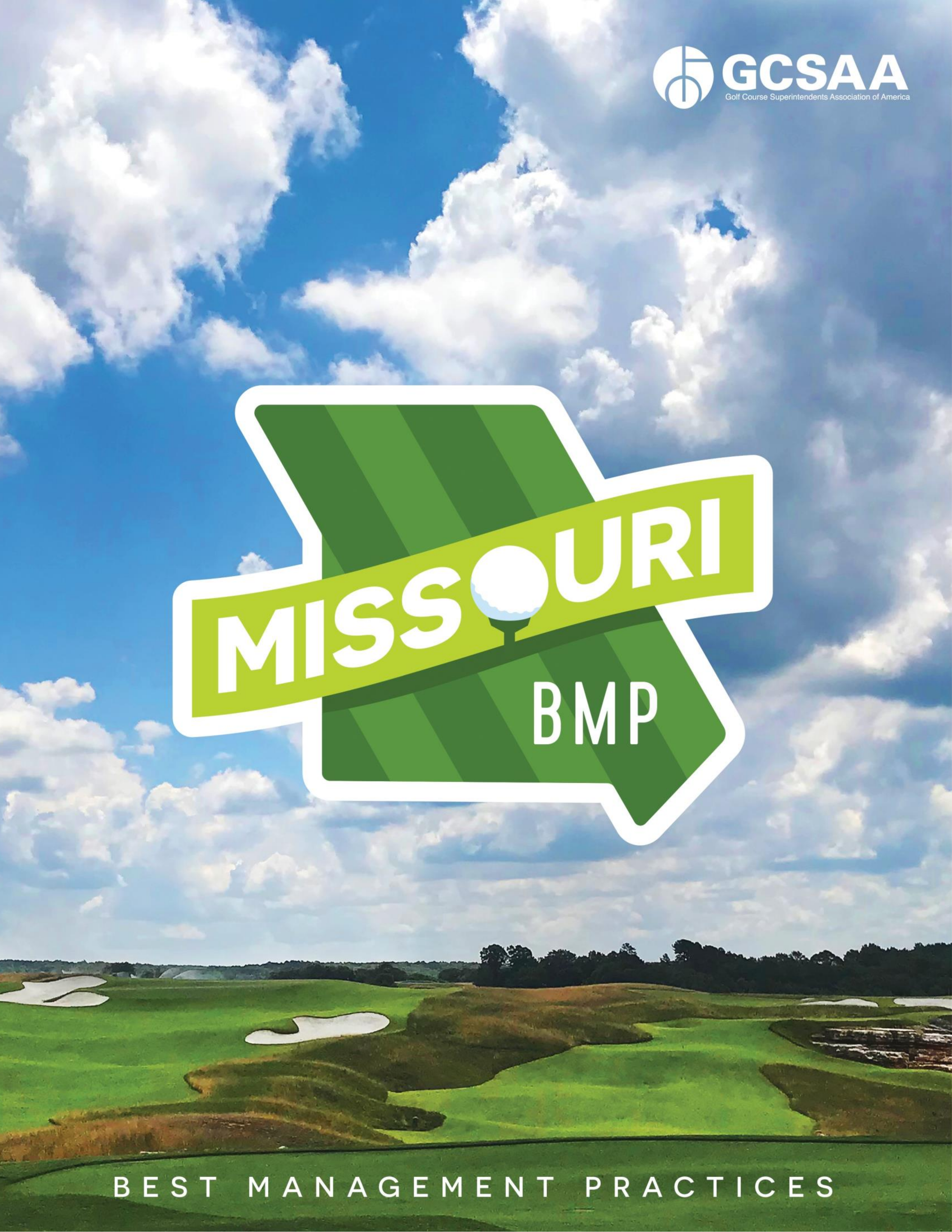

GCSAA
Golf Course Superintendents Association of America

MISSOURI BMP

BEST MANAGEMENT PRACTICES

BMP Best Management Practices

Planning Guide & Template

GCSAA USGA

In partnership with the PGA TOUR

Disclaimer: The information contained in this document is provided on an "as is" basis with no guarantees of completeness, accuracy, usefulness or timeliness and is solely at the discretion of and/or the opinion of the author. The opinions expressed in this publication are those of the authors. They do not purport to reflect the opinions or views of the GCSM, USGA, PGA TOUR.

EIFG

Funded through the Environmental Institute for Golf

Cover photo of Mountain Top Course, Big Cedar Golf in Hollister, MO. Course under the care of Todd Bohn, Director of Agronomy and Stephen Johnson, CGCS.

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ACRONYMS

ADP	Adenosine Tri-Phosphate	LEED	Leadership in Energy and Environmental Design
ATP	Adenosine Di-Phosphate	LMVP	Lakes of Missouri Volunteer Monitoring Program
B	Boron	MDC	Missouri Department of Conservation
BMAP	Basin Management Action Plan	Mg	Magnesium
BMP	Best Management Practices	Mn	Manganese
Bt	Bacillus thuringiensis	Mo	Molybdenum
C	Carbon	MU	University of Missouri
Ca	Calcium	MVGCSA	Mississippi Valley Golf Course Superintendents Association
CEC	Cation Exchange Capacity	N	Nitrogen
CGCS	Certified Golf Course Superintendent	NEMA	National Electrical Manufacturers Association
Cl	Chloride	Ni	Nickel
CMC	Chemical Mixing Center	NRCS	Natural Resources Conservation Service
Cu	Copper	O	Oxygen
CWA	Clean Water Act	OSHA	Occupational Safety and Health Administration
DCIA	Directly Connected Impervious Area	P	Phosphorus
DNA	Deoxyribonucleic Acid	PCU	Polymer/Resin-Coated Urea
DNR	Missouri Department of Natural Resources	PPE	Personal Protective Equipment
DO	Dissolved Oxygen	PPM	Parts Per Million
EC	Electrical Conductivity	QA/QC	Quality Assurance/Quality Control
EDTA	Ethylenediaminetetraacetic Acid	RCRA	Resource Conservation and Recovery Act
EIFG	Environment Institute for Golf	RNA	Ribonucleic Acid
EPA	United States Environmental Protection Agency	S	Sulfur
ESP	Exchangeable Sodium Percentage	SAR	Sodium Adsorption Ratio
ET	Evapotranspiration	SCU	Sulfur-Coated Urea
Fe	Iron	SDS	Safety Data Sheets
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act	SLAP	Statewide Lake Assessment Project
FRAC	Fungicide Resistance Action Committee	SWPPP	Stormwater Pollution Prevention Plan
GCSAA	Golf Course Superintendents Association of America	TDS	Total Dissolved Solids

GPS	Geographical Information System	TMDL	Total Maximum Daily Loading
H	Hydrogen	TVA	Tennessee Valley Authority
HAGCSA	Heart of America Golf Course Superintendents Association	UF	Urea-Formaldehyde
HRAC	Herbicide Resistance Action Committee	USDA	United States Department of Agriculture
HVAC	Heating, Ventilation, and Air Conditioning	USGA	United States Golf Association
IBDU	Isobutylidene Diurea	USGS	United States Geological Survey
IPM	Integrated Pest Management	VFD	Variable Frequency Drive
IRAC	Insecticide Resistance Action Committee	VOC	Volatile Organic Compounds
K	Potassium	WIN-PST	Windows Pesticide Screening Tool
K_{oc}	Sorption Coefficients	Zn	Zinc
LED	Light-Emitting Diode		

ACKNOWLEDGEMENTS

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 the men and women who manage golf courses 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. Founded in 1955 as the GCSAA Scholarship & Research Fund for the Golf Course Superintendents Association of America, 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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Steering committee members for this effort have included the following:

Dr. Lee Miller	Co-chair, University of Missouri
Matt Czarnecki	Co-chair, Superintendent, St. Peters Golf Club (MVGCSA representative)
Eddie Roach, CGCS	Co-chair, Grounds & Greens Superintendent, Hickory Hills Country Club (Ozark Chapter GCSAA representative)
Brent Stephenson	Co-chair, Chief Agronomist, Great Life Golf (HAGCSA representative)
Spencer Roberts, CGCS	Co-chair, Superintendent, Prairie Highlands Golf Club
Carter Demay	Superintendent, Tavern Creek Golf Course, Country Club of St. Albans
Chad Fetter	Superintendent, Bogey Hills Country Club
Dr. Rachel Owen	Owner/Consultant, Horizon Soil Solutions LLC

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- Missouri Department of Agriculture
- Missouri Department of Natural Resources
- Missouri Department of Conservation
- Golf Course Builders Association of America
- Dr. Jack Fry, Kansas State University
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- American Society of Golf Course Architects

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Introduction

Missouri's golf course superintendents are dedicated to protecting the state's natural resources. As a demonstration of this commitment, superintendents have partnered with University of Missouri scientists to develop and document best management practices (BMPs) for golf course management. These research-based, voluntary guidelines have been developed specifically for Missouri's 390 golf courses. When used alongside the state's pesticide and water quality and quantity regulations, the 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.

Golf courses, particularly in urban areas, may represent some of the largest areas of open space in metropolitan communities. Large expanses of grass allow water to infiltrate into the ground naturally instead of flowing into storm sewers or streams and rivers. Golf courses also provide additional environmental benefits to the public, such as providing habitat.

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. Because of the efforts aimed at protecting surface and groundwater quality, the majority of BMPs in this document relate to water quality. 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 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 grassed surface is easily achieved and markedly reduces the amount of nitrogen and phosphorus in clippings that end up in washwater.

Many BMPs reduce nonpoint source pollution (such as nutrients and pesticides in stormwater runoff), stormwater volume, and peak flow, and also conserve water. Through retention, infiltration, filtering, and biological and chemical actions, preventing or minimizing the effects of golf course management on surface and groundwater resources is easily achievable. In fact, several studies have shown that implementing BMPs improves water quality as it traverses golf course properties. Many BMPs also can be used to conserve our water resources and to prepare for water use restrictions that may be imposed in times of extended drought.

Pollution Prevention

BMPs reduce the potential for sedimentation, runoff, leaching, and drift -- the mechanisms that can transport these contaminants and impact water quality. For example, bare ground with exposed soil is much more likely to erode than soil supporting turf growth. Therefore, following grow- in BMPs during course construction or renovation to quickly establish dense turf ground cover helps minimize erosion potential. Maintaining vegetated areas, such as filter strips and buffers, which slow down stormwater and any 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

Water is a fundamental element for physiological processes in turf such as photosynthesis, transpiration, and cooling, as well as for the diffusion and transport of nutrients. Turf quality and performance depend on an adequate supply of water through either precipitation or supplemental irrigation. Too little water induces drought stress and weakens the plant, 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.

Pollinators

Protecting bees and other pollinators is important to the sustainability of agriculture. Minimizing the impacts of pesticides on bees and other pollinators, as well as on beneficial arthropods, is addressed in this document in two ways: promoting the use of integrated pest management (IPM) methods to reduce pesticide usage and to minimize the potential of exposure and providing specific guidance for pesticide applicators. Superintendents can also directly support healthy pollinator populations by providing and/or enhancing habitat for pollinator species and by supplying food sources and nesting sites and materials.

Conclusion

This document was developed using the latest science-based information and sources. This resource is intended to be a living document. The Missouri BMP steering committee intends to review this information annually. Therefore, the latest version of this document will be posted on the GCSAA website (gcsaa.org), the Heart of America Golf Course Superintendents Association website (hagcsa.org), the Mississippi Valley Golf Course Superintendents Association website (mvgcsa.com), and the Ozark Turf Association website (ozarkturf.org). As of the time of this publication, the information was the latest available. Some sources are updated regularly, and the reader should make an effort to identify the latest version. In addition, regulations may change and the reader should identify any changes since the publication date.

1 Planning, Design and Construction

1.1 Regulatory Considerations

Regulations are in place at the local, state, and national levels that impact planning, design, and construction activities on Missouri's golf courses. These laws are in place to minimize the environmental impact during and after course construction. Missouri golf course superintendents should consult with relevant regulatory agencies prior to beginning construction or renovation projects. Federally, the Army Corps of Engineers or Environmental Protection Agency may have jurisdiction of project impacting local surface waters. Local permitting agencies include the Missouri Department of Agriculture, Missouri Department of Natural Resources, and Missouri Department of Conservation. A stormwater pollution prevention plan (SWPPP) is required under all Missouri land disturbance general permits.

1.2 Planning Considerations

Proper planning for construction or renovation projects will minimize expenses resulting from unforeseen construction requirements. In order to prevent unforeseen requirement and permitting, project managers may consider involving golf course architects, superintendents, civil engineers, soil scientists, agronomists, irrigation designers, ecologists, etc. in the planning process.

Best Management Practices

- Assemble a qualified team.
- Determine objectives.
- Complete a feasibility study.
- Select an appropriate site.
- Identify strengths and weaknesses of selected site.
- Identify any rare, protected, endangered, or threatened plant or animal species on the site.

1.3 Design Considerations

Proper design will meet the needs of the stakeholders, protect the location's environmental resources, and be economically sustainable.

Best Management Practices

- Retain a qualified superintendent/project manager and qualified golf course architect early.
- Design course to minimize impact on native landscapes.
- Design course to retain natural vegetation as possible.
- Design out-of-play areas to retain or restore existing native vegetation where possible.
- Plant only certified turfgrass.
- Decide whether bunkers will contain drainage.
- Consider bunker entry and exit points.
- Select proper color, size, and shape of bunker sand.
- Define play and non-play maintenance boundaries.

- Greens:
    - Select location that has adequate sunlight.
    - Avoid close proximity to trees, which may limit sunlight or cause damage due to root intrusion.
    - Choose a green size that is large enough to accommodate traffic and minimize damage from play, but not so large that it is not sustainable.
    - Select an appropriate root-zone material.
    - Consider the number of bunkers (related to daily maintenance resources).
    - Greens should be irrigated separately from surrounding turf.
    - Select turf species/variety that meets needs while adhering to “right plant, right place".

1.4 Construction Considerations

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.
- Construction should maximize turfgrass establishment and site drainage.
- Use environmentally sound construction techniques.
- Use soil stabilization techniques to minimize erosion and maximize sediment containment.
- Maintain a construction progress report and communication report to proper permitting agencies.
- Use only qualified contractors who are experienced in the special requirements of golf course construction.
- Schedule construction and turf establishment to allow for the most efficient progress while optimizing environmental and resource conservation.
- Temporary construction compounds should minimize environmental impacts.

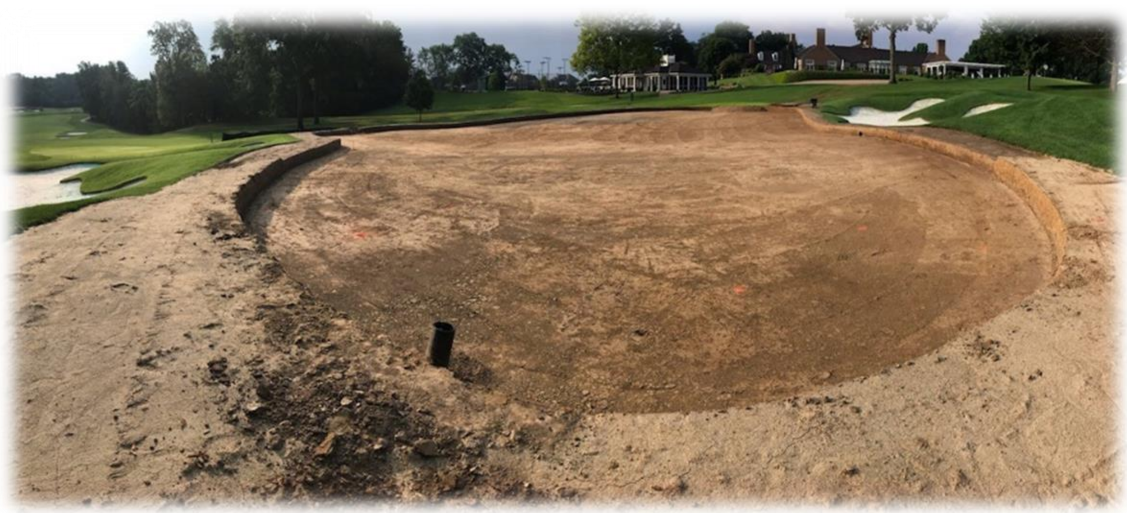

Figure 1-1. Green construction at the Bellerive Country Club (St. Louis, MO)

1.5 Grow-in

Turfgrass establishment is a unique phase in turfgrass growth, which can require greater quantities of water and nutrients than established turfgrasses. To this end, the establishment phase should be considered carefully to minimize environmental risk.

Best Management Practices

- The area to be established should be properly prepared and cleared of pests (e.g., weeds).
- Ensure erosion and sediment control devices are in place and properly maintained.
- Sprigs should be “knifed-in” and rolled to hasten root establishment.
- Sod should be top-dressed to fill in the gaps between sod pieces. This hastens establishment and provides a smoother surface.
- Use appropriate seeding methods for your conditions. When using sod, initial nutrient applications should be adjusted to encourage root growth for a quicker establishment.
- When using sprigs, application rates for nitrogen, phosphorus, and potassium should correspond to percent ground cover, but may vary by grass species.
- Slow-release nitrogen or light, frequent soluble-nitrogen sources should be used during grow-in.
- Nutrients should be applied to encourage robust establishment and decrease environmental risk.
- Mow as soon as the sod has knitted-down, when sprigs have rooted at the second to third internode, and seedlings have reached a height of one-third greater than intended height-of-cut. This will hasten establishment.

1.6 Erosion and Sediment Control

Soil carried by wind and water erosion may also transport contaminants attached to soil particles. Contaminants can be released from the soil particles, especially on entering water bodies, where they can cause pollution. Erosion and sediment control are critical components of construction and grow-in of a golf course.

Best Management Practices

- Develop a working knowledge of erosion and sediment control management specific to Missouri. See specific recommendations from Missouri Department of Natural Resources here: https://dnr.mo.gov/env/wpp/wpcp-guide/docs/chapt4.pdf
- Develop and implement strategies to effectively control sediment, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife, plant species, and designed environmental resource areas.
- Hydro-seeding or hydro-mulching offer soil stabilization.

1.7 Wetlands

Wetlands are a Classified Water of Missouri (Class W) and are defined by the *Corp of Engineers Wetlands Delineation Manual*. Class W waters does not include wetlands that are artificially created on dry land and maintained stormwater control or drainage associated with construction. Wetlands act both as filters for pollutant removal and as nurseries for many species. 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.

