass to pest and disease problems.

Best Management Practices

- Prune tree limbs and roots as needed to reduce competition for sunlight, water, and nutrients.
- When possible, trees located near closely mowed areas such as tees and greens should be removed or their canopy should be thinned to promote good turfgrass growth.
- Understand the variability in sun angles at different times of the year and how this affects turfgrass health.
- Conduct a shade audit to identify problem areas.
- Conduct a tree survey that identifies each tree's location, species, health, life expectancy, safety concerns, value, and special maintenance requirements.

7 Integrated Pest Management

Integrated pest management s a balanced, tactical approach to pest control. It involves taking action to anticipate pest outbreaks and to prevent potential damage, utilizing a wide range of methods or tactics to control pests such as insects, nematodes, weeds, diseases, and animals. The goal of this strategy is to prevent pests from reaching economically or aesthetically damaging levels with the least risk to the environment. Such pest management programs – based on the identification of pests, accurate measurement of pest populations, assessment of damage levels, and knowledge of available pest management strategies or tactics – enable superintendents to make intelligent decisions about control. IPM offers the possibility of improving the effectiveness of pest control programs while reducing some of the negative effects.

Regulatory Considerations

As described in detail in the "Pesticide Management" chapter, pesticide usage needs to follow local, state, and federal regulatory requirements.

IPM Overview

Principles

- IPM involves both prevention, or keeping the pest from becoming a problem, and suppression, or reducing the pest numbers or damage to an acceptable level.
- IPM utilizes regular monitoring and record keeping to determine if and when treatment is needed. This approach takes the form of a combination of control strategies (cultural, physical/mechanical, biological, and chemical controls) to prevent unacceptable damage.
- When warranted and after a considered selection process, pesticides can be used following state and federal regulations.

Best Management Practices

- ➢ Select turfgrass cultivars and species recommended for use in Pennsylvania and best suited for the intended use and environmental conditions of the specific site. Review NTEP data for Pennsylvania's two test sites.
- ➢ Correct the soil's physical and chemical properties that may impact turfgrass health and its ability to resist pests.
- ➢ Evaluate the potential impact of the timing of cultural practices and nutrient applications on the incidence of pest problems.
- ➢ Use a defined pesticide selection process to select the most effective pesticide with the lowest toxicity and least potential for off-target movement.

Written Plan

Principles

- A pest control strategy should be used only when the pest is causing or is expected to cause more damage than what can be reasonably and economically tolerated. A control strategy should be implemented that reduces the pest numbers to an acceptable level while minimizing harm to non-targeted organisms.
- When a pesticide application is deemed necessary, the plan should identify the selection process to be used. The process should be based on an evaluation of the product's effectiveness, toxicity to non-target species, cost, and site characteristics, as well as its solubility and persistence.

Best Management Practices

- ➢ Develop a facility-specific, written IPM plan. Available resources for writing an IPM plan include the GCSAA's IPM information and online tools.
- ➢ Document all IPM-related activities, including non-chemical control methods and pesticide usage.

Pest Thresholds

Principles

- IPM is commonly used in agricultural crop production, where the economic thresholds for key pests have been determined. Pest levels exceeding the site's threshold warrant treatment.
- Using IPM is more challenging on golf courses than in an agricultural setting. The golf industry is sensitive to aesthetic damage. Increased education of golfers and maintenance personnel could raise their tolerance of minor aesthetic damage that doesn't compromise plant health or golf play.

Best Management Practices

- ➢ Use available pest thresholds to guide pesticide application decisions.
- ➢ Use preventive chemical applications only when professional judgment indicates that properly timed preventive applications are likely to control the target pest effectively while minimizing the economic and environmental costs.

Monitoring

Principles

- In the IPM plan, pest monitoring or "scouting" efforts should be described for all areas of the course such as putting greens, tees and fairways, roughs, and landscaped areas.
- Scouting methods include visual inspection, soil sampling, soap flushes, and trapping for insects. Additional monitoring efforts can include weather tracking, which is especially helpful for predicting potential disease outbreaks.
- When pests are discovered during monitoring, the pest pressure should be quantified with measurements such as number of insects per unit area, disease patch sizes, and percent of area affected.
- Documentation of monitoring results should include information such as photographs, delineation of pest boundaries on an area map, outbreak date, description of the prevailing weather conditions, and recent management practices.
- Growing degree days (GDD) data and phenological indicators can be used predict pest activity and can be incorporated into the monitoring plan.

Best Management Practices

- ➢ Train personnel to document, identify, and record key pest activities on key plants, including knowing which life stage to target (e.g. larva versus adults).
- ➢ Train personnel to observe and document turfgrass conditions regularly (daily, weekly, or monthly, depending on the pest), noting the presence of pests and pest damage.
- ➢ Identify the symptoms of the pest, including primary symptoms (chlorosis, defoliation, dieback, etc.) and secondary signs of a pest infestation (animal damage, webbing, insect frass, mushrooms, or webbing).
- ➢ Determine the extent of the damage. Problem areas might include the edges of fairways, shady areas, or poorly drained areas.
- ➢ Document when the damage occurred. Note the time of day, year, and flowering stages of nearby plants.
- ➢ Map pest outbreaks locations to identify patterns and susceptible areas for future target applications and ultimate pesticide reductions.
- ➢ Train personnel to determine whether the corrective actions actually reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.

Figure 11. Monitoring

Diseases

Principles

- In the presence of a susceptible host and a conducive environment, plant pathogens can disrupt play by damaging and destroying intensely managed turfgrass.
- No measure can completely eliminate the threat of turfgrass disease on a golf course. However, turfgrass managers have multiple tactics and tools that can reduce the likelihood of disease.
- Cultural factors that can influence turfgrass stress and the likelihood of disease problems include organic layer management, fertility programs, water management, and mowing height selection. Healthy, well-managed turfgrass is less likely to develop disease problems.
- Disease outbreaks that do occur are less likely to be severe on turfgrass that is healthy because it has better recuperative potential than stressed, unhealthy turfgrass.

Figure 12. An IPM approach can help superintendents deal with disease outbreaks when they occur.

Best Management Practices

- Correctly identify the disease pathogen. This often involves sending samples to diagnostic clinics.
- Ensure that proper cultural practices that reduce turfgrass stress are used. Correct the conditions that produce stressful environments for the turfgrass. For example, improve airflow and drainage and reduce or eliminate shade.
- Integrate fungicide use into an overall management strategy. Preventively apply appropriate fungicides where diseases are likely to occur and when conditions favor disease outbreaks.
- Record and map disease outbreaks and identify trends and weather conditions that can help guide future treatments and management options and focus on changing conditions in susceptible areas to reduce disease outbreaks.

Weeds

Principles

- Weeds compete with desired plants for space, water, light, and nutrients and can harbor insect pests and diseases.
- Weeds are hosts for other pests such as plant pathogens, nematodes, and insects, and certain weeds can cause allergic reactions in humans.
- Weeds reproduce from seed, plant and root pieces, and special vegetative reproductive organs such as tubers, corms, rhizomes, stolons, or bulbs. People, equipment, animals, birds, wind, and water can distribute seeds.

- Weeds complete their life cycles in either one growing season (annuals), two growing seasons (biennials), or three or more years (perennials). Annuals that complete their life cycles from spring to fall are referred to as summer annuals. Those that complete their life cycles from fall to spring are winter annuals.
- A successful weed management program consists of:
    - Preventing weeds from being introduced into an area.
    - Using proper turfgrass management and cultural practices to promote vigorous, competitive turfgrass.
    - Properly identifying weeds.
    - Properly selecting and using the appropriate herbicide, if necessary.

Best Management Practices

- Select appropriate turfgrass species or cultivars that are adapted to the prevalent environmental conditions to reduce weed encroachment that may lead to bare soils.
- To prevent weed encroachment, adopt or maintain cultural practices that protect turfgrass from environmental stresses such as shade, drought, and extreme temperatures.
- To reduce weed infestation, address improper turfgrass management practices, such as the misuse of fertilizers and chemicals, improper mowing height or mowing frequency, and improper soil aeration, and physical damage and compaction from excessive traffic.
- Follow a fertilization program that sustains desirable color, growth density, and vigor and promotes resistance to diseases, weeds, and insects.
- Avoid scalping because it reduces turfgrass density, increasing weed establishment.
- Use only weed-free materials for topdressing.
- Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to broadleaf weeds.
- Properly identify weeds.
- Record and map weed infestations to help identify site specific issues for preventative actions.

Nematodes

Principles

- Plant-parasitic nematodes are microscopic roundworms (unsegmented), usually between 0.0156 and 0.125 inch (0.25 and 3 mm) in length and are difficult to control.
- Nematodes debilitate the root system of susceptible turfgrasses, causing turfgrass to be less efficient at water and nutrient uptake from the soil and increasing susceptibility to environmental stresses. Turfgrasses usually begin showing signs of nematode injury as they experience additional stresses, including drought, high temperatures, low temperatures, and wear.

- Weakened turfgrass favors pest infestation.
- Over time, turfgrass in the affected areas thins out and, with severe infestations, may die. The roots of turfgrasses under nematode attack may be very short, with few, if any, root hairs, or they may appear dark and rotten.

Best Management Practices

- ➢ When nematode activity is suspected, send soil/rootzone samples to a laboratory for a nematode analysis.
- ➢ Base the application of nematicides on laboratory recommendations.
- ➢ Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
- ➢ Increase mowing height to reduce plant stress associated with nematodes, root-feeding insects, disease outbreaks, or peak weed-seed germination.
- ➢ Reduce or eliminate other biotic and abiotic stresses when nematodes are compromising the root system and plant health.

Turfgrass Insects/Arthropods

Principles

- Many arthropods (especially insects and mites) live in turfgrass and the ornamental plant beds on golf courses. Some are beneficial (e.g. pollinators, decomposers, and natural enemies) or are aesthetically attractive (e.g. butterflies), while others may be nuisance pests or may negatively affect plant health.
- Arthropods can cause various types of damage to turfgrass, depending on where they attack the plant.
- Annually recurring insect pest groups include species such as armyworms and cutworms.
- Annually recurring insect pest groups include species such as armyworms, chinch bugs, nuisance ants and bees, and annual white grubs.
- White grubs can destroy significant areas of turfgrass, with damage appearing when turf undergoes stress. Turfgrass is damaged when grubs chew off the grass roots just below the soil surface, reducing the ability of the turfgrass to access water and nutrients from the soil and withstand the stress of hot, dry weather conditions.

Best Management Practices

- ➢ Determine the pest's life cycle and know which life stage to target (e.g. for insect pests, whether it is an egg, larva/nymph, pupa, or adult).
- ➢ Identify pests accurately.

- Scout for white grubs and identify larval stage to help in decision-making with respect to larvicide usage, including product selection and timing of application.

Cultural Controls

Principles

- Cultural practices, especially irrigation, mowing, topdressing, core cultivation, and venting, greatly affect both short- and long-term plant health.
- Using and/or altering cultural practices, especially in times of stress, to keep plants and soil healthy helps turfgrass to better withstand pest pressure.
- It is important to recognize that turfgrass management practices such as core aeration and sand topdressing, while beneficial, can also stress turfgrass.

Best Management Practices

- Implement proper cultural, irrigation, and turfgrass management practices to reduce stress and pressure of pest establishment.
- Maintain a proper fertilization schedule to improve turfgrass density and quality and reduce pest populations.
- Make sure materials, such as topdressing, are pest-free.
- Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to broadleaf weeds.
- Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.

Physical/Mechanical Controls

Principles

- Mechanical methods, such as vacuuming, or physical control methods, such as hand pulling weeds, exclude or remove pests, However, these methods may be time consuming and therefore work best when pest populations are low.

Biological Controls

Principles

- The biological component of IPM involves the release and/or conservation of natural predators, such as parasites and pathogens, and other beneficial organisms (pollinators).

- Natural enemies, including ladybird beetles, green lacewings, and mantids, may be purchased and released near pest infestations.
- Areas on the golf course can also be modified to better support natural predators and beneficial organisms.

Best Management Practices

- ➢ Identify areas on the golf course that can be modified to attract natural predators, provide habitat for them, and protect them from pesticide applications.
- ➢ Install flowering plants that can provide parasitoids with nectar, or provide sucking insects (aphids, mealybugs, or soft scales) with a honeydew source.
- ➢ Avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide a refuge for beneficial organisms.
- ➢ Release insect-parasitic nematodes to naturally suppress mole crickets and white grubs.

Conventional Pesticides

Principles

- A pest-control strategy using pesticides should be used only when the pest is causing or is expected to cause more damage than what can be reasonably and economically tolerated.
- Pesticides are designed to control or alter the behavior of pests. When, where, and how they can be used safely and effectively is a matter of considerable public interest.
- Pesticides should be evaluated on effectiveness against the pest, mode of action, life stage of the pest, personnel hazards, non-target effects, potential off-site movement, and cost.
- A control strategy should be implemented that reduces the pest numbers to an acceptable level while minimizing harm to non-targeted organisms.
- Always follow the directions on the label. These directions have been developed after extensive research and field studies on the chemistry, biological effects, and environmental fate of the pesticide. The label is the single most important document in the use of a pesticide. State and federal pesticide require strict adherence to label directions.