While wetlands do pose a special concern, their mere presence is not incompatible with the game of golf. With care, many golf holes have been threaded through sensitive areas, and with proper design and management golf can be an acceptable neighbor. When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turf areas with native vegetation or structural buffers. Constructed or disturbed wetlands may be permitted to be an integral part of the stormwater management system.

Best Management Practices

- Ensure the proper permitting has been obtained before working on any wetlands.
- Ensure that wetlands have been properly delineated before working in and around any wetlands.
- Establish wetlands where water enters lakes to slow water flow and trap sediments.
- Maintain appropriate silt fencing and BMP on projects upstream to prevent erosion and sedimentation.
- Natural waters cannot be considered treatment systems and must be protected. Natural waters do not include treatment wetlands.
- Establish a low- to no-maintenance level within a 75-foot buffer along non-tidal and tidal wetlands.
- Establish and maintain a 100-foot riparian buffer around wetlands, springs, and spring runs.

1.8 Drainage

Adequate drainage is necessary for growing healthy grass. A high-quality BMP plan for drainage addresses the containment of runoff, adequate buffer zones, and filtration techniques in the design and construction process to achieve acceptable water quality. Damaged, improperly installed, or poorly maintained drainage systems will result in inferior performance that negatively impacts play and increases water quality risks.

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 or underground aquifer, but should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- Drainage 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.

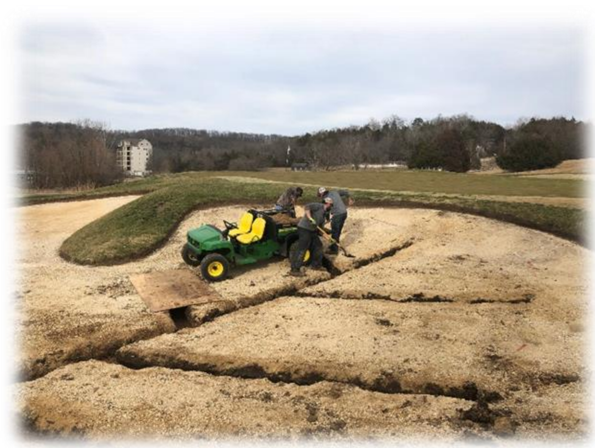

Figure 1-2. Drainage installation at Old Kinderhook Resort, Golf Club, and Spa (Camdenton, MO).

1.9 Surface Water: Stormwater, Ponds, Lakes

Stormwater is the conveying force behind nonpoint source pollution. Controlling stormwater on a golf course is more than preventing the flooding of facilities and play areas. In addition to controlling the amount and rate of water leaving the course, stormwater control also involves storing irrigation water, controlling erosion and sediment, enhancing wildlife habitat, removing waterborne pollutants, and addressing aesthetic and playability concerns. Keep in mind that not all stormwater on a golf course originates there; some may be from adjoining lands, including residential or commercial developments.

Best Management Practices

- Stormwater treatment is best accomplished by a "treatment train" approach, in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment.
- Eliminate or minimize as much directly connected impervious area (DCIA) as possible.
- Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms.
- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, 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.
- Disconnect runoff from gutters and roof drains from impervious areas, so that it flows onto permeable areas that allow the water to infiltrate near the point of generation.

1.10 Maintenance Facilities – Planning, Design, and Construction

Maintenance facilities should incorporate BMPs to minimize the potential for contamination of soil and water resources, and also minimize distractions and noise for players. The pesticide mixing and storage facility, the equipment wash pad, and the fuel center are focal points.

Best Management Practices

1.10.1 Pesticide Storage Area

- Design and build pesticide storage structures to keep pesticides secure and isolated from the surrounding environment.
- Store pesticides in a roofed concrete or metal structure with a lockable door.
- Construct floors of seamless metal or concrete sealed with a chemical-resistant paint.
- Ensure that flow from floor drains does not discharge directly to the ground and that drains are not connected to the sanitary sewer line or septic system.
- Equip the floor with a continuous curb to retain spilled materials.
- Do not store pesticides near burning materials or hot work (welding, grinding), or in shop areas.
- Provide storage for personal protective equipment (PPE) where it is easily accessible in the event of an emergency, but do not store in the pesticide storage area.
- Provide adequate space and shelving to segregate herbicides, insecticides, and fungicides.
- Use shelving made of plastic or reinforced metal. Keep metal shelving painted.
- Provide appropriate exhaust ventilation and an emergency wash area.

- Always place dry materials above liquids, never liquids above dry materials.
- Never place liquids above eye level.
- Locate operations well away from groundwater wells and areas where runoff may carry spilled pesticides into surface waterbodies.
- Do not build new facilities on potentially contaminated sites.
- An open building must have a roof with a substantial overhang (minimum 30° from vertical, 45° recommended) on all sides.
- In constructing a concrete mixing and loading pad, it is critical that the concrete have a water-to-cement ratio no higher than 0.45:1 by weight.
- The sump should be small and easily accessible for cleaning.
- Ensure that workers always use all personal protection equipment as required by the pesticide label and are provided appropriate training.
- Assess the level of training and supervision required by staff.
- Any material that collects on the pad must be applied as a pesticide according to the label or disposed of as a (potentially hazardous) waste according to state laws and regulations.
- Design pesticide storage to keep pesticides secure and isolated from the environment.
- Clean up spills immediately!

1.10.2 Fertilizer Storage Area

- Always store nitrogen-based fertilizers separately from solvents, fuels, and pesticides, since many fertilizers are oxidants and can accelerate a fire. Ideally, fertilizer should be stored in a concrete building with a metal or other type of flame-resistant roof.
- Always store fertilizers in an area that is protected from rainfall. The storage of dry bulk materials on a concrete or asphalt pad may be acceptable if the pad is adequately protected from rainfall and from water flowing across the pad.
- Sweep up any spilled fertilizer immediately.

1.10.3 Wash Pad Area

- Do not wash equipment unnecessarily.
- Clean equipment over an impervious area, and keep it swept clean.
- Brush or blow equipment with compressed air before, or instead of, washing.
- Use spring shutoff nozzles.
- If possible, install and utilize a closed-loop recycling system for wash water.
- Recycle system filters and sludge should be treated and disposed appropriately.
- Each piece of equipment should have an assigned parking area. This allows oil or other fluid leaks to be easily spotted and attributed to a specific machine so that it can be repaired.
- Use solvent-recycling machines or water-based cleaning machines to cut down on the use of flammable and/or toxic solvents.
- Use a service to remove the old solvents and dispose of them properly. A contractor can be found on the Missouri Department of Natural Resources' Licensed Hazardous and Infectious Waste Transporter List.

1.11 External Programs

Golf-centric environmental management programs or environmental management systems can help golf courses protect the environment and preserve the natural heritage of the game. Examples of external designations include Audubon International's Cooperative Sanctuary program and the Groundwater Foundation's Groundwater Guardian Green Site Program. These programs help people enhance the natural areas and wildlife habitats that golf courses provide, 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.

1.12 Wildlife Considerations

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 habitat specific to the site.
- Identify the habitat requirements (food, water, cover, space) for identified wildlife species.
- Identify species on the site that are 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 nuisance and exotic/invasive plants and replace them with native species that are adapted to a particular 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.

2 Irrigation

The supplemental use of water for course play and non-play areas is essential to supporting healthy turfgrass and landscape plant health. It is also necessary to sustain optimal course playability, aesthetics, marketability, and club membership participation.

While new technology makes many tasks easier or less labor-intensive, the principles discussed in this section are important to understand and apply. The purpose of this section is to identify best management practices related to water use that conserve and protect water resources.

Additionally, irrigation BMPs may provide economic, regulatory compliance, and environmental stewardship advantages to those who consider them part of their irrigation management plan. BMPs are not intended to increase labor or place an undue burden on the owner/ superintendent. If applied appropriately, BMPs can help stabilize labor cost, extend equipment life, and limit repair and overall personal and public liability.

The monetary investment in non-structural BMPs costs little to nothing to implement in a daily course water-use plan. Other advantages to using BMPs include: reduced administrative management stress, improved employee communication and direction, and effective facilities training procedures.

Several benefits of adopting BMPs are:

- Conserving the water supply
- Protecting existing water quality
- Maintaining optimal ball roll and playing conditions
- Minimizing electricity use
- Increasing pump and equipment life longevity
- Demonstrating responsible environmental stewardship
- Retaining knowledgeable and effective employees

2.1 Regulatory Considerations

There are no state laws, regulations, or policies that specify water use in Missouri. Missouri water rights are governed by a riparian rights law and a reasonable use law. Riparian rights dictate that the landowner of a tract of land with surface or groundwater has a right to access that water for irrigation use. Reasonable use is considered any use that does not deprive surrounding landowners from enjoying the water on their land. Any golf courses that utilize 100,000 gallons or more per day from any stream, river, lake, well, spring or other water source must complete a Major Water Use Report through the Missouri Department of Natural Resources.

2.2 Irrigation Water Suitability

2.2.1 Surface Water Sources

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 supply is not a preferred practice; therefore, municipal drinking water should be considered only when there is no alternative. Studies of water supplies are recommended for irrigation systems, as are studies of waterbodies or flows on, near, and under the property. These may be helpful to properly design a course's stormwater systems, water features, and to protect water resources.

- Use alternative water supplies/sources that are appropriate and sufficiently available to supplement water needs.
- Routinely monitor shallow groundwater table of freshwater for saltwater intrusion or contamination of heavy metals and nutrients.
- Identify appropriate water supply sources that meet seasonal and bulk water allocations for grow-in and routine maintenance needs.
- Monitor the quantity of water withdrawn to avoid aquatic life impairment.

2.2.2 Saline/Sodic Water Management

Saline and sodic water is most likely to be drawn from ground water in Missouri. According to the Missouri Geological Survey, groundwater tends to be salty in northern Missouri and along the state borders in eastern and western Missouri. Southern Missouri may not have issues with salty groundwater. When necessary, sodic water system treatment options should be included in the budget to address water quality and equipment maintenance.

- Use salt-tolerant varieties of turf and plants to mitigate saline conditions resulting from an alternative water supply or source, if necessary.
- Amend sodic water systems appropriately (with gypsum or an appropriate ion) to minimize sodium buildup in soil.
- 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.
- Monitor sodium and bicarbonate buildup in the soil using salinity sensors.
- Where practical, use reverse-osmosis filtration systems to reduce chlorides (salts) from saline groundwater.

2.2.3 Effluent Water Management

In areas where surface or groundwater resources are limited, effluent water from local sewage districts may be used to supplement irrigation; however, depending upon the degree of water treatment prior to being used for irrigation, effluent may contain bacteria and pathogens harmful to human health. Superintendents should take precautions to ensure that humans and water bodies do not come in direct contact with effluent irrigation water.

- Reclaimed, effluent, and other non-potable water supply mains should have a thorough cross-connection and backflow prevention device in place and operating correctly.
- Post signage in accordance with local utility and state requirements when reclaimed water is in use.
- Account for the nutrients in effluent (reuse/reclaimed) water when making fertilizer calculations.
- Monitor reclaimed water tests regularly for dissolved salt content.
- Use purple piping to indicate to employees and visitors that reclaimed, recycled, or effluent water is in use.

2.3 Water Conservation and Efficient Use Planning

Potable water supplies in some areas of Missouri are limited, and demand continues to grow. Our challenge is to find solutions to maintain the quality of golf while using less water. BMP and educational programs are necessary to change the public's mind-set toward the inevitable changes in water-related issues. Some courses are being designed using a "target golf" concept that minimizes the acreage of irrigated turf. Existing golf courses can try to convert out-of-play areas turf to naturally adapted native plants, grasses, or ground covers to reduce water use and augment the site's aesthetic appeal.

Best Management Practices

- Selecting drought-tolerant varieties of turfgrasses can help maintain an attractive and high-quality playing surface, while minimizing water use.
- Non-play areas may be planted with drought-resistant native or other well- adapted, noninvasive plants that provide an attractive and low maintenance landscape.
- Native plant species are important in providing wildlife with habitat and food sources. After establishment, site-appropriate plants normally require little to no irrigation.
- 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.
- If properly designed, rain and runoff captured in water hazards and stormwater ponds may provide supplemental water under normal conditions, though backup sources may be needed during severe drought.
- During a drought, closely monitor soil moisture levels. Whenever practicable, irrigate at times when the least amount of evaporative loss will occur(mornings and evenings).
- Control invasive plants or plants that use excessive water.

2.4 Irrigation System Design

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

2.4.1 Design Considerations

- Design should account for optimal distribution efficiency, distribution uniformity (> 80%) and effective root-zone moisture coverage.
- Design should allow the putting surface and surrounding slopes 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 evapotranspiration (ET) rate for the particular location.
- The application rate should not exceed the infiltration rate – the ability of the soil to absorb and retain the water applied during any one application. Saturated hydraulic conductivity tests identify infiltration rate, but in general, infiltration rates increase with increasing sand content in the soil and will be greatest on low slopes.
- The design operating pressure should not be greater than the available source pressure and should account for peak-use times and supply line pressures at 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.
- Turf and landscape areas should be zoned separately. Specific use areas zoned separately; greens, tees, primary roughs, secondary roughs, fairways, native, trees, shrubs, etc.
- Design should account for the need to leach out salt buildup from poor-quality water sources by providing access to freshwater.

2.4.2 Construction Considerations

- Only qualified specialists should install the irrigation system.
- Construction must be consistent with the design.
- The designer should 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.

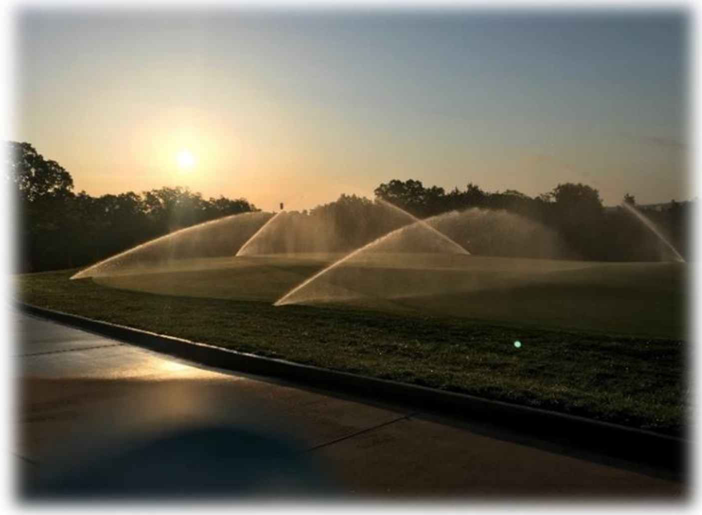

Figure 2-1. Sprinkler irrigators distributed across the fairway at the Branson Hills Golf Club (Branson, MO).

2.4.3 Distribution and Coverage

- 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 should have the same precipitation rate.
- Heads for turf areas should be spaced for head-to-head coverage.

2.4.4 Water Pressure

- Water supply systems (for example, wells, and pipelines) should be designed for varying control devices, rain shutoff devices, and backflow prevention.
- Water conveyance systems should be designed with thrust blocks and air- release valves.
- Flow velocity should 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 should be used where the system pressure exceeds the manufacturer's recommendations.

2.4.5 Special Valves and Heads

- Equipment with check valves should be used in low areas to prevent low head drainage.
- Isolation valves should be installed 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.
- Part-circle heads should be installed along lakes, ponds, and wetlands margins to conserve water.
- Use part-circle or adjustable heads to avoid 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.

2.5 Irrigation Pumping System

Pump stations should be sized to provide adequate flow and pressure. They should be equipped with control systems that protect distribution piping, provide for emergency shutdown necessitated by line breaks, and allow maximum system scheduling flexibility. Variable frequency drive (VFD) pumping systems should be considered if dramatically variable flow rates are required, if electrical transients (such spikes and surges) are infrequent, and if the superintendent has access to qualified technical support. Pumping systems should be designed to maximize energy conservation.

Best Management Practices

- The design operating pressure should not be greater than the available source pressure.
- The design operating pressure should account for peak-use times and supply- line pressures at final buildout for the entire system.
- Maintain the air-relief and vacuum-breaker valves by using hydraulic pressure- sustaining values.
- When possible, install VFD systems to lengthen the life of older pipes and fittings until the golf course can afford a new irrigation system.
- Install high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- Pumps should be sized to provide adequate flow and pressure.
- Pumps should be equipped with control systems to protect distribution piping.
- System checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers should follow the manufacturer's recommendations.
- 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.

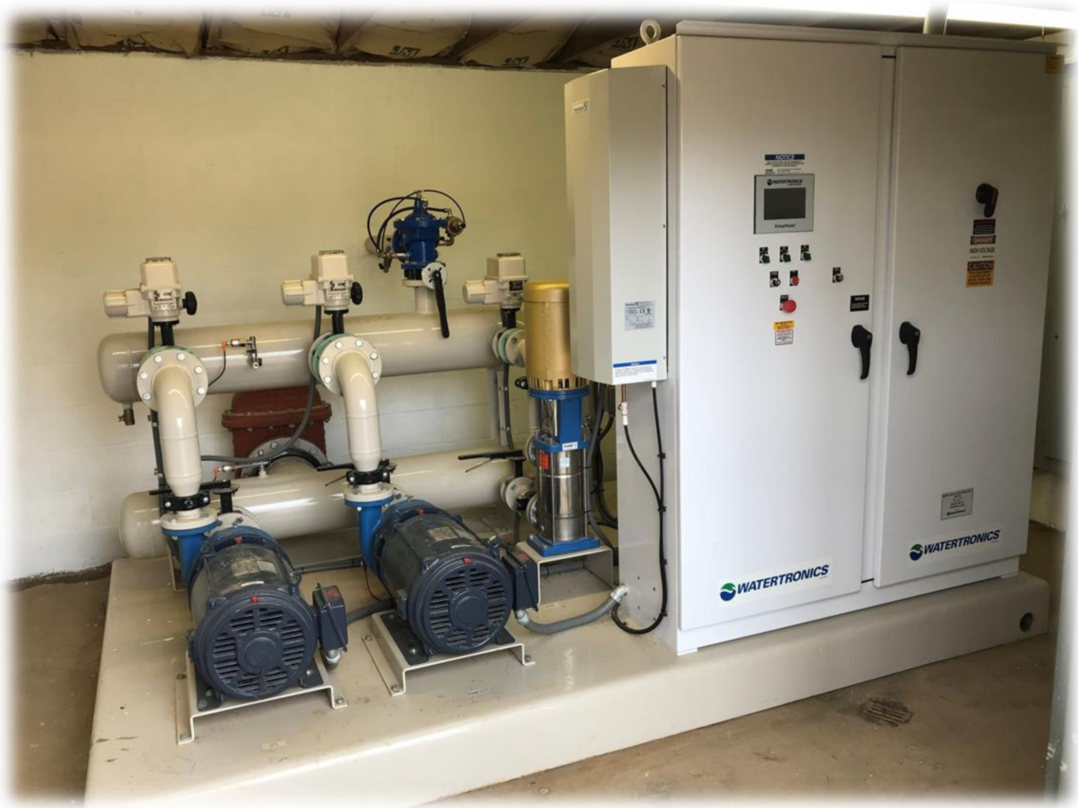

Figure 2-2. Gravity fed horizontal end suction pump system with VFD control panel at Bogey Hills Country Club (St. Charles, MO).