Best Management Practices

- ➢ Train employees in proper pest identification and pesticide selection techniques.
- ➢ Choose the product most appropriate for the problem or pest.
- ➢ Use GDD or phenological indicators to control pests preventatively (i.e., before they are visibly noticeable via scouting).
- ➢ Mix only the quantity of pesticide needed in order to avoid disposal problems, protect non-target organisms, and save money.

- Spot-treat pests whenever appropriate.
- Make note of any environmental hazards, pollinator advisories, or groundwater advisories included on the label.
- Rotate pesticide modes-of-action to reduce the likelihood of resistance.
- Follow guidelines and advice provided by the Fungicide Resistance Action Committee (FRAC), Herbicide Resistance Action Committee (HRAC), and Insecticide Resistance Action Committee (IRAC).

Record Keeping

Principles

- It is essential to record the results of scouting in order to develop historical information, document patterns of pest activity, and document successes and failures.
- Certain pesticides are classified as restricted-use pesticides (RUPs). Very few pesticides in this category are routinely used in turfgrass maintenance, but if used, record-keeping requirements apply.

Best Management Practices

- Record monitoring efforts and results.
- Record corrective actions taken to address pest issues.
- When chemical control is required, use records to establish proof of use and follow-up investigation of standard protocols regarding:
    - Date and time of application.
    - Name of applicator.
    - Person directing or authorizing the application.
    - Weather conditions at the time of application.
    - Target pest.
    - Pesticide used (trade name, active ingredient, amount of formulation, amount of water).
    - Adjuvant/surfactant and amount applied, if used.
    - Area treated (acres or square feet) and location.
    - Total amount of pesticide used.
    - Application equipment.
    - Additional remarks, such as the severity of the infestation or life stage of the pest.
    - Follow-up to check the effectiveness of the application.

8 Pesticide Management

Pesticide use should be part of an overall pest management strategy. When a pesticide application is deemed necessary, its selection should be based on effectiveness, toxicity to non-target species, cost, site characteristics, and its solubility and persistence in the environment.

Regulatory Considerations

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is the federal law regulating the manufacture, distribution, sale, and use of pesticides. PDA is the lead pesticide regulatory agency in the state. The primary statute in Pennsylvania that governs the use of pesticides is the Pennsylvania Pesticide Control Act of 1973 that is enforced by the PDA Bureau of Plant Industry. Pesticide storage, handling, and usage needs to follow all state and federal regulatory requirements. The label is the law and must be followed at all times.

In PA, persons who make applications to golf courses are required to be licensed as a public or commercial applicator, and the golf course employing them must possess a pesticide business license. All licensed pesticide businesses in PA must keep pesticide application records regardless if the pesticide applied is a general use or restricted use pesticide. Pesticide certification and training for commercial applicators is administered by PDA.

Pesticides must be registered for use in Pennsylvania. The National Pesticide Information Retrieval Service (NPIRS) maintains a database of registered pesticide products.

Human Health Risks

Principles

- Pesticides belong to numerous chemical classes that vary greatly in their toxicity. The human health risk associated with pesticide use is related to both pesticide toxicity and the level of exposure. For example, the risk associated with a highly toxic pesticide may be very low if the exposure is sufficiently small.
- The pesticide label provides information on personal protective equipment (PPE) required to minimize exposure, and first-aid information specific to the product.
- Safety Data Sheets (SDS) also provide important information on hazardous chemicals. Using SDS in conjunction with the product label will provide not only a good description of the potential risks, but also appropriate and required exposure-minimization measures that help reduce risk.

Best Management Practices

- Select the least toxic pesticide with the lowest exposure potential.
- Applicators should always read and follow the label before using a pesticide and use appropriate PPE in addition to following standard safe practices.
- Know the emergency response procedure in case excessive exposure occurs.

Personal Protective Equipment

Principle

- Exposure to pesticides can be mitigated by practicing good work habits and adopting modern pesticide mix/load equipment (e.g. closed-loading) that reduce potential exposure. PPE statements on pesticide labels must be followed.

Best Management Practices

- Provide adequate PPE for all employees who work with pesticides (including equipment technicians who service pesticide application equipment).
- Ensure that PPE is sized appropriately for each person using it.
- Make certain that PPE is appropriate for the chemicals used.
- Ensure that PPE meets rigorous testing standards and is not just the least expensive.
- Store PPE where it is easily accessible but not in the pesticide storage area.
- Forbid employees who apply pesticides from wearing facility uniforms home.
- Provide laundering facilities or a cleaning service for employee uniforms that come into contact with pesticides.
- Fit-test workers who must wear tight-fitting respirators, as required by the Occupational Safety and Health Administration (OSHA).
- Meet requirements for OSHA 1910.134 Respiratory Protection Program.

Environmental Fate and Transport

Principles

- Environmental characteristics of a pesticide can often be determined by the environmental hazards statement found on pesticide product labels. The environmental hazards statement provides the precautionary language advising the user of the potential hazards to the environment from the use of the product.
- Environmental hazards generally fall into three categories: general environmental hazards, non-target toxicity, and endangered species protection.
- The physical and chemical characteristics of pesticides determine a pesticide's interaction with the environment: solubility, adsorption, persistence, and volatilization. These characteristics influence the potential for pesticide runoff, leaching, or drift. Once applied, pesticides can move off-site in several ways: in water, in air, attached to soil particles, and on or in objects, plants, or animals.
- Weakly sorbed pesticides (compounds with small Koc values) are more likely to leach through the soil and reach groundwater. Conversely, strongly sorbed pesticides (compounds with large Koc values) are more likely to remain near the soil surface, increasing the chances of being carried to surface water via runoff or soil erosion.

Best Management Practices

- Before selecting a pesticide, evaluate the impact of site-specific characteristics, such as soil type, leaching potential of the chemical, depth to the water table, geology, and proximity to surface water. Site characteristics prone to leaching losses includes sand-based putting greens, coarse-textured soils, and shallow water tables. Areas prone to runoff include steep slopes and close proximity to surface waters.
- Evaluate pesticides using a selection process that considers the physical and chemical characteristics of products under consideration and the potential for runoff, leaching, or drift with respect to the treatment area.
- Avoid using highly water-soluble pesticides.
- Select pesticides with reduced impact on pollinators.
- Select pesticides that, when applied according to the label, have no known effect on endangered species present on the facility.
- Evaluate prevailing weather conditions, such as chance of precipitation, wind, temperature humidity, etc., with respect to the timing of pesticide applications.
- Exercise caution when using spray adjuvants that may facilitate off-target movement.