2.6 Irrigation System Program, Scheduling, and Metering

Responsible irrigation management conserves water and reduces nutrient and pesticide movement. Irrigation scheduling should intentionally 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 evapotranspiration (ET) rates, recent rainfall, recent temperature extremes and soil moisture. Irrigation should not occur on a calendar-based schedule, but should be based on ET rates and soil moisture replacement.

An irrigation system should be operated based only on the moisture needs of the turfgrass, or to water-in a fertilizer or chemical application as directed by the label. Time-clock-controlled irrigation systems preceded computer-controlled systems, and many are still in use today. Electric/mechanical time clocks cannot automatically adjust for changing ET rates. Frequent adjustment is necessary to compensate for the needs of individual turfgrass areas.

The proper use of rain gauges, rain shut-off devices, flow meters, soil moisture sensors, and/or other irrigation management devices should be incorporated into the site’s irrigation schedule. 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 will help determine how well the irrigation system and irrigation schedule are working.

2.6.1 System Programming

- Clock-control station timing systems should be calibrated seasonally.
- An irrigation system should have rain sensors to shut off the system after 0.25 to 0.5 inch of rain is received. Computerized systems allow a superintendent to call in and cancel the program if it is determined that the course has received adequate rainfall.
- Install control devices to allow for maximum system scheduling flexibility.
- Avoid use of a global setting; adjust watering times per head.
- Base water times on actual site conditions for each head and zone.
- Adjust irrigation run times based on current local meteorological data.
- Use computed daily ET rate to adjust run times to meet the turf's moisture needs.
- Manually adjust automated ET data to reflect wet and dry areas on the course.

2.6.2 Scheduling

- Generally, granular fertilizer applications should receive 0.25 inch of irrigation to move the particles off the leaves while minimizing runoff.
- Irrigation should ideally occur in the early morning hours before air temperatures rise and relative humidity drops, but may also be supplemented in the evenings.
- 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.
- Use soil moisture sensors to assist in scheduling or to create on-demand irrigation schedules.
- Install soil moisture sensors at a representative location within the root zone for each irrigation zone to enhance scheduled timer-based run times. Install a soil moisture sensor in the driest irrigation zone of the irrigation system.
- Wired soil moisture systems should be installed to prevent damage from aerification.
- Periodically perform catch-can uniformity tests.
- Reducing dry spots and soil compaction improves water infiltration, which in turn reduces water use and runoff in other areas.
- Install emergency shutdown devices to address line breaks.

2.6.3 Metering

- Calibrate equipment periodically to compensate for wear in pumps, nozzles, and metering systems.
- Properly calibrated flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods should be used to manage irrigation.
- Flow meters should have a run of pipe that is straight enough — both downstream and upstream — to prevent turbulence and bad readings.
- Flow meters can be used to determine how much water is applied.

2.7 Turf Drought Response

The presence of visual symptoms of drought stress is a simple way to determine when irrigation is needed on most play areas; however, managers of golf greens cannot afford to wait until symptoms occur, because unacceptable turf quality may result. Local water districts may also impose restrictions during times of drought. 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.
- Use soil moisture meters to determine moisture thresholds and plant needs.
- For fairways and roughs, use infrequent, deep irrigation to supply sufficient water for plants and to encourage deep rooting.
- Proper cultural practices such as mowing height, irrigation frequency, and irrigation amounts should be employed to promote healthy, deep root development and reduce irrigation requirements.
- Create a drought management plan for the facility that identifies steps to be taken to reduce irrigation/water use and protects critical areas, etc.

2.8 System Maintenance

Course owners/superintendents do routine maintenance to ensure water quality and responsible use of the water supply. System checks and routine maintenance include: pumps, valves, programs, fittings, and sprinklers. 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.

Best Management Practices

- Irrigation audits should be performed by trained technicians.
- A visual inspection should first be conducted to identify necessary repairs or corrective actions.
- 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 run to determine the uniformity of coverage and to accurately determine irrigation run times.
- Catch-can testing should be conducted on the entire golf course to ensure that the system is operating at its highest efficiency.
- Conduct an irrigation audit annually to facilitate a high-quality maintenance and scheduling program for the irrigation system.
- Inspect for interference with water distribution and 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 turf quality and plant health for indications of irrigation malfunction or needs for scheduling adjustments.
- Schedule documentation; make adjustments and repairs on items diagnosed during the visual inspection before conducting pressure and flow procedures.

2.8.1 Preventive Maintenance

- In older systems, inspect irrigation pipe and look for fitting breaks caused by surges.
- Install thrust blocks to support conveyances.
- The system should be inspected daily for proper operation by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads. 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.
- Maintain air-relief and vacuum-breaker valves.
- Systems need to be observed in operation at least weekly to detect controller or communication failures, stuck or misaligned heads, and clogged or broken nozzles.
- Check filter operations frequently; 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.
- Application/distribution efficiencies should be checked annually.
- Conduct a periodic professional irrigation audit at least once every five years.
- Document equipment run-time hours. Ensure that all lubrication, overhauls, and other preventive maintenance are completed according to the manufacturer's schedule.
- Monitor the power consumption of pump stations for problems with the pump motors, control valves, or distribution system.
- Qualified pump personnel should perform quarterly checks of amperage to accurately identify increased power usage that indicates 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.
- Document and periodically review the condition of infrastructure (such as pipes, wires, and fittings). If the system requires frequent repairs, it is necessary to determine why these failures are occurring.
- Increase frequency of routine inspection/calibration of soil moisture sensors that may be operating in high-salinity soils.
- Winterize irrigation system to prevent damage.

2.8.2 Corrective Maintenance

- Replace or repair all broken or worn components before the next scheduled irrigation.
- Replacement parts should have the same characteristics as the original components.
- Record keeping is an essential practice; document all corrective actions.

2.8.3 System Renovation

- Appropriate golf course renovations can improve system efficiencies, conserve water, improve playability, and lower operating costs.
- 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.

2.9 Irrigation Leak Detection

Irrigation systems are complex systems that should be closely monitored to ensure leaks are quickly detected and corrected. Golf courses without hydraulic pressure- sustaining valves are much more prone to irrigation pipe and fitting breaks because of surges in the system, creating more downtime for older systems. A good preventive maintenance program is very important.

Best Management Practices

- Monitor water meters or other measuring devices for unusually high or low readings to detect possible leaks or other problems in the system. Make any needed repairs.
- An irrigation system should also have high- and low- pressure sensors that shut down the system in case of breaks and malfunctions.
- The system should be monitored daily for malfunctions and breaks. It is also a good practice to log the amount of water pumped each day.
- Document and periodically review the condition of infrastructure (such as pipes, wires, and fittings). If the system requires frequent repairs, determine why these failures are occurring. Pipe failures may be caused not only by material failure, but also by problems with the pump station.
- Ensure that control systems provide for emergency shutdowns caused by line breaks, and allow maximum system scheduling flexibility.

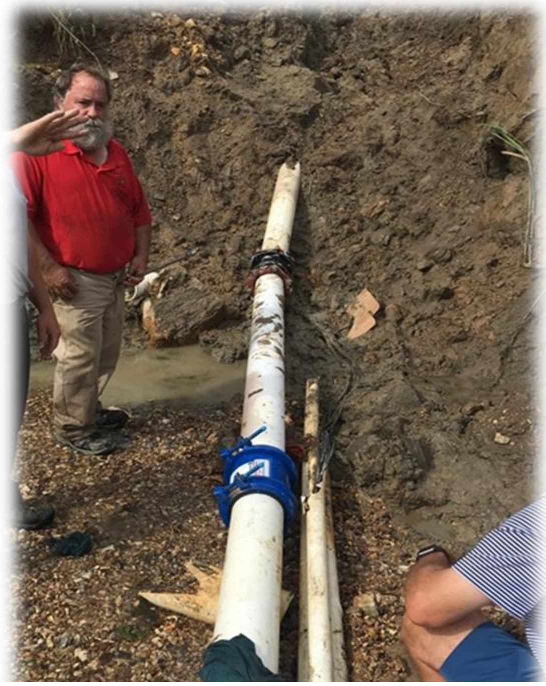

Figure 2-3. Fixing a leaking irrigation pipe at Tavern Creek Golf Course (St. Albans, MO).

2.10 Winterization and Spring Startup

Winterization of the irrigation system is important to protect the system and reduce equipment failures resulting from freezing.

Best Management Practices

- Perform pump and engine servicing/repair before winterizing.
- 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 with compressed air or open drain plugs at the lowest point on the system.
- Clean filters, screens, and housing; remove drain plug and empty water out of the system.
- Secure systems and close and lock covers/compartment doors to protect the system from potential acts of vandalism and from animals seeking refuge.
- Remove drain plug and drain above-ground pump casings.
- Record metering data before closing the system.
- Secure or lock irrigation components and electrical boxes.
- Recharge irrigation in the spring with water and inspect for corrective maintenance issues.

Figure 2-4. Irrigation system winterization at Tavern Creek Country Club (St. Albans, MO).

2.10 Non-Play and Landscape Areas

Map any environmentally sensitive areas such as sinkholes, wetlands, or flood-prone areas, and identify species classified as endangered or threatened by federal and state governments, and state species of special concern. Native or low-maintenance vegetation should be retained and enhanced for non-play areas to conserve water. The most efficient and effective watering method for non-turf landscapes is micro-irrigation. Older golf courses may have more irrigated and maintained acres than are 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 natural 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 problems related to emitter clogging, filter defects, and overall system functionality.

2.11 Wellhead Protection

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 the Missouri Department of Natural Resources. When installing new wells, contact the 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 may be needed 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 how deep the well is; 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 buffer distances on the pesticide label when applying pesticide near any water source.
- Avoid applying a fertilizer or pesticide next to a wellhead.
- Avoid mixing and loading pesticides next to a wellhead if not on a pesticide mix/load pad.

3 Surface Water Management

Although golf courses are typically large properties, they are just one link in a stormwater management chain. Generally, a quantity of stormwater enters the golf course area, supplemented by what falls on the golf course property, and then the stormwater leaves the golf course. Therefore, golf courses are realistically capable of having only a small impact on major stormwater flow. That impact should be to add only small increments of water over a given period of time. Engineers call this function "detention."

When golf courses are designed and built, their drainage capability concept is guided by an average rainfall event of a given frequency. For example, typically, a golf course drainage system is 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. This ability to detain large amounts of water requires accurate engineering and extensive construction to prevent physical or financial damage to the facility.

Best Management Practices are intended to prolong the detention 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.

3.1 Regulatory Considerations

Course owners and superintendents should investigate regulatory requirements that apply to the golf facility to protect surface water quality. The U.S. Environmental Protection Agency (EPA) regulates surface waters through the Clean Water Act (CWA) with the goal "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters". Within Missouri, the Department of Natural Resources (DNR) is the leading regulatory agency tasked with protecting surface and ground water quality. Municipalities may also have policies associated with surface and groundwater monitoring. While monitoring is often not a required practice, Missouri golf course owners and superintendents should investigate regulatory requirements that may exist in their location to protect surface and groundwater quality.

Aquatic plant management may require the use of chemical or biological controls that are regulated by Missouri state agencies. Aquatic herbicides are regulated by the Missouri Department of Agriculture Pesticide Control Board. Only registered herbicides may be used. The Missouri Department of Conservation has issued guidance for using grass carp as a biological control. More information about effective aquatic plant management can be found at *Managing Ponds and Lakes for Aquaculture and Fisheries in Missouri: Controlling Nuisance Aquatic Vegetation* by University of Missouri Extension.

Permitting requirements for surface water feature construction are included in Section 1: Planning, Design, and Construction. The Missouri DNR provides guidance for meeting Missouri's stormwater regulations at https://dnr.mo.gov/env/wpp/stormwater/. Surface waters may be subject to CWA monitoring if they fall into the definition of an impaired water body (303(d) List) or if they are in the watershed of an impaired water body. Superintendents should be aware of point-source and non-point source pollution that may enter or leave their property and be prepared to monitor total maximum daily loading (TMDL) or create a watershed basin management action plan (BMAP) if waters become impaired.

Natural wetlands may be an integral component of a stormwater management system within a golf course. Keep in mind that wetlands are protected areas and cannot be altered without consult with the U.S. EPA and Missouri DNR. In order to fill or dredge a wetland, 401 certification approval must be granted from the DNR Water Protection Program. Constructed wetlands should have an impervious bottom to prevent groundwater contamination.

3.2 Stormwater Capture

Stormwater is the conveying force behind what is called nonpoint source pollution. Nonpoint pollution, which is both natural and caused by humans, comes not from a pipe from a factory or sewage treatment plant, but from daily activity. Pollutants commonly found in stormwater include the microscopic wear products of brake linings and tires; oil; shingle particles washed off roofs; soap, dirt, and worn paint particles from car washing; leaves and grass clippings; pet and wildlife wastes; lawn, commercial, and agricultural fertilizers; and pesticides.

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 drought conditions. Capture systems should be considered part of the overall treatment. 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.

The control of stormwater on a golf course is more than just preventing the flooding of the clubhouse, maintenance, and play areas. In addition to controlling the amount and rate of water leaving the course, it involves storing irrigation water, controlling erosion and sediment, enhancing wildlife habitat, removing waterborne pollutants, and addressing aesthetic and playability concerns.

Best Management Practices

- Install berms and swells to capture pollutants and sediments from runoff before it enters the irrigation storage pond.
- Monitor pond water level for water loss (seepage) to underground systems. If seepage is occurring, it may be necessary to line or seal the pond 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, such as access to rural or city water lines, may need to be incorporated into the management plan.
- Inspect irrigation pumps, filtration systems, conveyances and control devices to prevent/correct system issues.

3.3 Water Quality Monitoring

Every golf course should have a plan to monitor the state of the environment and the effects the golf course may be having on the environment. Monitoring is used to determine whether outside events are changing the water quality entering the golf course, or whether the golf course is having a positive, neutral, or negative effect on water quality. It also provides a body of evidence on the golf course's environmental impact. A water-quality monitoring plan should be prepared to ensure the ongoing protection of groundwater and surface-water quality after construction has been completed. The same sites should be monitored during the preconstruction phase, although the monitoring plan can be modified based on site-specific conditions.

Sampling parameters are determined based on golf course operation and basin-specific parameters of concern (these may be identified by local/state TMDL Programs). Typically, samples should be analyzed for nutrients, pH and alkalinity, sediments, and suspended solids, dissolved oxygen (DO), heavy metals, and any pesticides expected to be used on the golf course. Ongoing, routine water sampling provides meaningful trends over time. A single sample is rarely meaningful in isolation. Post-construction sampling of surface-water quality should begin with the installation and maintenance of golf course turf and landscaping. Samples should be collected a minimum of three times per year. If there is no discharge on the scheduled sample date, samples should be taken during the next discharge event.

Post-construction surface-water quality sampling should continue through the first three years of operation and during the wet and dry seasons every third year thereafter, provided that all required water quality monitoring has been completed and the development continues to implement all current management plans. It may also be wise to sample if a significant change has been made in course operation or design that could affect nearby water quality. Sampling parameters should be determined based on golf course operation and any basin-specific parameters of concern (identified by the TMDL program or local regulators).

The purpose of quality assurance/quality control (QA/QC) is to ensure that chemical, physical, biological, microbiological, and toxicological data are appropriate and reliable. Data should be collected and analyzed using scientifically sound procedures. However, even if the data are only for proprietary use and are not reported to any regulatory agency, it is strongly recommended that a certified laboratory be used and all QA/QC procedures followed. Golf course management must have good data to make good decisions. If a golf course should ever want to produce data for an agency or go to court to defend the facility from unwarranted charges, those data must meet QA/QC standards to be defensible as evidence.

Best Management Practices

- Establish DO thresholds to prevent fish kills (occur at levels of 2 ppm), for example, use artificial aeration (diffusers).
- Reduce stress on fish; keep DO levels above 3 ppm.
- Select algaecides containing hydrogen peroxide instead of copper or endothall to treat high populations of phytoplankton.
- Use IPM principles to limit excess use of pesticides.
- Spot-treat filamentous algae or frequently remove algae by hand to prevent lowering oxygen concentrations in water.
- Use dyes and aeration to maintain appropriate light and DO levels.
- Apply algaecides to small areas to prevent fish mortality; do not treat the entire pond at once.
- Coordinate construction/renovation activities to minimize the amount of disturbed area and possible risk of contamination via runoff.
- Plan construction/renovation activities in phases to limit soil disruption and movement.
- Sod, spring, or reseed bare or thinning turf areas.
- Mulch areas under tree canopies to cover bare soil.
- Avoid the use of trimmers along the edge of the water body.
- Mow lake and pond collars at a higher height to slow and filter overland flow to waterbodies.
- Remove excess sediments to reduce irrigation system failures.

- Treat dredged materials as a toxic substance. Avoid contact with turf.
- Locate littoral shelves at the pond's inlets and outlets to reduce problems with the playability and maintainability of a water hazard.
- Seek professional assistance from an environmental specialist to design an appropriate water sample collection strategy.
- Determine which sites will be analyzed, and use reputable equipment and qualified technicians.
- Demonstrate responsible land and water use practices based on water data.
- Define data values appropriately based on the associated BMP used to protect water quality.
- Record observations of fish, wildlife, and general pond conditions.