Pesticide Transportation, Storage, and Handling

Principle

- Storage and handling of pesticides in their concentrated form poses the highest potential risk to surface or groundwater. For this reason, it is essential that facilities for storing and handling these products be properly sited, designed, constructed, and operated.
- See the Penn State Extension fact sheet *Pesticide Storage and Security* for more detailed information.

Best Management Practices

- Install back flow preventors on all equipment water fill lines.
- Store, mix, and load pesticides away from sites that directly link to surface water or groundwater.
- Store pesticides in a lockable concrete or metal building that is separate from other buildings.
- Locate pesticide storage facilities away from other types of structures to allow fire department access.
- Storage facility floors should be impervious and sealed with a chemical-resistant paint.
- Floors should have a continuous sill to retain spilled materials. There should be no drains, although a sump may be included.
- Sloped ramps at the entrance enable the use of wheeled handcarts for moving material in and out of the storage area safely.
- Shelving should be made of sturdy plastic or reinforced metal. Metal shelving should be kept painted to avoid corrosion. Wood shelving should never be used because it may absorb spilled pesticides.

- Always store dry pesticides above liquid pesticides.
- Automatic exhaust fans and an emergency wash area should be provided. Explosion-proof lighting may be required. Light and fan switches should be located outside the building, so that both can be turned on before staff enter the building and turned off after they leave the building.
- Avoid temperature extremes and protect pesticides from freezing inside the pesticide storage facility.
- Personal protective equipment should be easily accessible and stored immediately outside the pesticide storage facility.
- Do not transport pesticides in the passenger section of a vehicle.
- Never leave pesticides unattended during transport.
- Place a spill containment kit in the storage area, in the mix/load area, and on the spray rig.

Inventory and Shelf Life

Principles

- Adopt the "first in–first out" principle, using the oldest products first to ensure that the product shelf life does not expire.
- Pesticides degrade over time. Do not store large quantities of pesticides for long periods.

Best Management Practices

- Keep an inventory of the pesticides in the storage building. Utilize computer software systems to record inventory and use.
- Consult inventory when planning and before making purchases.
- Avoid purchasing large quantities of pesticides that require storage for greater than six months.
- Use the oldest products first to ensure that the product shelf life does not expire.
- Ensure labels are on every package and container.
- Ensure that labels remain properly affixed to their containers.
- Keep the SDS for the chemicals used in the operation accessible on the premises, but not in the pesticide storage facility itself.

Emergency Preparedness and Spill Response

Principle

- Accidents happen. Advance preparation on what to do when an accident occurs is essential to mitigate the human health effects and the impact on the environment.

Best Management Practices

- Develop a golf course facility emergency response plan that includes procedures to control, contain, collect, and store spilled materials.
- Prominently post "Important Telephone Numbers," including CHEMTREC, for emergency information on hazards or actions to take in the event of a spill.
- Ensure an adequately sized spill containment kit is readily available.
- Designate a spokesperson who will speak on behalf of the facility should an emergency occur.
- Host a tour for local emergency response teams (e.g. firefighters) to show them the facilities and to discuss the emergency response plan. Seek advice on ways to improve the plan.

Pesticide Record Keeping

Principle

- Maintaining accurate records of pesticide-related activities (e.g. purchasing, storage, inventory, and applications) is essential and required by state law for any pesticide with an USEPA registration number. Records must be created within 24 hours of the pesticide application and maintained for at least 3 years and must include the following information:

    - Date of the application and the time completed if a there is a reentry time on the product label.
    - Name and address of the application site and the name of the customer if it differs from the application site.
    - Brand name, USEPA registration number, amount, and rate or dosage of each pesticide used.
    - The names of all persons involved with the application and their certification/ registration numbers.

Best Management Practices

- Keep and maintain records of all pesticides used to meet legal (federal, state, and local) reporting requirements.
- Use records to monitor pest control efforts and to plan future management actions.
- Use electronic or hard-copy forms and software tools to properly track pesticide inventory and use.
- Develop and implement a pesticide drift management plan.
- Keep a backup set of records in a safe, but separate storage area.

Sprayer Selection and Calibration

Principles

- Various types and sizes of application equipment are readily available. The size of the equipment (tank size, boom width, etc.) should be matched to the scale of the area to be treated.
- Properly calibrated application equipment is paramount to mitigating environmental and human health concerns.

Best Management Practices

- ➢ Use appropriately-sized application equipment for the size of area being treated. Equipment too large in size requires greater volumes to prime the system, which can result in a significant amount of waste.
- ➢ Ensure that the applicator is experienced, licensed, properly trained, and listed under the golf facility's Pesticide Business License.
- ➢ Minimize off-target movement by using properly configured application equipment.
- ➢ Calibrate all application equipment at the beginning of each season (at a minimum) or after equipment modifications.
- ➢ Check equipment daily when in use.
- ➢ Calibrate walk-behind application equipment for each person making the application to take into consideration their walking speed.
- ➢ Use recommended label rates for the targeted pest to maximize efficacy.

Figure 13. Best management practices help to ensure that pesticides don't migrate off target.

Mixing/Washing Station

Principle

- Pesticide leaks or spills, if contained, will not percolate down through the soil into groundwater or run off the surface to contaminate streams, ditches, ponds, and other waterbodies. One of the best containment methods is the use of a properly designed and constructed chemical mixing center.

Best Management Practices

- Load and mix pesticides over an impermeable surface (such as lined or sealed concrete) so that spills can be collected and managed.
- Mixing station surface should provide for easy cleaning and the recovery of spilled materials.
- Pump the sump dry and clean it at the end of each day. Liquids and sediments should also be removed from the sump and the pad whenever pesticide materials are changed to an incompatible product (that is, one that cannot be legally applied to the same site) and used as a pesticide, strictly following label instructions.
- Absorbents such as cat litter or sand may be used to clean up small spills and then applied as a topdressing in accordance with the label rates, or disposed of as a hazardous waste.
- Sweep up solid materials and use as intended.

Disposal

Principles

- Washwater from pesticide application equipment must be managed properly because it contains pesticide residues.
- See PennState Extension's web page Pesticide Disposal web page for information on pesticide disposal.
- PDA's CHEMSWEEP program provides licensed pesticide applicators with a means to dispose of canceled, suspended, or unwanted pesticide products.

Best Management Practices

- Collect washwater (from both inside and outside the application equipment) and use it as a pesticide in accordance with the label instructions.
- The rinsate may be applied as a pesticide (preferred) or stored for use at the next compatible application.
- Dispose of unwanted pesticides through CHEMSWEEP or other legal means.

Pesticide Container Management

Principles

- The containers of some commonly used pesticides are classified as hazardous waste if not properly rinsed, and as such, are subject to the many rules and regulations governing hazardous waste. FIFRA requires pesticide applicators to rinse all empty pesticide containers before taking other container disposal steps. Under the federal Resource Conservation and Recovery Act, a pesticide container is not empty until it has been properly rinsed.
- The improper disposal of a hazardous waste can result in very high fines and/or criminal penalties.
- Pesticide containers that have been properly rinsed can be handled and disposed of as non-hazardous solid waste.

Best Management Practices

- Rinse pesticide containers immediately in order to remove the most residue.
- Rinse containers during the mixing and loading process and add rinsate water to the finished spray mix.
- Rinse emptied pesticide containers by either triple rinsing or pressure rinsing.
- Puncture empty and rinsed pesticide containers and dispose of them according to the label.

9 Pollinator Protection

Pennsylvania is home to hundreds of species of pollinators (bees, butterflies, moths, flies, beetles), with over 500 species of bees alone. While some plants are pollinated by wind, many require assistance from insects and other animals, including agricultural crops. Pennsylvania also has one of the most diverse cropping systems in the United States, producing an array of fruit and vegetable crops that benefit from the services of pollinators. These crops annually contribute $260 million to Pennsylvania's economy.

Pollinators are facing threats that can alter their health, abundance, and distribution. These threats include loss of habitat, parasites, diseases, and other pathogens, lack of genetic diversity, poor nutrition due to monoculture agriculture, and exposure to pesticides. Research indicates that some pesticides can be harmful for pollinators and can have negative effects at the sub-individual level (such as gene expression or physiology), individual level (such as mortality, foraging, or learning), or even the colony level (such as colony growth, overwintering, or honey production.

Because of the potential for non-target effects of products used in golf course management, pesticide applicators need to be mindful of the impact that pesticides have on pollinator species and their habitat. In addition to adhering to best management practices related to pesticide application, golf course managers can protect and enhance habitat on the course in a number of ways to help both wild pollinators and managed bees. More information on protecting pollinators in Pennsylvania can be found in *The Pennsylvania Pollinator Protection Plan*.

Regulatory Considerations

- Pollinator-protection language is a label requirement found on pesticide labels; follow the label, it is the law.
- Pesticide applicators must be aware of honey bee toxicity groups and understand the precautionary statements.
- Those applying pesticides should be aware of honey bee biology, the various routes of exposure (outside the hive and inside the hive), and the effects of pesticides on bees.
- Recordkeeping may be required by law in order to use some products. IPM principles suggest that you keep records of all pest control activity so that you may refer to information on past infestations or other problems to select the best course of action in the future.
- If keeping beehives at the facility, Pennsylvania requires that all beekeepers must be registered with the PDA.

Pest Management Practices

Principles

- Protecting pollinators on the golf course does not preclude the use of pesticides, but instead minimizes the potential impact from these chemicals.

- Pesticide applicators must use appropriate tools to help manage pests while safeguarding pollinators, the environment, and human health.
- Using IPM BMPs is an important key to protecting pollinators because they reduce pesticide usage and minimize the potential of exposure. Superintendents can utilize IPM BMPs for turfgrass that protect pollinators by following these simple steps:
    - Identifying what is truly a pest. For example, solitary ground-nesting bees and wasps might be alarming, but most are harmless.
    - Setting higher weed thresholds in low-use areas.
    - Monitoring bee activity to avoid applying pesticides during peak activity times (i.e. applying pesticides in the early morning or evening).
- When the use of pesticides is necessary, being mindful of pollinators includes selecting chemicals with low toxicity to bees, short residual toxicity, or properties repellent to bees; using caution when applying near flowering plants, including flowering weeds (mow first whenever possible); and avoiding drift.
- Applicators are encouraged to utilize FieldWatch to locate any nearby apiaries before applying pesticides on the course.

Best Management Practices

- Before applying a pesticide, inspect the area for both harmful and beneficial insect populations.
- Use pesticides only when a threshold of damage has been indicated.
- Consider biological control agents, lures, baits, and pheromones as alternatives to insecticides for pest management.
- When pesticides are needed, select those with a lower impact on pollinators.
- If a granular formulation will control the pest, choose it over liquid formulations if honey bees are not in the vicinity. Granular versions of pesticides are generally less hazardous to most bees. However, honey bees may gather the granular version and pack it into cells in hives.
- Restrict applications to early morning or evening when pollinators are not as active.
- Avoid applying pesticides during bloom season; during bloom season, mow first to remove blooms, including those of flowering weeds such as white clover.
- Avoid applications during unusually low temperatures or when dew is forecast.
- Use the latest spray technologies, such as drift-reduction nozzles, to prevent off-site movement of pesticide.

Enhancing Pollinator Habitat

Principles

- Habitat for pollinators includes foraging habitat, nesting sites, and water sources.
- Pollinator habitat on the golf course includes existing out-of-play areas (such as buffer strips around water courses and bodies of water) and areas renovated specifically with pollinators in mind that include native plants, wildflowers, and flowering trees and shrubs.
- Pollinator-friendly habitat contains a diversity of blooming plants of different colors and heights, with blossoms throughout the entire growing season. Native plants are best for providing the most nutritious food source for native pollinators. Even plants considered weeds provide important habitat.
- Increasing habitat to meet pollinator needs can be accomplished simply by adding to existing plantings or through more intensive efforts to establish a larger native area.
- To convert existing out-of-play areas to a new native area, site preparation is key and may require more than one season of effort to reduce competition from invasive or other undesirable plants prior to planting.

Figure 14. Golf courses can provide significant pollinator habitat in out of play areas.

Best Management Practices

- Follow site preparation guidelines when renovating areas to ensure success.
- Choose south-facing sites whenever possible for establishing native areas.
- Place plants in masses (three or more) to attract pollinators.
- Select plants that feature different shapes, sizes, and colors and that bloom at different times of the year. Use both perennials and annuals.
- Provide water sources with shallow sides for pollinators.
- Select native grasses that provide foraging and nesting habitat, including hollow stem grass species that can be used as nesting sites.
- Leave dead trees, stumps, posts, stems and other coarse, woody debris in native areas for pollinator nesting.
- Leave exposed patches of well-drained soil in native areas for pollinator nesting.
- Consider installing bee blocks for solitary nesters such as mason and leafcutter bees and artificial boxes for nesting bumble bees.