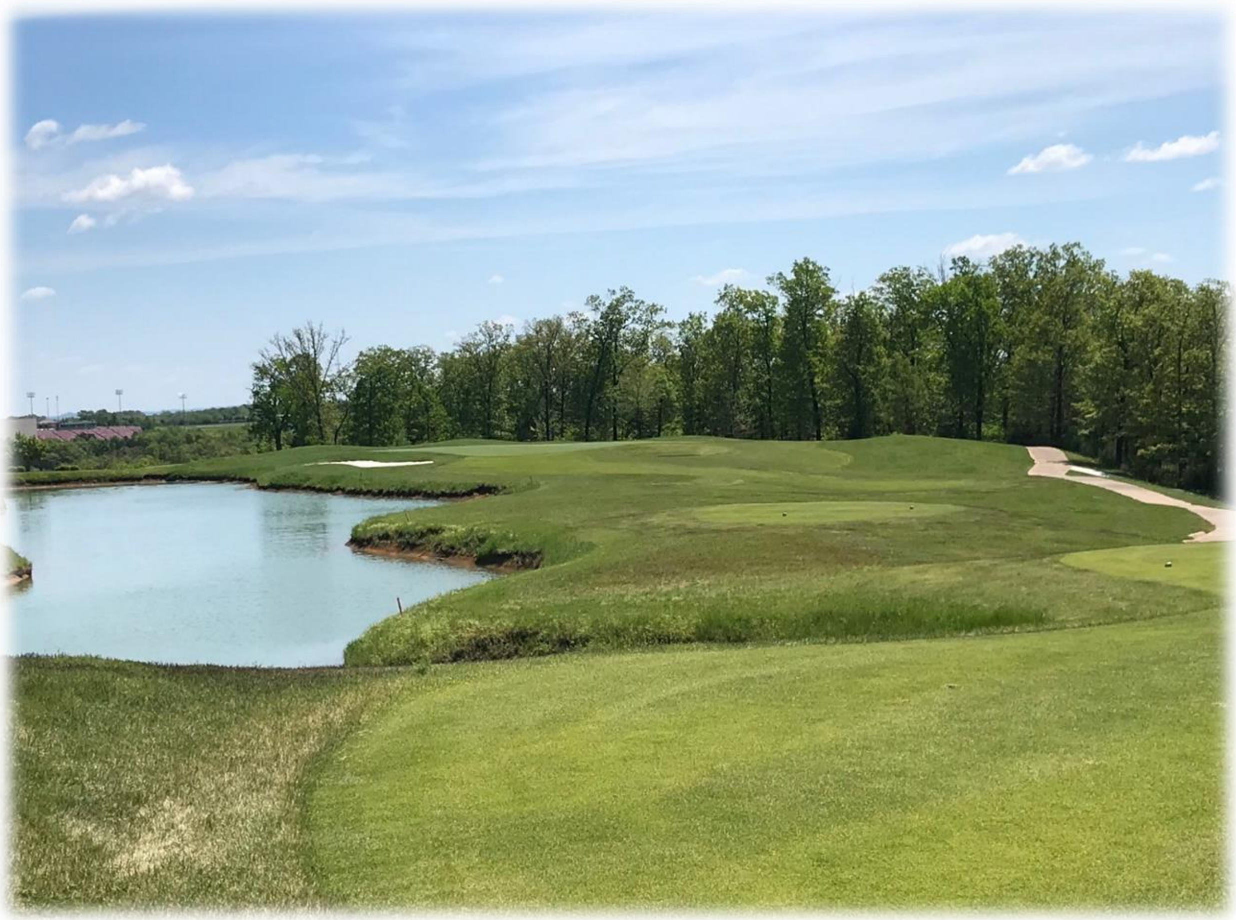

Figure 3-1. Grass buffer with a taller mow height surrounding a pond at the Branson Hills Golf Club (Branson, MO).

3.4 Aquatic Plants

3.4.1 Aquatic Plant Strategy

An aquatic plant management strategy should address the intended uses of the waterbody to maintain water quality. Proper documentation of the site's physical attributes and location, the presence of invasive or weedy species, aesthetics, watershed and groundwater assessments, and other environmental considerations.

Phytoplankton, which give water its green appearance, 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 (immersed 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). Different types of aquatic macrophytes have different functions in ponds. Plant life growing on littoral shelves may help to protect receiving waters from the pollutants present in surface water runoff, and a littoral shelf is often required in permitted surface water-retention ponds. Floating plants suppress phytoplankton because they absorb nutrients from the pond water and create shade.

The use of aquatic plants to improve the appearance of a pond (aquascaping) can be included as part of the overall landscape design. Ponds may be constructed on golf courses strictly as water hazards or for landscape purposes, but they often have the primary purpose of drainage and stormwater management, and are also often a source of irrigation water.

Best Management Practices

- Accommodate natural lake processes in the construction of lakes and ponds; include herbaceous and woody vegetation and emergent and submergent shoreline plants to reduce operational costs.
- Irrigation should not directly strike or run off to waterbodies, and no fertilization buffers should be maintained along water edges.
- Outline goals and priorities to guide the development of the BMP necessary to support the lake/aquatic management plan.
- Identify position of property in relation to its watershed.
- Identify overall goals and validate concerns of the local watershed.
- Identify surface water and flow patterns.
- Indicate stormwater flow as well as existing and potential holding capacity.
- Indicate impervious surfaces, such as buildings, parking lots, or pathways.
- Indicate major drainages and catch basins that connect to local surface water bodies.
- Identify and understand depth to water tables and soil types.
- Locate and protect wellheads.
- Properly designed ponds with a narrow fringe of vegetation along the edge are more resistant to problems than those with highly maintained turf.
- In ponds with littoral plantings, problem plants should be selectively controlled without damaging littoral shelves.
- Encourage clumps of native emergent vegetation at the shoreline.

3.4.2 Aquatic Plant Control

The use of pesticides should be part of an overall pest management strategy that includes biological controls, cultural methods, pest monitoring, and other applicable practices, referred to altogether as integrated pest management (IPM). Address areas where standing water may provide habitat for nuisance organisms. Only licensed individuals or contractors should be allowed to select and apply aquatic pesticides.

Best Management Practices

- Use IPM principles to address insects that may pose a hazard to human health.
- A comprehensive lake management plan should include strategies to control the growth of nuisance vegetation that can negatively affect a pond's water quality and treatment capacity.
- Drain areas of standing water during wet seasons to reduce insect populations.
- Use Bacillus thuringiensis (Bt) products according to label directions to manage waterborne insect larvae.
- Apply appropriate herbicides to minimize damage to non-target littoral plantings.
- Maintain a narrow band of open water at the pond edge to control the expansion of plants into more desirable littoral plantings.
- Use appropriate aquatic herbicides to prevent turfgrass injury and to protect water quality and wildlife habitat.
- Superintendents should monitor designated waters in their area for the persistence of toxic herbicides and algaecides in the environment.
- Secondary environmental effects on surface water and groundwater from the chemical control of vegetation should be monitored and recorded.
- Apply fertilizer and reclaimed (reuse) irrigation/fertigation appropriately to avoid surface water and groundwater contamination.
- Apply copper products per label instructions to reduce the risk of impairing water quality and causing negative biological impacts.
- Frequently remove filamentous algae by hand and/or frequently apply algaecide to small areas of algae (spot treatment).
- To reduce the risk of oxygen depletion, use an algaecide containing hydrogen peroxide instead of one with copper or endothall.

3.5 Stormwater, Ponds, and Lakes

Most golf courses plan their lakes and water hazards to be a part of the stormwater control and treatment system. However, natural waters of the state cannot be considered treatment systems and must be protected. Lakes and ponds may also be used as a source of irrigation water. It is important to consider these functions when designing and constructing the ponds. Peninsular projections and long, narrow fingers may prevent mixing. Ponds that are too shallow may reach high temperatures, leading to low oxygen levels and promoting algal growth and excess sedimentation. Stormwater treatment is best accomplished by a treatment train approach, in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment. Source controls are the first car on the BMP treatment train. They help to prevent the generation of stormwater or introduction of pollutants into stormwater. The most effective method of stormwater treatment is not to generate stormwater in the first place, or to remove it as it is generated.

Best Management Practices

- Install swales and slight berms where appropriate around the water's edge, along with buffer strips, to reduce water flow and maintain distance between the water and cultural practices on turf areas.
- Design stormwater treatment trains to 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.

- Ensure that no discharges from pipes go directly to water.
- Eliminate or minimize directly connected impervious areas.
- Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms.
- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, 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.
- Disconnect runoff from gutters and roof drains from impervious areas, so that it flows onto permeable areas that allow the water to infiltrate near the point of generation.
- Golf course stormwater management should include “natural systems engineering” or “soft engineering” approaches that maximize the use of natural systems to treat water.
- Ensure that no discharges from pipes go directly to water.
- Use a treatment train approach.
- Institute buffers and special management zones.

3.6 Floodplain Restoration

Reestablishment of natural water systems helps mitigate flooding and control stormwater. Address high sediment and nutrient loads and vertical and lateral stream migration causing unstable banks, flooding, and reductions in groundwater recharge. 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.
- Install detention basins to store water and reduce flooding at peak flows.

4 Groundwater Protection

Missouri contains abundant groundwater resources throughout the state, with slightly less groundwater resources north of the Missouri River in northern Missouri compared to southern Missouri. Much of the groundwater is replenished by local rainfall. Missouri's groundwater resources are not at risk of being depleted, but they may become locally depleted when municipalities pull large amounts of water in one place. Over 90% of the state's public water supply is derived from groundwater. For more information on Missouri's groundwater resources, visit https://dnr.mo.gov/education/water/ground- water.htm.

4.1 Regulatory Considerations

The Missouri Department of Natural Resources (DNR) and U.S. Geological Survey (USGS) are charged with monitoring and protecting groundwater resources. Missouri is a riparian water law state, and all landowners touching or lying above water sources have a right to a reasonable use of those water resources. There are no regulations specifying the quantity of water that can be drawn from groundwater sources as long as nearby landowners or users are not adversely impacted.

The Missouri DNR requires permitting for new well construction to ensure that groundwater is not contaminated from the surface. Wells should be installed by certified well drillers, according to the Water Well Drillers' Act. Landowners who drill their own well and/or install their own pump are exempt from permit requirements, but must adhere to all other sections of the rules.

4.2 Preventing Leaching

Leaching refers to the process of soluble compounds being transferred from the surface into groundwater. Compounds that more readily dissolve in water have a higher leaching potential than non-soluble compounds. Fertilizer and pesticide labels typically provide information regarding leaching potential.

The Missouri Department of Health recommends that groundwater be tested every three years for contaminants, particularly if the well water is being used for drinking water. Microorganisms, nitrates, and heavy metals are common contaminants found in groundwater.

Best Management Practices

- Identify areas on the course that may be prone to leaching (shallow depth to groundwater, sandy soils, etc.).
- Manage irrigation to avoid over-watering.
- Consider the leaching potential of fertilizers or pesticides before applying.

4.3 Protecting Water Supplies

The areas surrounding groundwater wells should be protected in order to prevent contamination. Fertilizers, pesticides, or other chemicals should not be stored near wellheads. The Missouri DNR specifies minimum set-backs for surface features that may contaminate groundwater. Landfills, wastewater treatment plants, fertilizer storage, and above and below ground storage tanks, among others must be 300 ft. away from groundwater wells; pressurized sewer lines, animal feeding operations, and dry litter storage must be 100 ft. away from groundwater wells; and wells must be set back 50 ft. from existing wells or septic tanks. Wells may not be built within 1000 ft. of solid waste disposal areas.

Best Management Practices

- Use backflow-prevention devices at the wellhead, on hoses, and at the pesticide mix/load station to prevent contamination of water sources.
- Follow pesticide labels for setback distance requirements (typically a minimum of 50 feet).
- Properly decommission illegal, 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 routinely for leaks or cracks; make repairs as needed.
- Maintain records of new well construction and modification 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.
- Develop a written Wellhead Protection Plan that minimizes environmental risk and potential contamination.

5 Water Quality Monitoring

5.1 Regulatory Considerations

The U.S. Environmental Protection Agency (EPA) regulates surface waters through the Clean Water Act (CWA) with the goal "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters". Within Missouri, the Department of Natural Resources is the leading regulatory agency tasked with protecting surface and ground water quality. Municipalities may also have policies associated with surface and groundwater monitoring. While monitoring is often not a required practice, Missouri golf course owners and superintendents should investigate regulatory requirements that may exist in their location to protect surface and groundwater quality. Voluntary water quality monitoring may demonstrate a commitment to water quality and can alert golf course owners and superintendents to harmful issues, such as algal blooms or other toxins. The Missouri Stream Team Program coordinates a Volunteer Water Quality Monitoring Program in collaboration with the Department of Natural Resources, Department of Conservation, Conservation Federation of Missouri and Missouri citizens. The Department of Natural Resources also funds two lake monitoring programs: Statewide Lake Assessment Project (SLAP) and Lakes of Missouri Volunteer Monitoring Program (LMVP). Additionally, the Department of Natural Resources allocates resources to collecting lake monitoring samples to gain an understanding of the trophic status of small lakes (< 10 acres) that are not monitored as part of SLAP or LMVP.

5.2 Site Analysis

When selecting and evaluating a site for a potential water feature, consider the site's physical attributes and location, the invasive or weedy species present, aesthetics, watershed and groundwater assessments, and other environmental considerations.

Best Management Practices

- Accommodate natural lake processes in the construction of lakes and ponds; include herbaceous and woody vegetation and emergent and submergent shoreline plants to reduce operational costs.
- Use Integrated Pest Management (IPM) and native or naturalized vegetation wherever practical.
- Apply appropriate herbicides to minimize damage to non-target littoral plantings.
- Maintain a narrow band of open water at the pond edge to control the expansion of plants into more desirable littoral plantings.
- Use appropriate aquatic herbicides to avoid turfgrass injury.
- Avoid direct irrigation strike or runoff to waterbodies and maintain fertilization buffers along edges.
- Outline goals and priorities to guide the development of the BMP necessary to support the lake/aquatic management plan.
- Monitor designated waters in the area for the persistence of highly toxic herbicides and algaecides in the environment.
- Record secondary environmental effects on surface water and groundwater from the chemical control of vegetation.
- Apply fertilizer and reclaimed (reuse) irrigation/fertigation appropriately to avoid surface and groundwater contamination.

- Apply copper products per label instructions to reduce the risk of negative biological impacts and impairing water quality.
- Identify position of property in relation to its watershed by indicating surface water and flow patterns, stormwater flow, existing and potential holding capacity, and major drainages and catch basins that connect to local surface water bodies.
- Identify overall goals and quality concerns of the local watershed.
- Indicate impervious surfaces, such as buildings, parking lots, or pathways in the watershed.
- Identify and understand depth to water tables and soil types.
- Locate and protect wellheads.

5.3 Water Quality Sampling Program

It is beneficial for every golf course to have a plan to monitor the state of the environment and the effects the golf course may be having on the environment. Monitoring is the method used to determine whether outside events are impacting the water quality entering the golf course, or whether the golf course is having a positive, neutral, or negative effect on water quality. Monitoring also provides documentation of the golf course's environmental impact. A water quality monitoring plan that captures samples from consistent sites before and after construction ensures the ongoing protection of groundwater and surface-water quality after construction is completed.

Sampling parameters are determined based on golf course operation and basin-specific parameters of concern (these may be identified by local/state TMDL Programs, such as SLAP or LMVP). Typically, samples should be analyzed for nutrients, pH and alkalinity, sediments, suspended solids, DO, heavy metals, and any pesticides expected to be used on the golf course. Golf courses may also sample for macroinvertebrates as determined useful by water quality specialists. Ongoing, routine water sampling provides meaningful trends over time. A single sample is rarely meaningful in isolation.

Post-construction surface-water quality sampling is most effective beginning with the installation and maintenance of golf course turf and landscaping. To capture adequate water quality information, samples should be collected a minimum of three times per year. If there is no discharge on the scheduled sample date, samples can be taken during the next discharge event. It may also be wise to sample if a significant change has been made in course operation or design that could affect nearby water quality.

Best Management Practices

- Establish DO thresholds to prevent fish kills (occur at levels of 2 ppm). For example, use artificial aeration (diffusers) to prevent DO from dropping below established thresholds.
- To reduce stress on fish, keep DO levels above 3 ppm.
- Select algaecides containing hydrogen peroxide instead of one containing copper or endothall to treat high populations of phytoplankton.
- Use IPM principles to limit excess use of pesticides.
- Spot-treat filamentous algae or frequently remove algae by hand to prevent lowering oxygen concentrations in water.
- Use dyes and aeration to maintain appropriate light and DO levels.
- Apply algaecides to small areas to prevent fish mortality; do not treat the entire pond at once.
- Coordinate construction/renovation activities to minimize the amount of disturbed area and possible risk of contamination via runoff.
- Plan construction/renovation activities in phases to limit soil disruption and movement.

- Sod, sprig, or reseed bare or thinning turf areas to minimize runoff.
- Mulch areas under tree canopies to cover bare soil.
- Avoid the use of trimmers along the edge of the water body.
- Mow lake and pond collars at 2 inches or higher to slow and filter overland flow to water bodies.
- Remove excess sediments to reduce irrigation system failures.
- Treat dredged materials as a toxic substance. Avoid contact with turf.
- Locate littoral shelves at the pond's inlets and outlets to reduce problems with the playability and maintainability of a water hazard.

5.4 Sampling Parameters, Collection, and Analysis

A robust water quality monitoring program includes monitoring of surface water, groundwater, and pond sediments. It should be implemented in three phases: background, construction, and long-term management. Sampling of all watershed ingress and egress points is important to know what is coming into the property to identify potential impacts and baseline of water quality data. The purpose of QA/QC is to ensure that chemical, physical, biological, microbiological, and toxicological data are appropriate and reliable, and are collected and analyzed using scientifically sound procedures. It is strongly recommended that a certified laboratory be used even if the data are only for proprietary use and are not reported to any regulatory agency. QA/QC procedures should be followed. Data collected using proper QA/QC procedures not only allows golf course management to make informed decisions, but also protects the golf course should it be asked to produce data for an agency or in court.

Best Management Practices

- Seek professional assistance from an environmental specialist to design an appropriate water sample collection strategy.
- Determine what sites will be analyzed and use reputable equipment and qualified technicians.
- Demonstrate responsible land and water use practices based on water data.
- Define data values appropriately based on the associated BMP used to protect water quality.
- Record observations of fish, wildlife, and general pond conditions.

5.5 Buffer Zones

Buffers around the shore of a waterbody or other sensitive areas filter and purify runoff as it passes across the buffer. Additionally, buffers may trap sediments associated with runoff and minimize the need for dredging and removing sediments from the water basin. Ideally, plant buffers with native species provide a triple play of water quality benefits, pleasing aesthetics, and habitat/food sources for wildlife; however, an appropriate-sized buffer (steeper slope requires great buffer width) of turf mowed at a higher height of cut and minimally fertilized with enhanced-efficiency fertilizers can provide an effective buffer.