10 Maintenance Operations

Facilities related to the storage and handling of pesticides, fertilizers, and other chemicals, especially in their concentrated form, pose the highest potential risk to water sources if accidentally released in quantity. Therefore, anyone storing, mixing, or loading potentially hazardous chemicals should treat all leaks, spills, and fires as emergencies and be prepared to respond to these emergencies promptly and correctly. For unintended releases of any chemicals, an emergency plan, spill kit, and first-aid kit should be readily available.

The "Pesticide Management" chapter includes maintenance-related BMPs specifically for pesticides. This chapter provides additional guidance for maintenance operations and points out differences between managing fertilizer equipment and pesticide equipment.

Regulatory Considerations

As discussed in the "Pesticide Management" chapter, PDA regulates pesticides in Pennsylvania. Employees who handle pesticides must be trained. Applicators must be certified. Local regulations may also be in place with respect to the siting of maintenance facilities.

Underground Storage Tanks

Petroleum tanks greater than 110 gallons are regulated by the DEP's Division of Storage Tanks under the Storage Tank and Spill Prevention Act. Owners and operators of underground storage tanks (UST) must register tanks. UST online services are available to help tank owners with registration.

Aboveground Storage Tanks

Above ground storage tanks (AST) with a capacity greater than 250 gallons are regulated by the DEP's Division of Storage Tanks under the Storage Tanks and Spill Prevention Act. More information concerning storage tanks can be found at the Division of Storage Tank's page on the DEP's website, including informational facts sheets.

Storage and Handling of Chemicals

Principle

- Proper handling and storage of fertilizers, pesticides, and petroleum-based products is important to reduce risk of serious injury or death of an operator or bystander. Fires or environmental contamination may result in large fines, cleanup costs, and civil lawsuits if these chemicals are not managed properly.

Best Management Practices

- Post warning signs on chemical storage buildings, and especially near any entry or exit areas.
- Storage facilities must be secured and allow only authorized staff to enter.
- Pesticide and fertilizer storage areas should preferably be located away from other buildings.
- Floors should be sealed with chemical-resistant paint.
- Floors should have a continuous sill to help contain any spills.
- Install a fire suppression system or equipment.
- Shelves should be made of plastic or reinforced metal. Metal shelving should be coated with paint to avoid corrosion. Wood should not be used due to its ability to absorb spilled chemicals.
- Exhaust fans and an emergency wash station should be provided.
- Light and fan switches should be installed to illuminate and ventilate the building.
- Store chemicals in original containers.
- Store chemicals so that the label is clearly visible. Loose labels should be refastened.
- Store flammable chemicals separately from non-flammable chemicals.
- Store liquid materials below dry materials to prevent contamination from a leak.
- Use regulatory agency-approved, licensed contractors for the disposal of chemicals.
- Provide adequate staff training pertaining to the risks and liabilities of chemical storage and use.
- Train staff how to access and use the facility's SDS database.
- Maintain accurate inventory lists.

Equipment Storage and Maintenance

Principle

- Storing and maintaining equipment properly extends useful life and reduces repairs.

Best Management Practices

- Store and maintain equipment in a covered area complete with a sealed impervious surface to limit risk of fluid leaks contaminating the environment and to facilitate the early detection of small leaks that may require repair before causing significant damage to the turfgrass or the environment.
- Seal floor drains unless they are connected to a holding tank or sanitary sewer with permission from the local wastewater treatment plant.
- Store pesticide and fertilizer application equipment in areas protected from rainfall. Rain can wash pesticide and fertilizer residues from the exterior of the equipment and possibly contaminate soil or water.
- Store solvents and degreasers in lockable metal cabinets away from ignition sources in a well-ventilated area. These products are generally toxic and highly flammable. Never store them with fertilizers or in areas where smoking is permitted.

- Keep an inventory of solvents and SDS for those materials on-site but in a different location where they will be easily accessible in case of an emergency.
- Keep basins of solvent baths covered to reduce emissions of volatile organic compounds.
- When possible, replace solvent baths with recirculating aqueous washing units. Soap and water or other aqueous cleaners are often as effective as solvent-based products and present a lower risk to the environment.
- Always use appropriate PPE when working with solvents.
- Never allow solvents or degreasers to drain onto pavement or soil, or to discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.
- Collect used solvents and degreasers in containers clearly marked with contents and date. Schedule collection by a commercial service.
- Blow off all equipment with compressed air to reduce damage to hydraulic seals.

Equipment Washing

Principle

- Washwater generated from equipment-washing facilities can be a source of both surface and groundwater pollution. Steps should be taken to prevent pollution.

Best Management Practices

- Equipment washing areas should drain to an oil/water separator before draining to a sanitary sewer or holding tank.
- Consider the use of a closed-loop washwater recycling system.
- Grass-covered equipment should be brushed or blown off with compressed air before being washed.
- Wash equipment with a bucket of water and a rag to minimize the amount of water used and use only the minimal amount of water required to rinse the machine.
- Spring-operated shut-off nozzles should be used.
- Do not allow any wastewater to flow directly into surface waters or storm drains.

Fueling Facilities

Principles

- Fueling areas should be properly sited, designed, constructed, and maintained to prevent petroleum products from spilling or leaking.
- An AST is easier to monitor for leaks and is therefore the preferred storage method.
- Because of the potential for groundwater contamination from a leaking UST, leak detection monitoring is a critical aspect of UST compliance.

Best Management Practices

- Fueling stations should be located under roofed areas with concrete pavement whenever possible.
- Fueling areas should also have spill containment and recovery facilities located near the stations.
- Develop a record-keeping process to monitor and detect leakage in USTs and ASTs.
- Visually inspect any AST for leakage and structural integrity.
- Secure the fuel storage facilities and allow access only to authorized and properly trained staff.
- Ensure that fuel tanks and pumps are properly labeled.
- Post "No Smoking" signs near fueling facilities.

Waste Handling

Principles

- Proper disposal of waste materials is critical for the protection of water and natural resources. State or local laws and regulations related to disposal of hazardous waste products may vary.
- Identify and implement waste-reduction practices.
- Look for ways to increase recycling efforts and programs.
- Purchase environmentally preferred products in bulk packaging when possible.

Best Management Practices

- Collect used oil, oil filters, and antifreeze in separate marked containers and recycle them as directed by local and state authorities.
- Antifreeze may be considered hazardous waste by state or local laws and should be handled accordingly. Commercial services are available to collect and recycle antifreeze.
- Lead-acid batteries are classified as hazardous waste unless they are properly recycled.
- Store old batteries on impervious services where they are protected from rainfall and recycle them as soon as possible.
- Recycle used tires.
- Recycle or dispose of fluorescent tubes and other lights according to state requirements.