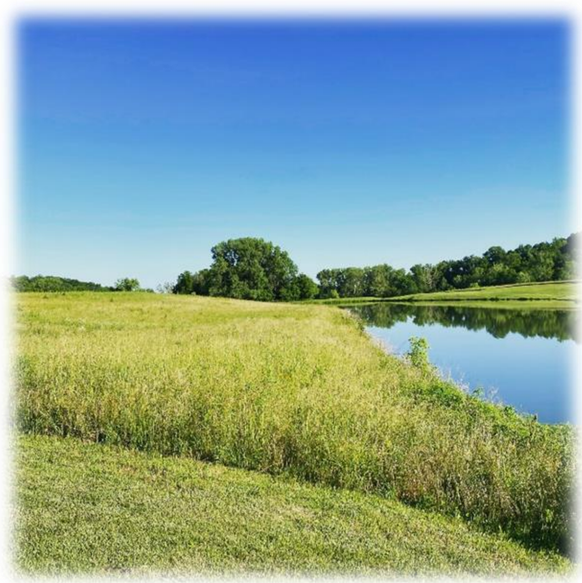

Figure 5-1. Grass buffer surrounding a pond at Railwood Golf Club (Holts Summit, MO).

As discussed above, it is important to continue these plantings into the water to provide emergent vegetation for aquatic life, even if the pond is not used for stormwater treatment. Effective BMPs in these areas include filter and trap sediment, site-specific natural/organic fertilization, and limits on pesticide use, primarily focusing on the control of invasive species. Golf course stormwater management may include “natural systems engineering” or “soft engineering” approaches that maximize the use of natural systems to treat water.

Best Management Practices

- Maintain riparian buffer areas above the high-water mark and leave unfertilized and in a natural state.
- Reduce the frequency of mowing at the lake edge and collect or direct clippings to upland areas.
- Institute buffers and special management zones.
- The placement of bunkers and the shaping of contours surrounding a green should allow proper drainage and provide for the treatment and absorption of runoff from the green.
- Use turf and native plantings to enhance buffer areas. Increase height of cut in the riparian zone to filter and buffer nutrient movement to the water.
- Use a deflector shield to prevent fertilizer and pesticide prills from contacting surface waters.
- Apply fertilizer and pesticides based on the effective swath; keep application on target and away from buffers or channel swales.
- Use a swale and berm system to allow for resident time (ponding) for water to infiltrate through the root zone to reduce lateral water movement to the surface water body.
- Ideally, littoral zones should have a slope of about 1 foot vertical to 6-10 foot horizontal. Planting on slopes steeper than a 6-foot horizontal to a 1-foot vertical may not be as successful over the long term.
- Encourage clumps of native emergent vegetation at the shoreline.
- Establish special management zones around pond edges.
- Reverse-grade around the perimeter to control surface water runoff into ponds and reduce nutrient loads.
- Construct random small dips and ridges of a few inches to a foot to promote diversity within the plant community and provide a healthier and more productive littoral zone.
- All or most of the out-of-play water bodies should have shoreline buffers planted with native or well-adapted noninvasive vegetation to provide food and shelter for wildlife.
- Nutrient rich runoff encourages algal blooms and other phytoplankton; apply appropriate fertilizer rates and application setbacks. Practice good fertilizer management to reduce the nutrient runoff into ponds that causes algae blooms and ultimately reduces DO levels.
- Manipulate water levels to prevent low levels that result in warmer temperatures and lowered DO levels.
- Aerate shallow lakes less than 6 feet in depth to maintain acceptable DO levels.
- Where applicable, aerate at night to control oxygen depletion in any pond.
- Install desirable plants to naturally buffer DO loss and fluctuation.
- Dispose of grass clippings where runoff and wind will not carry them back to the lake.
- Dredge or remove sediment to protect beneficial organisms that contribute to the lake’s food web and overall lake health.

5.6 Wetland Protection

Wetlands are a Classified Water of Missouri (Class W) and are defined by the *Corp of Engineers Wetlands Delineation Manual*. Class W waters does not include wetlands that are artificially created on dry land and maintained stormwater control or drainage associated with construction. Wetlands act both as filters for pollutant removal and as nurseries for many species. 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. While wetlands do pose a special concern, their mere presence is not incompatible with the game of golf. With care, many golf holes have been threaded through sensitive areas, and with proper design and management golf can be an acceptable neighbor. When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turf areas with native vegetation or structural buffers. Constructed or disturbed wetlands may be permitted to be an integral part of the stormwater management system.

Best Management Practices

- Establish wetlands where water enters lakes to slow water flow and trap sediments.
- Maintain appropriate silt fencing and BMP on projects upstream to prevent erosion and sedimentation.
- Natural waters cannot be considered treatment systems and must be protected. (Natural waters do not include treatment wetlands.)
- Establish a low- to no-maintenance level within a 75-foot buffer along non-tidal and tidal wetlands.
- Establish and maintain a 100-foot riparian buffer around wetlands, springs, and spring runs.

5.7 Stormwater Management

Controlling stormwater on a golf course is more than just preventing the flooding of the clubhouse, maintenance, and play areas. In addition to controlling the amount and rate of water leaving the course, stormwater involves storing irrigation water, controlling erosion and sedimentation, enhancing wildlife habitat, removing waterborne pollutants, and addressing aesthetic and playability concerns. Not all stormwater on a golf course originates there; some may be from adjoining lands, including residential or commercial developments.

Best Management Practices

- Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms.
- 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.
- Design stormwater control structures to hold stormwater for appropriate residence times in order to remove suspended solids.
- Use a stormwater treatment train to convey water from one treatment structure to another.
- Eliminate or minimize directly connected impervious areas as much as possible.
- Disconnect runoff from gutters and roof drains from impervious areas, so that it flows onto permeable areas that allow the water to infiltrate near the point of generation.

- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, 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.
- Ensure that no discharges from pipes go directly to surface or groundwater reservoirs.

5.8 Sediment

During construction and/or renovation, temporary barriers and traps can be used to prevent sediments from being washed off-site and into water bodies. Wherever possible, keep a vegetative cover on the site until it is ready for construction, and then plant, sod, or otherwise cover it as soon as possible to prevent erosion.

Best Management Practices

- Use shoreline grasses to prevent bank erosion.
- Use dry detention basins/catchments to buffer flooding and excessive runoff that may contain sediment.
- 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 water body, but should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- Maintain a vegetative cover on construction sites until construction begins.

5.9 Sodic/Saline Conditions

Natural waters contain soluble salts; however, the amount and type of salts they contain vary greatly. Irrigation water can degrade when groundwater wells are pumped at high rates or for prolonged periods. Sometimes “up-coning” can occur from pumping, whereby saline water, rather than freshwater, is drawn into the well. Saline water typically is unsuitable for irrigation because of its high content of total dissolved solids (TDS).

Best Management Practices

- Use surface water to mix (blend) affected groundwater to lower the total salt concentration.
- Routinely monitor water quality to ensure that salt concentrations are at the acceptable levels.
- Consider fertilizer that uses soluble nitrogen forms with a relatively low concentration of salts in frequent applications.
- Consider a controlled-release fertilizer to reduce salt injury.
- Identify salt additions and saline sources that contribute to the total salt concentration.
- Base management plan on routine soil tests to determine sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP), electrical conductivity (EC), and free calcium carbonate content.
- Select alternative turfgrass and landscape plants that are more salt-tolerant if irrigation water will routinely contain high salt concentrations.
- Reduce salt accumulations in the soil by flushing soils as needed with a higher- quality water source.
- Design irrigation systems to account for flushing of salt accumulation from soil.
- Amend soil and water to remove salt ions from affected areas.

6 Nutrient Management

Proper nutrient management plays a key role in the reduction of environmental risk and increases course profitability. Among other benefits, applied nutrients increase the reserve pool of available nutrients allowing 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, runoff, or denitrification, which may directly impair our environment. Other organisms also respond to increases in nutrients and, in some cases, these organisms may deleteriously alter our ecosystem. The goal of a proper nutrient management plan should be to apply the optimum necessary nutrients to achieve an acceptable playing surface and apply these nutrients in a manner that maximizes their plant utilization.

Essential plant nutrients are typically designated into mineral and non-mineral categories. Non-mineral nutrients (carbon, C; hydrogen, H; and Oxygen, O) are obtained from water and air. Mineral nutrients are commonly further broken down into macronutrients (nitrogen, N; phosphorus, P; and potassium, K), secondary macronutrients (calcium, Ca; magnesium, Mg; and sulfur, S), and micronutrients (boron, B; chloride, Cl^-; copper, Cu; iron, Fe; manganese, Mn; molybdenum, Mo; nickel, Ni; and zinc, Zn). While turf responses to applied nutrients may vary, the requirement of grasses for the aforementioned nutrients (on a mass basis) are *macronutrients* > *secondary macronutrients* > *micronutrients*.

6.1 Fertilizers Used in Golf Course Management

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

6.1.1 Terminology

- Grade or analysis is the percent by weight of Nitrogen (N), Phosphorous fertilizer (P_2O_5) and Potassium fertilizer (K_2O) that is guaranteed to be in the fertilizer.
- Fertilizer grade is expressed as N-P_2O_5-K_2O and represents a percentage of each nutrient.
- Missouri Law constitutes that available N, P_2O_5, and K_2O be clearly labelled. Any additionally marked nutrients must have a guaranteed elemental analysis in accordance with Missouri Fertilizer Law: 6 CSR 250-11.030 Labeling Additional Plant Nutrients.

6.1.2 Conversions

To calculate a desired applied rate of a nutrient (lb fertilizer / 1000 ft^2) from a fertilizer analysis (N-P_2O_5-K_2O):

$$\textit{(lb nutrient / 1000 ft}^2\textit{) / (\% nutrient in fertilizer / 100) = lb fertilizer / 1000 ft}^2$$

Soil test reports commonly report values in parts per million (ppm). To convert ppm to lb / 1000 ft^2:

$$\textit{ppm elemental nutrient x 0.023 = lb elemental nutrient / 1000 ft}^2$$

To convert elemental phosphorus and potassium to oxide form:

$$ppm\ P \times 2.2913 = ppm\ P_2O_5 \quad ppm\ K \times 1.2046 = ppm\ K_2O$$

Relevant soil test report components that may be requested:

- Soil pH, Buffer pH, Lime requirement
- Organic matter
- Macronutrients: Phosphorus, Potassium, Calcium, Magnesium, Nitrate-N & Ammonium-N
- Micronutrients: Zinc, Sulfur, Iron, Sodium, Boron
- Cation exchange capacity (CEC)
- Soluble salts
- Particle size analysis (soil texture)

6.1.3 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 in Missouri must contain:

- Brand or Trademark
- Name and address of person guaranteeing the fertilizer
- Guaranteed chemical analysis
- Net weight

6.1.4 Macronutrients

Macronutrients are required in the greatest quantities and include nitrogen (N), phosphorus (P), and potassium (K). 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.

6.1.4.1 The role of nitrogen (N)

Nitrogen is required by the plant in greater quantities than any other element except carbon (C), hydrogen (H), and oxygen (O). Nitrogen plays a role in numerous plant functions including being an essential component of amino acids and nucleic acids, chlorophyll, and plant metabolytes.

Fate and transformation of Nitrogen*:* The goal of all applied nutrients is to maximize plant uptake while minimizing nutrient losses. Understanding each process will increase your ability to make sound management decisions and ultimately leads to an increase in course profitability and a reduction in environmental risk.

Nitrogen processes

- Mineralization: the microbially-mediated conversion of organic N into plant- available ammonium (NH_4) and nitrate (NO_3)
- Nitrification: the microbial-mediated conversion of NH_4 to NO_3
- Denitrification: the microbial mediated conversion of NO_3 to N_2 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 through the soil profile below the rootzone
- Runoff: the surficial lateral movement of an element beyond the intended turfgrass location

Nitrogen release from available sources: Understanding how certain N sources should be blended and applied is an essential component in an efficient nutrient management plan. In many 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 timing, placement, and turfgrass species all should be included in your nutrient application decision.

Table 6-1. Grade, salt index, and water solubility of the most common readily-available nitrogen sources used in turf and landscape management fertility programs. The salt index scale is <1 = low, 1 to 2.5 = moderate, and > 2.5 = high.[1]

Fertilizer	**Grade**	**Salt Index[1]**	**Water Solubility g/liter (lb/gal)**
Urea	46-0-0	1.7	1810 (15)
Ammonium nitrate	34-0-0	3.2	710 (5.9)
Ammonium sulfate	21-0-0	3.3	130 (1.1)
Diammonium phosphate	18-46-0	1.7	230 (1.9)
Monoammonium phosphate	11-52-0	2.7	430 (3.6)
Potassium nitrate	13-0-44	5.3	780 (6.5)

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. Common slow release N sources are found in Table 6.2.

Table 6-2. Common slow-release N fertilizers

Fertilizer	Typical Analysis	General Comments
Sulfur-Coated Urea (SCU)	32-0-0	-Urea granules coated with molten S. -Analyses and release rate vary depending on amount of coating. -N release due to osmosis, so moisture and temperature govern release rate. -Relatively inexpensive compared to other slow release sources. -Reduces soil pH. -Handling is important because scratching the coat removes the controlled release characteristic.
Polymer/Resin-Coated Urea (PCU)	32-0-0	-Polymer coating of urea (sometimes also combined with S). -N analyses vary depending on coating thickness. -Noted for very predictable release characteristics and handling is not as much of a concern as for SCU.
Isobutylidene diurea (IBDU)	31-0-0	-Synthetic organic with N release rates primarily governed by particle size and adequate soil moisture.
Urea-formaldehyde (UF)	38-0-0	-Synthetic organic with predominantly long-chain carbon polymers and very controlled N release. -N availability based on microbial activity. -Very limited response in cold temperatures.
Natural organic	6-2-0 (or similar analysis)	-Derived from waste byproducts. -Very low N analyses, usually contains some phosphate and other micronutrients. -Very controlled release that is dependent on microbial activity (driven by adequate moisture and relatively warm soil temperatures).

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.

Table 6-3. Annual Nitrogen Rate Recommendations.

Grass species	Nitrogen Rate
Cool-season grasses (fescue, bluegrass, rye)	2-4 lb N / 1000 ft^2
Warm-season grasses (Bermuda, zoysiagrass, buffalograss)	1-3 lb N / 1000 ft^2

6.1.4.2 *The role of phosphorus (P)*

Phosphorus is vital for essential functions in plants such as energy storage and transfer and is a main component in DNA and RNA. Phosphorus can be a limiting nutrient for turfgrass and many unintended organisms that contribute to the eutrophication of water bodies. Thus, proper timing and rates should be implemented to reduce the risk of off-site movement of phosphorus. Phosphorus forms high-energy (ATP and ADP) compounds that are used to transfer energy within the plant. Phosphorus may remain in an inorganic form or may become incorporated into organic compounds. Phosphorus application rates should be based upon soil test results derived from documented correlations demonstrating a turf response to soil test phosphorus levels.

Table 6-4. Typical grade, salt index, and water solubility of the most common P sources used in turf and landscape management programs. The salt index scale is <1 = low, 1 to 2.5 = moderate, and > 2.5 = high.[1] Rock phosphate levels of P_2O_5 can range from 27-41%.[2] N/A = Not Applicable.[3]

Fertilizer	**Grade**	**Salt Index[1]**	**Water Solubility g/liter (lb/gal)**
Superphosphate	0-20-0	0.4	20 (0.16)
Treblesuperphosphate	0-45-0	0.2	40 (0.32)
Monoammonium phosphate	11-52-0	3.2	230 (3.4)
Diammonium phosphate	18-46-0	1.7	230 (1.8)
Rock Phosphate	0-30-0[2]	N/A[3]	N/A
Bone Meal	4-12-0	N/A	N/A

<u>P deficiency symptoms</u>: Visible symptoms of P deficiency are unusual unless turf is grown on a high sand rootzone. 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. Because P is a mobile nutrient inside the plant, it can be easily translocated to new tissue. Phosphorus deficient turfgrasses will exhibit reduced root growth and a lack of adequate branching.

Table 6-5. P sufficiency ranges for turf grasses. Applications are not recommended for soil test P greater than 25 ppm P.[1]

P Rating	**P soil test value (ppm)**	**P application (lb P_2O_5 / 1000 ft^2)**	**P application (lb P_2O_5 / 1000 ft^2)**
		Establishment	***Maintenance***
Very Low	≤ 10	2.0 - 3.5	1.0 - 1.5
Low	10 - 20	1.0 - 2.0	0.5 - 1.0
Medium[1]	20 - 30	0 - 0.5	0 - 0.5
High	30 - 60	0	0
Very High	> 60	0	0

6.1.4.3 The role of potassium (K)

Potassium is of no environmental concern, but can be an economic concern, particularly when potassium is over-utilized, which can be quite common. Generally, potassium concentrations in turfgrass tissue are about 1/3 to ½ that of nitrogen. Potassium is not a component of any organic compound and moves readily within the plant. Potassium is a key component of osmoregulation which has been documented to increase stress resistance.

Table 6-6. Typical grade, salt index, and water solubility of the most common K sources used in turf and landscape management programs. The salt index scale is <1 = low, 1 to 2.5 = moderate, and > 2.5 = high.[1]

Fertilizer	Grade	Salt Index[1]	Water Solubility g/liter (lb/gal)
Potassium chloride (muriate of potash)	0-0-60	1.9	350 (2.8)
Potassium sulfate (sulfate of potash)	0-0-50	0.9	120 (1)
Potassium nitrate	13-0-44	5.3	130 (1)

<u>K deficiency symptoms</u>: 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. Water stressed turfgrass can be more prone to K deficiencies.

Table 6-7. K sufficiency ranges in turf grasses. Applications are not recommended for soil test K greater than 80 in < 8 CEC, 90 in 8-14 CEC, 110 in 14-20 CEC, and 120 in >20 CEC soils.[1]

K Rating	K soil test value (ppm)	K application (lb P_2O_5 / 1000ft^2) CEC (meq / g soil) ranges			
-	-	**≤ 8**	**8 - 14**	**14 – 20**	**≥ 20**
Very Low	≤ 50	1.5 – 3.0	2 – 3.5	2.5 – 4.0	3.0 – 4.5
Low	50 – 90	0 – 1.5	0.5 – 1.5	1.0 – 2.0	1.5 - 2.5
Medium[1]	90 – 120	0	0 - 0.5	0.5	0.5 – 1.0
High	120 – 140	0	0	0	0
Very High	> 140	0	0	0	0

6.1.5 Secondary Macronutrients

Secondary macronutrients are essential to plant function and are required in quantities less than N, P, and K, but more than micronutrients. These include calcium (Ca), magnesium (Mg), and sulfur (S). Suspected deficiencies for these nutrients should be confirmed with a tissue analysis due to complex dynamics in the plant and soil, and because of the multitude of interactions between nutrients. It is always best to test a small-scale application of non-macronutrients to confirm a turfgrass response. This will ensure correct identification of the deficiency and avoid applications of unwarranted products.

Calcium is primarily a component of cell walls and structure. Ca sufficiency varies based on soil cation exchange capacity (CEC). Soil test values of 1000 to 1600 ppm (CEC < 10), 3000 to 5000 ppm (CEC 10-20), and 5000-8000 ppm (CEC > 20) indicate sufficient soil Ca content.

Magnesium is the central ion in the chlorophyll molecule and chlorophyll synthesis. If K or Ca are excessively applied, Mg may be deficient. Mg deficiency is more common in acidic or coarse-textured soils. Mg sufficiency is also dependent on the soil CEC. If the Mg saturation is > 5-10%, fertilizer applications are not needed or recommended.

Sulfur is metabolized into the amino acid, cysteine, which is used in various proteins and enzymes. Correlation and calibration of turfgrass response to sulfur has not warranted a soil test interpretation or recommendation to be used.

Table 6-8. Common inorganic sources of secondary macronutrients

Material	**Chemical Formula**	**Ca**	**Mg**	**S**
		Percent		
Calcium chloride	$CaCl_2$	36	0	0
Burned lime, or Calcium oxide	CaO	70	0	0
Calcitic limestone	$CaCO_3$	32	3	0.1
Dolomitic limestone	$CaCO_3$, $MgCO_3$	21-30	6-12	0.3
Gypsum	$CaSO_4$	22	0.4	17
Hydrated lime	$Ca(OH)_2$	50	0	0
Magnesium ammonium phosphate	$MgNH_4PO_4\text{-}6H_2O$	0	15	0
Magnesium oxide	MgO	0	45	0
Magnesium sulfate	$MgSO_4\text{-}7H_2O$	2	10	14
Potassium magnesium sulfate	$K_2SO_4\text{-}2MgSO_4$	0	11	22
Ammonium sulfate	$(NH_4)_2SO_4$	0.3	0	24
Ammonium thiosulfate	$(NH_4)_2S_2O_3$	0	26	0
Elemental S -Flowable -Wettable, Flowers	S	0	0	- 52-70 90-100
Potassium sulfate	K_2SO_4	0.7	1.0	18
Sulfuric acid	H_2SO_4	0	0	20-33

6.1.6 Micronutrients

Understanding the role of each micronutrient within the plant should provide you with 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 to macronutrients. Micronutrients include iron (Fe), manganese (Mn), boron (B), copper (Cu), zinc (Zn), molybdenum (Mo), and Chloride (Cl-). Soil test recommendations for micronutrients are listed below. For some micronutrients the soil test values are simply broken into "low, medium, or high" classes with no prescribed application rate. This is because turfgrass response to some micronutrients has not been identified with enough predictable replication to determine rates, however "low" soil test levels represent suboptimal and "high" concentrations represent above optimal levels.

Table 6-9. Micronutrient sufficiency ranges and role in plant development and function.

Material	Soil Test Value (ppm)			Role in Plant Development
	Low	Mod.	High	
Iron (Fe)	< 2.1	2.1 - 4.5	> 4.5	-Part of catalytic enzymes-Required for chlorophyll synthesis -Affects photosynthesis and respiration
Manganese (Mn)	< 1.0	-	> 1.0	-Involved in photosynthesis -Required as a cofactor for ~35 enzymes -Lignin biosynthesis depends on Mn
Boron (B)	< 0.4	0.4 - 0.9	< 0.9	-Found in the cell wall. -Likely required for structural integrity of the cell wall -Critical role in DNA synthesis
Copper (Cu)	< 0.2	-	> 0.2	-Cu-protein plastocyanin is involved in photosynthesis -Cofactor for a variety of oxidative enzymes
Zinc (Zn)	< 0.5	0.5 – 1.0	> 1.0	-Structural component of enzymes -Protein synthesis requires Zn -Carbohydrate metabolism is affected by Zn
Molybdenum (Mo)	-	-	-	-Primarily related to nitrogen metabolism -Structural and catalytical functions of enzymes
Chloride (Cl)	-	-	-	-Required for the oxygen-evolving reactions of photosynthesis -Appears to be required for cell division in leaves and shoots

With the exception of iron deficiency on high pH soils, visible deficiency of micronutrients is rare on fine textured soils. Deficiencies of all micronutrients can occur on sandy soils. Some micronutrients may also cause toxicity at high-levels. When supplemental applications are needed (often based on issue testing), chelated are very effective.

Table 6-10. Standard micronutrient fertilizer sources

Material	Analysis	Notes
Iron (Fe)		
Iron sulfates Iron oxides Iron ammonium sulfate Iron chelates	19 - 23% Fe 69 - 73% Fe 14% Fe 5 - 14% Fe	-Foliar applications of Fe fertilizers and soil applications of chelated Fe fertilizers can reduce iron deficiency symptoms -Managing soil pH and maintaining higher organic matter content are effective long -term strategies to reduce Fe deficiencies
Manganese (Mn)		
Manganese sulfate and oxide Manganese EDTA	0.05 – 7.27% Mn 0.05% Mn	-Mn application rates of 0.3 to 0.6 oz/1000 ft^2 are recommended when Mn is deficient
Boron (B)		
Boric acid	0.02% B	-B application rates of 0.5 to 1.5 oz/1000 ft^2 are recommended when B is deficient
Copper (Cu)		
Copper oxide Copper EDTA	0.05 – 0.5% Cu 0.05% Cu	-No copper fertilizer recommendations have been determined in Missouri -Excessive copper concentrations in tissue are important to avoid (> 20-30 mg Cu/kg biomass)
Zinc (Zn)		
Zinc sulfate and oxide Zinc EDTA	0.05 – 1.3% Zn 0.05% Zn	-Zn deficiencies are more common in coarse-textured and low organic matter soils
Molybdenum (Mo)		
Sodium molybdate	0.0005 – 0.026% Mo	-Mo recommendations have not been prevalent enough and are very difficult to diagnose. No recommendations have been identified in Missouri. -Deficiency symptoms typically occur in alkaline soils
Chloride (Cl)		
Potassium chloride	< 10% Cl	-Cl deficiencies are not common due to potassium chloride used as a K source -Excessive Cl should be avoided (> 1%) and toxicity issues can be exacerbated in saline soils

6.2 Soil pH

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. Increasing soil pH to a desired value are more effective with liming products which (1) have greater chemical acid-neutralizing potential and (2) are more finely ground. If an initial soil pH is too high, reducing pH with acidifying products is more costly and time consuming, and rarely cost-effective. Testing irrigation water for pH is also useful in determining its potential effect on soil acidity. A soil's ability to buffer pH changes (measured by the buffer pH) will lead to either more or less liming/acidifying product needed to achieve the desired pH change.

Table 6.11. Soil pH ratings. Excessive soil pH values commonly lead to reduced micronutrient availability.[1]

Rating	pH
Very Low	< 5.0
Low	5.0 – 5.8
Medium	5.8 – 6.5
High	6.5 – 7.5
Very High	7.5 – 9.0
Excess[1]	> 9.0

6.3 Assessing Nutrient Needs

6.3.1 Soil Testing

Soil testing may or may not provide the appropriate answers to your nutrient management questions; however, when soil samples are collected properly, they can reduce fertilizer costs and help to prevent nutrient leaching. In some cases, such as evaluating N needs, tissue testing or other evaluations may be better suited.

Best Management Practices

- Accurate and consistent sampling is essential to providing useful 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 randomly taken from each section and 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.
- The purpose of a soil test is to provide the grower with a prediction of a plant's response to an applied nutrient.
- If the 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, then soil test recommendations may be of little value.
- Keeping soil tests from prior years will allow you to observe changes over time. This practice can provide good evidence of the impact of your nutrient management plan.

6.3.2 Plant Tissue Analysis

Because of the mobility and conversion of elements within the soil, soil sampling can be less predictable than tissue testing. Tissue testing provides a precise measurement of nutrients within the plant. Tissue test sufficiency ranges are only as good as the correlation data of a given element to an acceptable quality level of a given turfgrass. Typically, tissue correlation data are more prevalent than soil test correlation data and, therefore, programs designed around tissue testing may provide more reliable results. However, tissue sampling results are more variable over time. Through proper sampling, consistent intervals, and record keeping, tissue sampling may be used to measure existing turf 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 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.
- Keeping tissue tests from prior years will allow you to observe changes over time.
- Tissue testing can provide good evidence of the impact of your nutrient management plan.

6.4 Practical Nutrient Management Considerations

Within each state, environmental conditions vary greatly 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. Understand the importance of application timing for effective use of applied nutrients.

Best Management Practices

- The objective of all nutrient applications is plant uptake and the corresponding desirable response.
- Apply nutrients when turfgrass is actively growing.
- Apply slow-release N fertilizers at the appropriate time of year to maximize the products' release characteristics. For example, an application of slow-release N to warm-season turfgrasses in fall may not be as effective as the same application applied in early summer because of the prolonged release time infall.
- Follow N application rate recommendations from University of Missouri Extension.
- N application rates from slow-release materials consider the release rate of the chosen material. If insufficient material is applied, the desired response may not be observed.

- The reduced height of cut and excessive traffic damage on putting greens results in an increased need for growth leading to an increase in 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 fewer nutrient inputs than other locations because of their increased height of cut, less damage, and clipping return.
- Exercise caution when applying nutrient applications during turfgrass establishment as these applications are particularly susceptible to loss via leaching and runoff.
- Provide appropriate rates and products to minimize N loss without reducing turfgrass establishment.
    - Increased water applications
    - Increased nutrients to hasten establishment
    - Reduced root mass
- Be aware of the different types of spreaders and understand the advantages and disadvantages of each.
- Not all fertilizers can be spread with every spreader. For example, if sulfur-coated urea was spread through a drop spreader, the sulfur coating could be damaged, essentially leading to an application of soluble urea.
- Choose the appropriate spreader for a given fertilizer material.
    - Walk-behind rotary
    - Drop spreader
    - Bulk rotary
    - Spray
- Calibration reduces environmental risk and increases profitability.
- University of Missouri Extension provides an excellent overview of spreader calibration: https://extension.missouri.edu/publications/g6751.
- Proper fertilizer storage, loading, and clean-up reduce environmental risk.
- Avoid applying fertilizer to soils that are at, or near, field capacity or following rain events that leave the soils wet.
- Do not apply fertilizer when the National Weather Service has issued a flood watch or warning, or if heavy rains are likely.

7 Cultural Practices

Cultivation practices are an important part of golf course turf management. Certain cultural practices such as mowing, verticutting, and rolling are necessary to provide a high-quality playing surface, while others such as aerification are required to enhance plant health. 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 to 4 inches of the soil profile and should be actively managed to enhance turf health and improve nutrient and water uptake. Unlike annual crops, which offer the opportunity for periodic tilling of the soil profile to correct problems like soil compaction that might develop over time, turfgrass does not offer opportunities for significant physical disturbance of the soil without disturbing the playing surface.

7.1 Mowing

Mowing is the most basic yet most important cultural practice to consider when developing a management plan. The mowing practices implemented on a facility not only impact playability, but will also have an impact on turf density, texture, color, root development, and wear tolerance. Mowing practices affect turfgrass growth. Frequent mowing will increase shoot density and tillering. It will also decrease 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 (Table 7-1). 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 will require a substantial amount of time to provide the food needed to produce shoot tissue for future photosynthesis. If turf 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 will result in weakened turf with poor density and quality.

Table 7-1. Common grass species used in Missouri with recommended cultural practices. For more information, see Managing Lawns and Turfgrass by University of Missouri Extension.

Grass Species	Greens *Height of Cut (inches)*	Tees, Collars, Approaches *Height of Cut (inches)*	Fairways *Height of Cut (inches)*	Roughs *Height of Cut (inches)*	Frequency *mowings/week*
Kentucky bluegrass	-	0.6 – 0.8	0.6 – 0.8	2 – 4	1 – 2
Perennial ryegrass	-	0.4 – 0.6	0.4 – 0.6	2 – 4	1 – 2
Tall fescue	-	-	-	2 – 4	1 – 2
Fine leaf fescue	-	-	0.6 – 0.8	2 – 4	1
Zoysiagrass	-	0.4 – 0.6	0.5 – 0.75	-	1 (taller height) 2 (shorter height)
Bermudagrass	0.1 – 0.2	0.4 – 0.5	0.4 – 0.6	0.8 – 2.5	1 (taller height) 2-3 (shorter height)
Buffalograss	-	-	0.6 – 0.75	1.5 – 3	0.5 – 1

7.1.1 Mowing Frequency and Height of Cut

- Mowing frequency should increase during periods of rapid growth and decrease during dry, stressful periods.
- If turf becomes too tall, it should not be mowed down to the desired height (Table 7-1) all at once. Such severe scalping reduces turf 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 turf grown in a shaded environment.
- The use of the plant growth regulator trinexapac-ethyl has been shown to improve overall turf 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 turf health. Increase mowing heights as much as use will allow in order to increase photosynthetic capacity and rooting depth of plants.

7.1.2 Mowing Equipment

- 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 to other types of mowers.
- Rotary mowers, when sharp and properly adjusted, deliver acceptable cutting quality for turf that is to be cut above 1.5 inches in height. Dull blades will result in shredding of leaf tissue, increasing the potential for disease development and reduction in turf quality.
- Flail mowers are most often used to maintain utility turf areas that are mowed infrequently and do not have a high aesthetic requirement.
- Mowing patterns influence both the aesthetic and functional characteristics of a turf surface.

7.1.3 Managing Clippings

- 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.
- Nutrients contained in clippings can be sources of pollution and should be handled properly.
- Clippings should be returned to the site during the mowing process unless the presence of grass clippings will have a detrimental impact on play. Cases when clippings should be removed include times when the number of clippings is so large that it could smother the underlying grass or on golf greens where clippings might affect playability.
- 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.

7.2 Cultivation

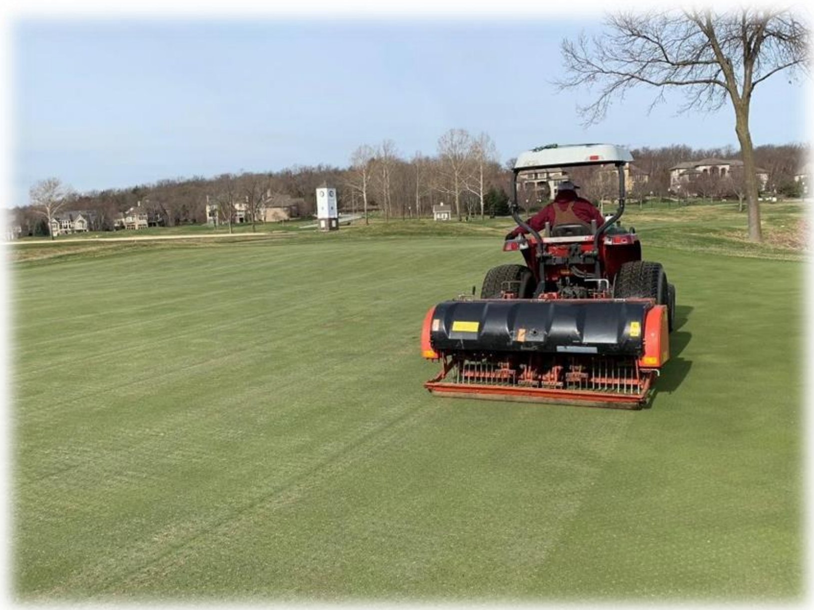

Figure 7-1. Using a deep tine aerator on the green surface at The National Golf Club of Kansas City

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. Cultivation techniques will result in disturbance of the playing surface that can require significant time for recovery. Frequency of cultivation should be based on traffic intensity and level of soil compaction. Core aerification (Figure 7-1) is effective at managing soil compaction, aiding in improvement of soil drainage, and improving surface firmness.

Accumulation of excessive thatch and organic matter will reduce root growth, encourage disease, and create undesirable playing conditions. Light and frequent applications of sand will smooth the playing surface, control thatch, and potentially change the physical characteristics of the underlying soil when done in conjunction with core aerification.

Cultivation techniques have various impacts on compaction, thatch control, water and air movement, and disruption of play (Table 7-2).

7.2.1 Aerification

- Core aerification involves removal of small cores or plugs from the soil profile. Cores are usually 0.25 to 0.75 inch in diameter. Annual core aerification programs should be designed to remove 15%-20% of the surface area. High traffic areas may require a minimum of two to four core aerifications annually.
- Core aerification on turf mowed at fairway/tee height or higher can also encourage thatch breakdown, particularly if cores are allowed to dry on the surface, and then broken up so soil penetrates the turf canopy.
- 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 varying length tines to prevent development of compacted layers in the soil profile as a result of cultivation.
- Solid tines cause less disturbance to the turf surface and can be used to temporarily reduce compaction and soften surface hardness during months when the growth rate of grasses has been reduced. Benefits of solid-tine aerification are temporary because no soil is removed from the profile.

- 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 is 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.

Table 7-2. Turfgrass cultivation methods and rankings of agronomic benefits. Verticutting removes a greater amount of thatch, but does so only to a maximum of about 0.7"; core aerification is a better approach if excess thatch and organic matter accumulation from 0-3" must be removed.[1] Use of verticutters with wider blades, closer blade spacing, and deeper settings increase length of play disruption.[2]

Method	Compaction Relief	Thatch Control	Water/Air Movement	Disruption of Play
Core aerification	High	Good[1]	High	Medium to High[1]
Verticutting	Low	Best[1]	Medium	Low to High[2]
Spiking/Slicing	None	Very Low	Low	None
Deep drilling	Medium	Medium	High	High

7.2.2 Vertical Mowing

- Vertical mowing (verticutting) can be incorporated into a cultural management program to achieve a number of different goals (Figure 7-2). The grain of a putting green can be reduced by setting a verticutter to a depth that just nicks the surface of the turf. Deeper penetration of knives will stimulate new growth by cutting through stolons and rhizomes while removing accumulated thatch.
- Verticutting depth for thatch removal should reach the bottom of the thatch layer and extend into the surface of the soil beneath the thatch.