Emergency Preparedness and Spill Response

Principles

- Minor spills of pesticide or rinsate that have occurred from the handling, loading, or cleansing of bulk containers and that accumulate in the secondary containment area must be

disposed of as provided by the pesticide label.

- Enough absorbent material must be available to handle a spill of the largest container in storage.
- Sorbent materials include booms, socks or mini booms, pillows, pads and rolls, and loose sorbents. These sorbent materials may be universal or more specific (such as for petroleum products).
- A spill kit is a necessity at any facility where chemicals are used or stored.

Best Management Practices

- Develop a golf course facility emergency response plan that includes procedures to control, contain, collect, and store spilled materials.
- Prominently post "Important Telephone Numbers," including the regional DEP office between the hours of 8 a.m. and 4 p.m. For emergencies between 4 p.m. and 8 a.m., call 1-800-541-2050.
- Report any uncontained releases or spills.
- Ensure an adequately sized spill containment kit is readily available.
- Designate a spokesperson who will speak on behalf of the facility should an emergency occur.

11 Landscape Management

Landscape (non-play) areas are an essential part of the overall course design, providing enhanced course aesthetics, wildlife habitat, external sound/noise abatement, and natural cooling and freeze protection.

An environmental landscape design approach addresses environmentally safe and energy-saving practices. Therefore, environmentally sound landscape management is also economically important. Non-play areas require a mix of sun and shade, optimal soil conditions, and adequate canopy air movement to sustain growth and function.

Species Selection and Size Considerations

Principles

- The fundamental principle for the environmentally sound management of landscapes is "right plant, right place." The ideal plant from an environmental standpoint is the one that nature and evolution placed there. It has adapted specifically to the soil, microclimate, rainfall, light patterns, insects, other pests, and endemic nutrient levels.
- Know the ultimate sizes and growth rates of trees, shrubs, and ground covers. This reduces the need for pruning and debris removal and lowers maintenance costs.
- The addition of proper soil amendments can improve soil's physical and chemical properties, increase its water-holding capacity, and reduce the leaching of fertilizers. Amendments may be organic or inorganic. However, soil microorganisms rapidly decompose organic amendments such as peat or compost.
- The goal of species-selection BMPs is to maintain as close to a natural ecosystem as practical, while meeting the needs of a golf course.
- Landscape areas should be fundamentally designed to facilitate rapid plant establishment, to conserve water, and to require lower nutritional inputs once plants mature. Plants within areas that are not in play or are not critical to the design of the course may be removed and replanted with native plant material that requires little to no maintenance after establishment. Additionally, 50% to 70% of the non-play areas should remain in natural cover.
- As much natural vegetation as possible should be retained and enhanced through the supplemental planting of native trees, shrubs, and herbaceous vegetation in non-play areas that provide wildlife habitat and along water sources that support fish and other water-dependent species.
- Leaving dead trees (snags) where they do not pose a hazard, a well-developed understory (brush and young trees), and native grasses reduces the amount of work needed to prepare a course while maintaining habitat for wildlife.

Best Management Practices

- Base plant selection as close to a natural ecosystem as practical, while meeting the needs of the golf course. Native plants have adapted specifically to the soil, microclimate, rainfall, light patterns, insects, other pests, and endemic nutrient levels.
- Select trees, plants, and grass species to attract birds seeking wild fruits, herbs, seeds, and insects.
- Know the ultimate sizes and growth rates of trees, shrubs, and ground covers.
- Use plants that are adapted for the site based on the United States Department of Agriculture (USDA) cold-hardiness zone.
- Select stress-tolerant species or cultivars to manage periodic dry/wet conditions.
- Choose the most stress-tolerant species or cultivar for a particular area.

Figure 15. Out of play areas can be converted to native areas and meadows, which not only add aesthetic value to the course, but also habitat for pollinators and other wildlife.

Design and Function

Principles

- Aesthetic gardens, window boxes, and container gardens should include a variety of plants of different heights that provide nectar for hummingbirds and butterflies. Again, "right plant, right place" is the key to success.
- When integrating turfgrass areas into the landscape around the clubhouse, entries, and other areas, design them for ease of maintenance and keep in mind that turfgrasses grow best in sunny areas. Consider the effect that tree canopy and other design features may have on the health and function of the turfgrass.
- Garden plants, shrubbery, ground covers, or native plants may provide a pleasing a view and also provide useful food, cover, or other environmental benefits to wildlife. They may also require reduced maintenance.
- Trees and shrubs along streams provide temperature moderation through shade, which lowers water temperature in summer and increases it in winter.

Best Management Practices

- Well-designed riparian buffers should contain a mixture of fast- and slow-growing native trees, shrubs, and grasses to provide a diverse habitat for wildlife.
- Use riparian buffers to trap and remove upland sources of sediments, nutrients, and chemicals.
- Use riparian buffers to protect fish and wildlife by supplying food, cover, and shade.
- Use riparian buffers to maintain a healthy riparian ecosystem and stable stream channel.
- Leave snags whenever possible for nesting and as a food source. However, make sure snags are a safe distance from playing surfaces should they fall or get blown over.
- Use turfgrass as a landscape element where needed.

Planting Methods

Principles

- The use of organic mulches in gardens and aesthetic areas increases the moisture-holding capacity of plantings and prevents weed growth when applied in sufficient depth. Organic amendments are decomposed by soil microorganisms and add to soil tilth.
- Keep mulch 2 to 3 inches away from plants, to prevent fungal growth from excess dampness.
- Excess mulch or compacted mulch may be detrimental, causing water to shed away from the root zone and encourage overwatering. Compaction or excessive mulch buildup should be avoided, especially when annual re-mulching is performed.

Best Management Practices

- The plant palette and irrigation system should be appropriate for site conditions, taking into account that, in some cases, soil improvement can enhance water-use efficiency.
- Plants should be grouped together based on irrigation demand.
- The percentage of landscaped area in irrigated high-water-use hydrozones should be minimized. Local government ordinances should address the percentage of irrigated landscaped area that may be included in high-water-use hydrozones.
- In most instances, established, drought-tolerant landscape plants have a root system substantial enough to keep them alive with little or no supplemental irrigation.
- Pruning and fertilizing will also benefit landscape plants while they are becoming established.
- Add proper soil amendments in garden areas to improve the soil's physical and chemical properties, increase its water-holding capacity, and reduce the leaching of fertilizers.

12 Energy

Energy, in the form of electricity, natural gas, diesel, propane, heating oil, gasoline and other fuels, is a significant expense on the golf course. According to GCSAA, the average 18-hole golf course uses nearly 450,000 kilowatt-hours in electricity (Golf Course Environmental Profile, 2012). Fortunately, golf course managers can reduce energy consumption in many areas of course operations. Investments in energy efficiency saves money and positions the course to be more resilient to future increases in energy prices or regulatory changes. An energy efficient golf course is also a good steward of natural resources, which can enhance the facility's standing in the community.

Energy Conservation

Principles

- Determine goals and establish an energy policy that is part of the facility's overall environmental plan.
- Establish an energy management plan for the facility based on current energy use baselines to optimize efficiency.
- Communicate policy to all staff regarding use patterns and management practices to effect change.
- Relate the policy to the entire facility, including the services the facility provides to its customers and community.
- Incorporate quality management elements for continual improvement (plan, do, check, and act) to reduce environmental and economic impacts.
- Understand that the irrigation pump is the largest user of energy. A well-engineered pump station is critical to reducing energy consumption.

Best Management Practices

- Conduct an energy audit and a lighting audit.
- Conduct a carbon footprint analysis.
- Add insulation where needed.
- When possible, use non-demand electrical hour rates for charging golf carts, using pumps, and charging maintenance equipment later in the day or early in the morning.
- Limit high-consumption activities during periods when demand is high.
- Use alternative energy from natural sources, such as solar, wind, and geothermal.
- Upgrade or install National Electrical Manufacturers Association premium efficiency-rated pump motors.
- Install LED lighting and/or retrofit devices.
- Install motion sensors lights where appropriate.
- Install programmable thermostats.
- Install solar/geothermal pumps for pools and spas.

Evaluation

Principles

- Continually track and measure energy use at the facility based on energy assessment units (e.g. kilowatt hour).
- Benchmark practices to evaluate existing facility consumption with other local golf facilities of similar size.

Best Management Practices

- ➢ Monitor energy use by tracking data and evaluating billing statements.
- ➢ Install adequate meters, gauges, etc.
- ➢ Develop an equipment inventory incorporating individual equipment's energy use and use or traffic patterns. Include maintenance records and operation hours.
- ➢ Establish a baseline for performance parameters to optimize irrigation pumps.
- ➢ Consider benchmarking performance against similar-sized facilities.

Efficiency

Principles

- Evaluate energy efficiency performance.
- Evaluate electric equipment/operations and ensure proper selection, operation, charging, and maintenance.

Best Management Practices

- ➢ Evaluate all energy providers (electricity, natural gas, and liquid petroleum fuels) for costs, efficiency/assistance programs, and incentives.
- ➢ Identify and categorize operations for energy efficiency opportunity and conservation analysis.
- ➢ Perform assessments of all the facility's infrastructure and operations.
- ➢ Perform appropriate audits throughout the facility depending on operation, infrastructure, and planning stage.
- ➢ Identify efficiency and conservation elements of infrastructure/hard items and behavioral/process-oriented items.
- ➢ Consider alternative equipment, products, and practices.

Design and Renovation

Principles

- Incorporate an analysis of the assessments, audits, and data.
- Incorporate first cost consideration (initial investment and long-term gain).
- Redesign and evaluate future projects with a priority for energy conservation.
- According to system and compliance standards, communicate with utility providers, insurance companies, and any state or local regulatory officials.

Best Management Practices

- ➢ Identify buildings, amenities, and operations including existing, new construction, or renovation activities where energy efficiency enhancements are needed.
- ➢ Identify the golf course, course infrastructure, and related agronomic operations including existing and future developments or renovations that would benefit from energy efficiency improvements.

Implementation Plan

Principles

- Set goals for buildings/amenities and the golf course operation. Develop an implementation plan.
- Set energy-use goals according to efficiency/conservation of the building, infrastructure, and equipment efficiency.

Best Management Practices

- ➢ Evaluate effectiveness of upgrades according to efficiency/conservation goals for energy use.
- ➢ Continue to identify future energy needs and maintain good record keeping.
- ➢ Prioritize energy consumption in the decision-making process for the purchase of HVAC, food service, laundry, and swimming pool equipment.
- ➢ Consider other devices as part of the plan. Do research on building, pumps, and power generation.

Infrastructure

Principles

- Ensure efficient building, facility, amenities and related infrastructure.
- Consider the materials, such as insulation and color selection.
- Ensure efficient lighting in both interior and exterior areas.

Best Management Practices

- Maximize use of space.
- Inspect and repair leaks.
- Monitor temperature and environmental settings for heat loss, etc.
- Evaluate building automation systems and monitoring systems, etc.
- Incorporate technology and up-to-date equipment for lights, controls, and switches.
- Implement schedules and controlled use.
- Evaluate off-grid pole lighting and similar technology.

Alternative Products, Operations, and Practices

Principles

- Educate and motivate club members.
- Educate, train, and motivate employees on energy efficiency practices pertaining to golf course operations.
- Identify incentives and programs from energy providers.
- Identify state/local programs and certification.
- Consider U.S. Green Building Council's Leadership in Energy and Environmental Design (LEED) program.
- Consider USEPA's EnergyStar and Portfolio Manager.
- Consider energy management software and services.
- Consider national and local programs and programs like the USEPA's WaterSense as it relates to buildings.

Best Management Practices

- Evaluate alternative transportation.
- Evaluate cleaning practices (dry versus wet).

- Consider local versus distant purchases and product selection.
- Evaluate energy acquisition and energy coming into the facility.
- Evaluate golf car equipment/operations and ensure proper selection, operation, charging, and maintenance.
- Incorporate training for employees.
- Incorporate the use of incentives.

Course Management Plan

Principles

- Set energy-use goals for efficiency and conservation including infrastructure, equipment, behavior, and agronomic practices.
- Ensure proper selection (type, size, etc.), operation, and equipment maintenance.
- Ensure efficient design, selection, operation, and maintenance of irrigation pumps, irrigation controls, and other irrigation components.
- Implement energy source selection, management, and efficiency and conservation practices.

Best Management Practices

- Evaluate alternative transportation.
- Work with energy providers and evaluate existing programs and resources.
- Consider long-term costs in addition to acquisitions.
- Schedule reviews to evaluate future technology and fuel types.
- Evaluate upgrades.
- Evaluate the use of alternative energy and fuels.
- Identify future energy needs.
- Prioritize energy consumption as part of selection.
- Optimize equipment use data including hours operated, use patterns, etc.
- Incorporate new technology and upgrades when feasible.
- Consider alternative equipment, products, and practices.

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