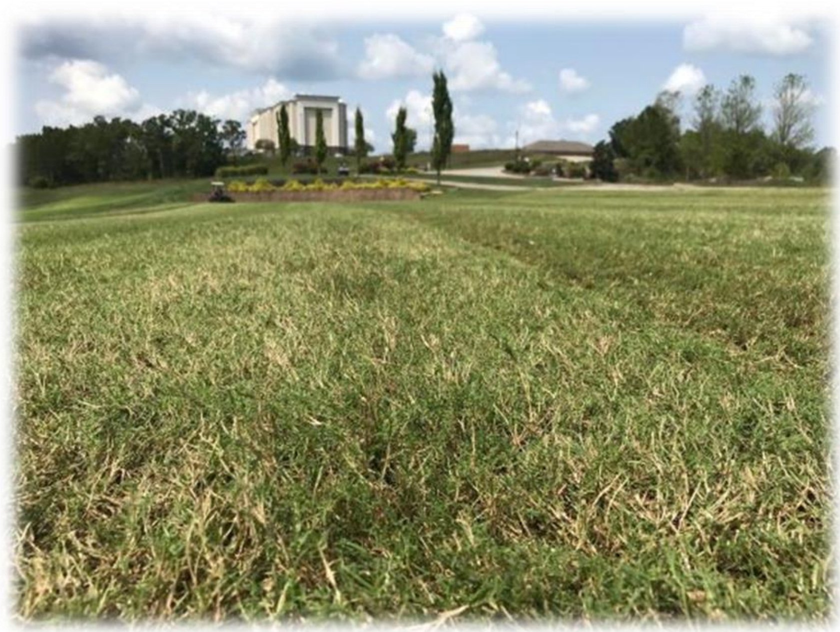

Figure 7-2. Post-verticut bermudagrass at Branson Hills Golf Club (Branson, MO).

- Dethatching with a verticutter is an aggressive practice that is only recommended on golf greens when the plant is actively growing and not under stress.

- Initiate vertical mowing when thatch level reaches 0.25 to 0.5 inch in depth. Shallow vertical mowing should be completed monthly on putting greens to prevent excessive thatch accumulation.
- 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.

7.2.3 Other Cultivation Techniques

- If a deep drilling, drill-and-fill machine is used, backfill holes with new root-zone materials.
- Topdress the playing surface with sand following core aerification and heavy vertical mowing to aid in recovery of turf. Rates will vary from 0.125 to 0.25 inch in depth and will depend on the capacity of the turf canopy to absorb the material without burying the plants (Table 7-3).
- Light, frequent applications of topdressing sand on putting greens can smooth out minor surface irregularities, aiding in the management of thatch accumulation and improving playability.
- Use only weed-free topdressing materials with a particle size similar to that of the underlying root zone.
- Use of finer materials can result in layering and can have a negative impact on water infiltration over time and not in conjunction with aerification practices. Using coarser materials can also create layering issues, and can cause damage to reel mowers after topdressing.
- Daily rolling of putting surfaces following mowing can increase putting speeds by roughly 10%, allowing for improved ball roll without lowering height of cut.
- To minimize potential for compaction caused by rolling, use light weight rollers.

Table 7-3. Light and frequent topdressing rates

Quantity ($ft^3/1000\ ft^2$)	Quantity ($lbs/1000\ ft^2$)	Quantity (tons/acre)	Depth of Application (inches)
0.50	50	1.1	0.006
0.75	75	1.7	0.009
1	100	2.2	0.012
2	200	4.4	0.24
4	400	8.8	0.48

7.3 Overseeding Warm-Season Turfgrass

The fundamental purpose of overseeding is to establish a temporary cool-season grass into the 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 will prevent 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 turf 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 nitrogen 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 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 winter color to dormant grasses.
- Overseeding practices can generate significant dust that may require dust control measures.

7.4 Shade and Tree Management

In general, most turfgrasses perform best in full sun. Excessive shade reduces photosynthesis and air circulation, thus reducing turf quality and increasing the susceptibility of the turf 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 turf growth.
- Understand the variability in sun angles at different times of the year and how this affects turf 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.
- Utilize a root pruner to help the grass compete for soil moisture and nutrients.

8 Integrated Pest Management

Integrated Pest Management (IPM) is the combination of various methods to manage pest populations and limit their impact on plant health and playing conditions. An IPM program does not rely exclusively on pesticides for pest control, but incorporates cultural, biological, and genetic tactics into a comprehensive pest management framework. The objectives of IPM include reducing pest management expenses, conserving energy, and reducing the risk of pesticide exposure to people, animals, and the environment.

Pest management on golf courses results in significant inputs of time, labor, and financial resources. To grow healthy turfgrass, golf course superintendents should implement IPM for each pest group (insects, rodents, nematodes, diseases, and weeds). Superintendents should be familiar with pest identification, understand pest life cycles and/or conditions that favor pests, and stay current on all possible pest control methods. True IPM therefore never begins as a complete set of procedures, but evolves over time into a dynamic, complex and site-specific program.

8.1 Regulatory Considerations

Pesticides are regulated at the state and federal level through different legislation and programs. The United States Environmental Protection Agency (EPA) oversees pesticide manufacturing and use based on guidelines outlined in the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Restricted-use pesticides, as deemed by FIFRA, must be applied by a certified applicator. The Missouri Pesticide Use Act and Missouri Pesticide Registration Act further guide pesticide use and registration in Missouri and are overseen by the Missouri Department of Agriculture. See *Pesticide Laws and Regulations* by University of Missouri Extension for a comprehensive overview of regulatory considerations.

Controlled burns may also be used to reduce and control weed populations and maintain native vegetation. Open burning is governed by the Missouri Department of Natural Resources, but local governments may have more stringent laws. See *Facts on Open Burning Under Missouri Regulations* for more information.

Record keeping of pesticide use is required by law for certified commercial and noncommercial applicators and public operators. Commercial applicators are required by law to maintain records of all pesticides used. Noncommercial applicators and public operators are required by law to maintain records for restricted-use pesticides used.

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. Superintendents and applicators are required to obtain a certified applicator license in Missouri in order to apply restricted-use pesticides. Further information about obtaining a license can be obtained from the Missouri Department of Agriculture Bureau of Pesticide Control.

Best Management Practices

- Proper records of all pesticide applications should be kept according to local, state, or federal requirements.

- Use records to establish proof of use and follow-up investigation of standard protocols regarding:
    - Name and license number of certified applicator
    - Name of noncertified applicator or name and license number of the pesticide technician using the pesticide if applicable.
    - Application date
    - Name and address of golf course, with brief description and total area of application site (i.e. hole numbers and area type (i.e. tee, green, etc.)).
    - Target pest(s) controlled or prevented by pesticide use.
    - Complete trade name and EPA registration number from the pesticide label.
    - Total amount and application rate of pesticide used
    - Weather conditions, including wind direction and speed and air temperature, at the time of application
    - Optional records to aid in review of pest control
    - Formulation type, carrier volume, sprayer pressure and application equipment (including nozzle type).
    - Amount applied of adjuvant/surfactant, pH buffer, spray/marking dye or pigment, etc.
    - Additional pest information, such as the severity of the infestation or life stage of the pest
    - Follow-up notes detailing the effectiveness of the application

8.2 IPM Overview

IPM utilizes a range of pest control methods to prevent pest populations from reaching an economical or aesthetic damage threshold while minimizing environmental impact. In most cases, a pest population will not be eradicated from a site by these control methods, therefore understanding the plant status and environmental conditions that spur pest outbreaks is crucial to a successful IPM program. Key steps in implementing an IPM program include:

1. Monitor and identify pests
2. Understand pest biology and etiology
3. Determine threshold levels
4. Select IPM tactics based on pest biology and occurrence
5. Evaluate and adapt IPM plan as necessary

A healthy, dense stand of turfgrass is the least susceptible to pest damage and weed encroachment. Cultural practices that properly manage turfgrass growth and development through seasonal differences in environmental growing conditions are the first line of defense against pest occurrence. Mowing at the proper height, avoiding excessive or inadequate fertility and irrigation, providing adequate drainage and air movement and reducing shade will aid in minimizing the need for chemical pest control. However, even in the best growing conditions, some pests can cause considerable damage to turfgrasses.

IPM is commonly used in agricultural crop production, where the economic thresholds for key pests on yield have been determined. On golf courses, aesthetics and playability are the more common drivers of acceptability, resulting in thresholds that are much lower and more difficult to achieve than in agriculture. Increased education of golfers and maintenance personnel could raise their tolerance of minor, short-term aesthetic damage that does not compromise plant health or play.

Best Management Practices

- Chemical pesticide applications should be carefully chosen for effective and site- specific pest control with minimal environmental impact.
- Identify key pests on key plants.
- Determine the pest's life cycle. Know which life stage to target (i.e. insects – grub, larvae, or adult, diseases – during the pathogen infection period, weeds – preemergent or 2-3 leaf stage).
- Direct control to where the pest is (i.e. foliar vs. soil).
- Use cultural, mechanical, or physical methods to prevent problems from occurring (for example, site preparation, selection of resistant cultivars), reduce pest habitat (for example, good sanitation practices, pruning and dethatching), or to help promote biological control (for example, provide nectar or honeydew sources).
- Decide which pest management practice is appropriate and is least toxic to humans and the environment.
- Use preventive chemical applications only when your professional judgment indicates that properly timed preventive applications are likely to control the target pest effectively while minimizing the economic and environmental costs.
- Determine whether the corrective actions actually reduced or prevented pest populations, were economical, and minimized risks.
- Observe and document turf conditions regularly (daily, weekly, or monthly, depending on the pest), noting which pests are present, so intelligent decisions can be made regarding how damaging the pests are and what control strategies are necessary.

8.3 Pest Monitoring and Record Keeping

Routine, effective, and careful monitoring, (or scouting), is the cornerstone of a successful IPM program. A monitoring plan should be described for all areas of the course including putting greens, tees, fairways, roughs, and landscaped areas. Scouting practices include visual inspection, plant and soil sampling, soap flushes, and insect trapping. Detailed records are necessary to develop historical information, document patterns of pest activity, and document successes and failures. Being aware of regional weather and pest occurrence trends through communication with colleagues, or resources such as the University of Missouri (MU) turfgrass pathology reports, is important to intervention with timely and effective pest control.

Figure 8-1. Monitoring soil cores for pests at Bogey Hills Golf Country Club

(St. Charles, MO).

Best Management Practices

- Train and encourage personnel to observe and document turf conditions regularly (daily, weekly, or monthly, depending on the pest and area), including recognition and alerting others of potential pest problems.

- Train personnel to recognize the life cycle of important pests, and know which life stage is most susceptible to target and limit plant damage.
- 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.
- Systematically record pest occurrences as they occur. Documentation should include useful information such as:
    - Time and date, including important pest-specific environmental information such as growing degree day accumulation and/or flowering stages of phenological indicator plants.
    - Plant symptoms and pest signs. Photographs organized in a database referenced with time and geospatial information can serve as an important historical resource.
    - Quantified measurements of pest pressure such as size of affected or diseased area, or the number of insects or weeds per unit area.
    - The size of the damaged area, and what areas the pest impacted first on the course (aka “hot spots”).
    - Outline areas of high pest pressure on area, GPS or satellite maps (i.e. drone photos, irrigation map, Google Earth, etc.) to focus future control measures and monitoring practices. Use map to communicate with clientele and train personnel.
    - Targeted control practices and how they performed.

8.4 Turfgrass Selection

A key first step in an IPM program is putting the right plant in the right place. Located in the transition zone, Missouri is subject to yearly environmental extremes of extremely warm summers and sub-freezing winters. Therefore, selection of the most adapted plant species and cultivars for the Missouri environment is challenging, yet critical to ensuring site success and reducing pest pressure. Species and cultivars should be managed under conditions similar to their intended use (for example, not exceeding mowing height limitations for which a grass was bred or selected).

Turfgrasses must be scientifically selected for the eco-region of the golf course, resulting in minimized irrigation requirements, fertilization needs, and pesticide use. Golf course superintendents should collaborate with builders, developers, golf course and landscape architects, sod producers, golfers, and university turfgrass scientists to select plants best suited to their areas. A valuable resource for cultivar selection is the National Turfgrass Evaluation Program, which has facilitated years of research on cultivars at sites throughout North America, including at MU.

Best Management Practices

- Select the most suitable turfgrass for existing conditions and one that adheres to design specifications.
- Avoid use of turfgrass in heavy shade.
- Select shade-adapted grasses for areas receiving partial sun or shaded areas.
- Reduce pest and disease pressures by correcting dead spots and air-circulation issues by pruning understory and adjusting irrigation scheduling.
- Reduce fertilizer applications in shaded areas.
- Reduce traffic in shaded areas to protect turfgrasses and trees from injury and soil compaction, if practical.

8.5 Pest Identification and Management

After detection, properly identifying the pest is paramount to selecting appropriate control. Identification of common pest issues may be routine, but in many cases plant symptoms can appear similar and result in an incorrect diagnosis. Superintendents and staff should engage in continuing education at the state and national level, including attendance at regional conferences, seminars and field days to stay current on pest occurrence and management.

The resources listed below can aid in pest identification, and more importantly also provide information on pest biology, etiology and management techniques.

- Turfgrass Weed Control for Professionals – color images, descriptions and management recommendations of many turf weeds.
- Compendium of Turfgrass Diseases – color images, descriptions and management recommendations of turfgrass diseases.
- Handbook of Turfgrass Insects - color images, descriptions and management recommendations of turfgrass insects.
- Chemical Control of Turfgrass Diseases – descriptions and management recommendations for a comprehensive list of turfgrass diseases.
- MU Extension Publications – various publications on turfgrass pest issues
- MU Plant Diagnostic Clinic – To submit a turfgrass sample, review the submission form and sampling instructions.

8.5.1 Weeds

Weeds compete with desired plants for space, water, light, and nutrients and can harbor insect pests and diseases. Weed management is an integrated process where good cultural practices are employed to encourage desirable turfgrass ground cover, and where herbicides are intelligently selected and judiciously used.

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 turf;
- properly identifying weeds; and
- properly selecting and using the appropriate herbicide, if necessary.

Best Management Practices

- Proper weed identification is essential for effective management and control. Common Missouri weeds can be found at https://weedid.missouri.edu/.
- Select appropriate turf species or cultivars that are adapted to harsh environmental conditions that may lead to bare soils, which increases weed encroachment.
- 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 turf 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.
- Proper fertilization is essential for turfgrasses to sustain desirable color, growth density, and vigor and to better resist diseases, weeds, and insects.

- Avoid scalping; it reduces turf density, increasing weed establishment.
- Weed-free materials should be used for topdressing.
- Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to broadleaf weeds.
- Record and map weed infestations to help identify site specific issues for preventative actions.

8.5.2 Insects

Common insects that impact turfgrass in Missouri include annual white grubs, aphids, billbugs, chinch bugs, cutworms, armyworms, and sod webworms. Insects like aphids, chinch bugs, armyworms, and sod webworms may be sporadic, non-annual issues that lead to turfgrass decline. Therefore, preventive insecticide applications on lower amenity areas may be unnecessary and monitoring for threshold levels should drive application decisions. Conversely, cutworms on putting greens and annual white grubs on high amenity turfgrass may require treatment annually. Black cutworm and fall armyworm moth flights can be tracked on the MU IPM website, which should be combined with regular monitoring with soap water flushes and notice of intensive bird feeding in areas of high infestation.

Best Management Practices

- Select turfgrass species that offer insect resistance if agronomically suitable. Endophyte-enhanced turfgrasses – perennial ryegrass and tall fescue – can resist insect damage by producing deterring toxins.
- Reduce turfgrass stress by mowing at appropriate height.
- During period of peak beetle flight, letting turfgrass dry out slightly will reduce egg-laying and larvae survival compared to well-irrigated sites.
- Excessive fertilizer application can lead to thatch buildup and suitable habitat for chinch bugs, billbugs, and sod webworms.
- Reduce thatch with aerification and verticutting to reduce habitat for egg laying and insect development.
- Use a granular insecticide formulation for root feeding insects, and immediately water in to lessen impact on pollinators and beneficials. See section 8.6 below for more information.

8.5.3 Diseases

While superintendents can employ practices to reduce the likelihood of disease, in many cases diseases will develop when conditions are favorable regardless of management strategy. Disease severity can be greatly reduced by using genetic, cultural and biological practices. As a rule, healthy, well-managed turfgrass is less likely to develop severe disease. Disease outbreaks that do occur are less likely to be severe on turf that is healthy due to higher recuperative potential than stressed, unhealthy turf. Cultural factors that can influence turfgrass stress and disease severity include organic layer management, adequate fertility, water management, and mowing height.

Best Management Practices

- Correctly identify the disease pathogen. If uncertain of the problem, samples can be sent to the MU Plant Diagnostic Clinic.
- Ensure proper cultural practices that reduce turfgrass stress are used.
- Correct conditions that produce stressful environments for the turf (for example, improve airflow and drainage, reduce or eliminate shade.)

- Fungicide use should be integrated into an overall management strategy for a golf course.
- Preventively apply appropriate fungicides where diseases are likely to occur and when conditions favor disease outbreaks.
- Understand which diseases are caused by foliar vs. soilborne pathogens. Diseases caused by soilborne pathogens will require fungicide delivery into the root zone, usually through post-application irrigation.
- Record and map disease outbreaks and identify trends that can help guide future treatments and focus on changing conditions in susceptible areas to reduce disease outbreaks.

8.5.4 Nematodes

Plant-parasitic nematodes can adversely affect turfgrass health. 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. In Missouri, sand- based putting greens are most often affected, with turfgrasses grown on native soil rarely if ever showing symptoms. Turfgrass-parasitic nematodes feed on roots, limiting water and nutrient uptake and increasing susceptibility to environmental stresses. Additionally, nematode feeding creates an infection court for soilborne turfgrass pathogens that cause diseases such as Pythium root rot and summer patch. Turfgrasses usually begin showing signs of nematode injury as they experience additional stresses from other diseases, drought, high temperatures, or excessive traffic.

Best Management Practices

- When nematode activity is suspected, an assay of soil and turfgrass roots is needed to determine the extent of the problem.
- Assays for identification of plant parasitic nematodes can be sent to the MU nematode screening lab.
- The application of a nematicide on golf course turf should always be based on assay results.
- Nematicides will need to be moved into the soil profile, usually with post- application irrigation.
- Increase mowing height to reduce plant stress associated with nematodes, root- feeding insects, disease outbreaks, or peak weed seed germination.
- Reduce/eliminate other biotic/abiotic stresses when nematodes are compromising the root system and plant health.

8.6 Beneficial Pollinators and Insects

An effective IPM plan can help superintendents make pesticide application decisions that reduce environmental impacts on non-target organisms and maximize economic returns. In particular, the non-target impacts of pesticide applications on bees and beneficial arthropods need to be minimized. Instructions on how to protect pollinators is a requirement on pesticide labels, and therefore should be read, understood, and adhered to. When applying pesticides, focus on minimizing exposure to non-target pollinators on all areas of the course.

Figure 8-2. Monarch butterflies and native bees pollinating wildflowers at the Meadowbrook Country Club (Ballwin, MO).

Best Management Practices

- When using pesticides, minimize injury and damage by following label directions.
- Follow label information concerning the application of pesticides when plants may be in bloom. Avoid applying pesticides during bloom season.
- Stay on target by using coarse-droplet nozzles and monitor wind to reduce drift.
- Use the latest spray technologies, such as drift-reduction nozzles to prevent off site (target) translocation of pesticide.
- Apply pesticides early in the morning or late in the evening when pollinators are less active.
- Before applying a pesticide, scout/inspect area for both harmful and beneficial insect populations. Apply insecticides only when the indicated threshold of damage has been reached.
- Mow flowering plants (weeds) before insecticide application.
- If flowering weeds are prevalent, control them before applying insecticides.
- Use pesticides that have a lower impact on pollinators.
- Use granular formulations of pesticides that are known to be less hazardous to bees.
- Water insecticides in immediately if targeting root feeding insects.
- Consider lures, baits, and pheromones as alternatives when feasible.

8.7 Control Mechanisms

8.7.1 Biological Controls

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.

Biopesticides may also be considered a biological control. Biopesticides are derived from natural materials, such as animals, plants, bacteria, and some minerals. Three examples of biopesticides are biochemical pesticides, microbial pesticides, and plant- incorporated protectants. Typically, these control mechanisms are less toxic to humans, pose little risk to non-target organisms, rapidly degrade in the environment, and fit well into IPM strategies. Integrated Pest Management at University of Missouri produced *Biopesticides: Eco-Friendly Pest Control* to provide more information.

8.7.1.1 Best Management Practices: Natural Predators

- 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 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.
- Consider the use of insect-parasitic nematodes or fungi to naturally suppress mole crickets and white grubs.

8.7.1.2 Best Management Practices: Biopesticides

- Train employees in proper pest identification and pesticide selection techniques.
- Choose the product most appropriate for the problem or pest.
- 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.

8.7.2 Controlled Burns

In Missouri, native grass ecosystems were historically controlled by fire, thus, controlled burns can be an effective tool to reduce or control undesired species, promote native species, provide wildlife habitat, and remove excess plant debris. In particular, controlled burns will reduce woody species and suppress cool-season grasses, leaving behind a landscape more similar to a native prairie ecosystem. The Missouri Department of Conservation (MDC) offers guidance on controlled burns in *Prescribed Fire: A Management Tool*.

Best Management Practices

- Participate in voluntary prescribed fire training, such as those offered by MDC.
- Prepare a burn plan and stick with the plan.
- Monitor weather forecast to avoid conditions that would cause unnecessary spread.
- Consider securing the services of a prescribed fire contractor.
- Use prescribed fire periodically to simulate historical conditions.
- Consider smoke dispersal when planning a prescribed fire, especially in urban locations.

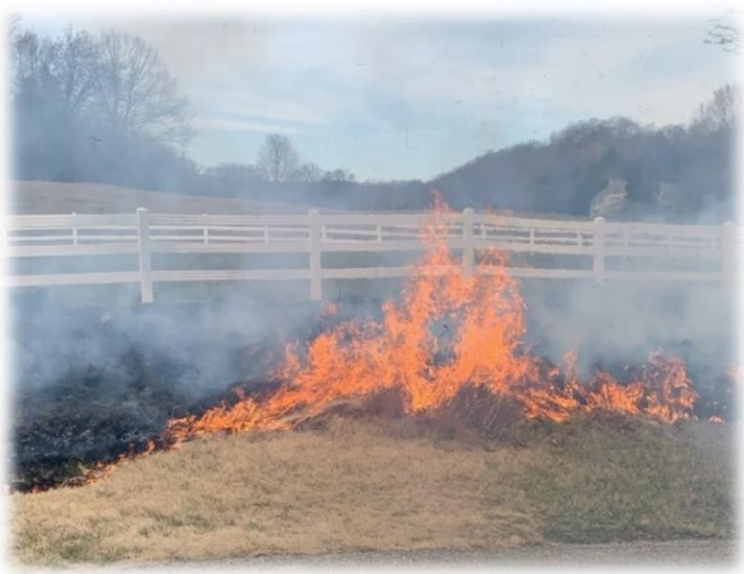

Figure 8-3. Controlled burn at Tavern Creek Golf Course (St. Albans, MO).

8.7.3 Pesticides/Chemical Controls

IPM does not preclude the use of pesticides. IPM involves both prevention — keeping the pest from becoming a problem, and suppression — reducing the pest numbers or damage to an acceptable level. 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 laws require following label directions!

8.7.3.1 Conventional Pesticides

- Train employees in proper pest identification and pesticide selection techniques.
- Choose the product most appropriate for the problem or pest.
- 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 and 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).

Evaluating the environmental risk and potential for water quality impacts can include the use of software, such as the Windows Pesticide Screening Tool (WIN-PST), which was developed by the USDA's Natural Resources Conservation Service (NRCS) to evaluate the potential of pesticides to move with water and eroded soil/organic matter and to affect non-targeted organisms. WIN-PST users can select combinations of active ingredient, soil type, and growing conditions to select an active ingredient that has less potential to leach and/or runoff into surface water.

8.7.3.2 Reduced Risk Pesticides

Reduced risk pesticides and biopesticides are an alternative option to conventional pesticides. The EPA's Conventional Reduced Risk Pesticide Program is a voluntary program that expedites the review and regulatory decision-making process of pesticides that pose less risk to human health and the environment than existing conventional alternatives. A complete list of reduced risk pesticides and the conventional pesticide for which they are an alternative can be found at: https://www.epa.gov/pesticide-registration/reduced- risk-and-organophosphate-alternative-decisions-conventional.

9 Pesticide Management

"Pesticide" is a general term that refers to chemical control products for a wide variety of unwanted golf course pests, such as weeds, insects, fungal diseases, and rodents. Herbicides, insecticides, fungicides, nematicides, and rodenticides are all pesticides that target specific organisms. Pesticide use should be part of an overall pest management strategy that includes biological controls, cultural methods, pest monitoring, and other applicable practices, referred altogether as IPM. When a pesticide application is necessary, selection should be based on cost, effectiveness, formulation type, site characteristics, toxicity to humans and non-target species, and persistence in the environment.

9.1 *Regulatory Considerations*

Pesticides are regulated at the state and federal level through different legislation and programs. The United States Environmental Protection Agency (EPA) oversees pesticide manufacturing and use based on guidelines outlined in the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Restricted-use pesticides, as deemed by FIFRA, must be applied by a certified applicator. The Missouri Pesticide Use Act and Missouri Pesticide Registration Act further guide pesticide use and registration in Missouri and are overseen by the Missouri Department of Agriculture. See *Pesticide Laws and Regulations* by University of Missouri Extension for a comprehensive overview of regulatory considerations.

Record keeping of pesticide use is required by law for certified commercial and noncommercial applicators and public operators. Commercial applicators are required by law to maintain records of all pesticides used. Noncommercial applicators and public operators are required by law to maintain records for restricted-use pesticides used. 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. Superintendents and applicators are required to obtain a certified applicator license in Category 3: Ornamental & Turf Pest Control in order to apply restricted-use pesticides. Further information about obtaining a license can be obtained from the Missouri Department of Agriculture Bureau of Pesticide Control. Curriculum is developed by University of Missouri Extension, with applicator training for obtaining a license and fulfilling recertification requirements is conducted by MU Extension and other entities.

Best Management Practices

- Only apply pesticides that are legally registered at all levels of jurisdiction.
- Only apply pesticides that are legally registered for use on the facility (for example, do not apply pesticides labeled for agricultural uses even though they may have the same active ingredient).
- Apply according to manufacturer recommendations as seen on label.
- Proper records of all pesticide applications should be kept according to local, state, or federal requirements (See 9.6. Record-Keeping).

9.2 *Human Health Risks*

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. The risk of a very highly toxic pesticide may be very low if the exposure is sufficiently small. Most modern pesticides have been developed to limit risks on humans and other non-target organisms; however, prolonged exposure, especially for pesticide applicators, can result in chronic or acute illnesses.

Exposure to pesticides can be mitigated by practicing good work habits and adopting modern pesticide mix/load equipment (for example, closed-loading) that reduce potential exposure. Personal Protective Equipment (PPE) statements on pesticide labels provide the applicator with important information on protecting himself/herself. Applicators should view PPE stated on the label as the required minimum, and when possible protect themselves beyond the label language when feasible.

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.
- Provide laundering facilities or uniform service for employee uniforms to prevent employees from wearing facility uniforms home where they may come into contact with children.
- Meet requirements for federal Occupational Safety and Health Administration (OSHA) 1910.134 Respiratory Protection Program.
- OSHA requires employers to fit test workers who must wear tight-fitting respirators.

9.3 Environmental Fate and Transport

Pesticides are effective tools for controlling unwanted plants and insects, among other taxa, but they may also pose a threat to non-target organisms as they move through the environment. Pesticides should aim to efficiently control the target pest(s), while degrading quickly enough or remaining in place so that they do not harm other organisms. For example, a soluble pesticide may be beneficial for systemic uptake into a plant; however, it may also be subject to transport through leaching or runoff.

Environmental characteristics of a pesticide can often be determined by the environmental hazards statement found on pesticide product labels. The environmental hazards statement (referred to as “Environmental Hazards” on the label and found under the general heading “Precautionary Statements”) provides the precautionary language advising the user of the potential hazards to the environment from the use of the product. The environmental hazards generally fall into three categories: (1) general environmental hazards, (2) non-target toxicity, and (3) endangered species protection.

In general, pesticides should be selected to reduce environmental fate and transport, reduce impact on non-target organisms, such as pollinators, and to have little or no effect on endangered species. Follow best management practices to reduce leaching, runoff, and drift.

Best Management Practices

9.3.1 Leaching and Runoff

The potential for pesticides to be transported by water can be defined by sorption coefficients (K_{OC}). A K_{OC} value describes the relative partition of a pesticide between soil particles and water. Compounds with a low K_{OC} value are more likely to dissolve in water than bind with soil particles or organic matter. These compounds weakly bind to particles and are more likely to leach through the soil and reach groundwater.

Conversely, compounds that bind more strongly to soil and organic matter particles (high K_{OC}) are likely to remain near the soil surface. While this reduces the likelihood of leaching, it increasing the chances of being carried to surface water via runoff or soil erosion. Pesticide active ingredients with high K_{OC} values may also be more difficult to move into the soil profile and control soil dwelling pests.

- Select pesticides that have a low runoff and leaching potential.
- Before applying a pesticide, evaluate the impact of site-specific characteristics (for example, proximity to surface water, water table, and well-heads; soil type; prevailing wind; etc.) and pesticide-specific characteristics (for example, half-lives and partition coefficients)
- Understand pesticide sorption principles so that appropriate decisions can be made.
- Understand site characteristics that are prone to leaching losses (for example, sand-based putting greens, coarse-textured soils, shallow water tables).
- Identify label restrictions that may pertain to your facility.
- Avoid using highly water-soluble pesticides.
- Exercise caution when using spray adjuvants that may facilitate off target movement.

9.3.2 Drift

Pesticide drift occurs as either physical or secondary drift. Physical drift is associated with off target movement due to wind, with areas directly downwind of the application demonstrating higher effects. Secondary drift may occur from pesticide volatilization, temperature inversions, and movement due to rainfall or on dust particles. Drift poses several problems, including economically damaging plants or crops downwind of the pesticide application, less effective control in the target area, and airborne contamination that may be harmful to humans and other organisms. In severe cases, pesticide drift that causes economic or social harm can lead to legal ramifications; therefore, precautions should be taken to reduce and avoid pesticide drift. For additional information, reference *Controlling Drift of Crop Protection Materials* and *Preventing Pesticide Spray Drift* (Video) by MU Extension.

- Avoid spraying when sustained winds are greater than 10 mph and/or when relative humidity is less than 50%.
- Keep sprayer nozzle or boom close to the soil surface or crop canopy by using wide-angle nozzles.
- Select an appropriate sprayer and nozzle for the pesticide being applied.
- Calibrate the sprayer and perform routine maintenance.

9.4 Pesticide Transportation, Storage and Handling

Storage and handling of pesticides in their concentrated form poses the highest potential risk to ground or surface waters. For this reason, it is essential that facilities for storing and handling these products be properly sited, designed, constructed, and operated. For construction and design best management practices, see *Planning, Design, and Construction* section.

Best Management Practices

9.4.1 Pesticide Storage and Transport

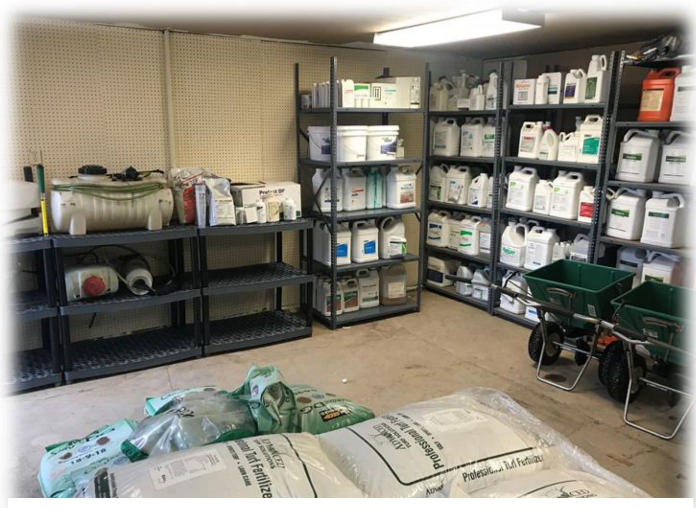

Figure 9-1. Chemical storage with pesticides and fertilizer stored separately on metal shelving at Bogey Hills Country Club (St. Charles, MO).

- 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 from other types of structure 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 and no drains, although a sump may be included.
- Sloped ramps should be provided at the entrance to allow 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.
- 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 inside the pesticide storage facility.
- PPE should be easily accessible and stored immediately outside the pesticide storage area.
- 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.
- An inventory of the pesticides kept in the storage building and the Safety Data Sheets (SDS) for the chemicals used in the operation should be accessible on the premises, but not kept in the pesticide storage room itself.

9.4.2 Pesticide Shelf Life

- Avoid purchasing large quantities of pesticides that require storage for greater than six months.
- Adopt the “first in–first out” principle, using the oldest products first to ensure that the product shelf life does not expire.
- Ensure labels are on every package and container.
- Consult inventory when planning and before making purchases.
- Ensure that labels remain properly affixed to their containers.
- A hazardous waste determination is required of any pesticide destined for disposal. Refer to Missouri DNR’s Managing Pesticide Waste document.
- If possible, use up old pesticides according to the label to avoid the costly disposal option.

9.5 Emergency Preparedness and Spill Response

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. If a spill or emergency occurs, call the Missouri Department of Natural Resources immediately for consultation on the most effective course of action. Notification is required by law. The 24-hour Environmental Emergency Response Hotline is (573) 634-2436.

Best Management Practices

- Develop a golf course facility emergency response plan which 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 (for example, fire fighters, etc.) to show them the facilities and to discuss the emergency response plan. Seek advice on ways to improve the plan.
- Consult the U.S. EPA's Emergency Planning and Community Right-to-Know Act on additional reporting protocol.

9.6 Pesticide Record Keeping

Maintaining accurate records of pesticide-related activities (for example, purchasing, storage, inventory, applications, etc.) is essential. Record keeping and maintenance of those records for three years after application is required by law for use of all pesticides by certified commercial applicators and for use of restricted-use pesticides by certified noncommercial applicators and public operators. 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.

Best Management Practices

- Records must contain the following information:
  - Name and license number of certified applicator
  - Name of noncertified applicator or name and license number of the pesticide technician using the pesticide if applicable.
  - Application date
  - Name and address of golf course, with brief description and total area of application site (i.e. hole numbers and area type (i.e. tee, green, etc.)).
  - Target pest(s) controlled or prevented by pesticide use.
  - Complete trade name and EPA registration number from the pesticide label.
  - Total amount and application rate of pesticide used
  - Weather conditions, including wind direction and speed and air temperature, at the time of application
  - Optional records to aid in review of pest control
  - Formulation type, carrier volume, sprayer pressure and application equipment (including nozzle type).
  - Amount applied of adjuvant/surfactant, pH buffer, spray/marking dye or pigment, etc.

    - Additional pest information, such as the severity of the infestation or life stage of the pest
    - Follow-up notes detailing the effectiveness of the application
- 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.

9.7 Pesticide Sprayers

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 facility. Properly calibrated application equipment is paramount to mitigating environmental and human health concerns.

Best Management Practices

- Use an appropriately sized applicator for the size of area being treated.
- Equipment too large in size requires greater volumes to prime the system. This can result in significant waste that must be properly handled.
- Ensure spray technician is experienced, licensed, and properly trained.
- Minimize off-target movement by using properly configured application equipment.
- Properly calibrate all application equipment at the beginning of each season (at a minimum) or after equipment modifications - Guide for Calibrating Boom Sprayers – USDA NRCS.
- Check equipment daily when in use. Use of the 128th rule routinely can help determine if nozzles are operating efficiently.
- Use recommended spray volumes for the targeted pest to maximize efficacy.
- Calibration of walk-behind applicators should be conducted for each person making the application to take into consideration their walking speed, etc.

9.8 Mixing/Washing Station

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 (CMC).

Best Management Practices

- Loading pesticides and mixing them with water or oil diluents should be done 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).
- Apply liquids and sediments as you would 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 waste.

- Prior to discarding any pesticide/pesticide waste, a hazardous waste determination must be made to ensure proper disposal. See the Managing Pesticide Waste publication from the Missouri DNR.
- Sweep up solid materials and use as intended.

9.9 Pesticide Disposal

Wash water from pesticide application equipment must be managed properly, since it contains pesticide residues. The containers of some commonly used pesticides are classified as hazardous wastes if not properly rinsed, and as such, are subject to the many rules and regulations governing hazardous waste. The improper disposal of a hazardous waste can result in very high fines and/or criminal penalties. However, pesticide containers that have been properly rinsed can be handled and disposed of as nonhazardous solid waste.

Federal law (FIFRA) and some state laws require pesticide applicators to rinse all empty pesticide containers before taking other container disposal steps. Under federal law (the Resource Conservation and Recovery Act, or RCRA), a pesticide container is not empty until it has been properly rinsed.

Best Management Practices

9.9.1 Wash Water Disposal

- Collect wash water (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 as makeup water for the next compatible application.
- If pesticide rinsate cannot be used according to the label it must be disposed of properly. See the Pesticide Rinsate Management publication from the Missouri Department of Natural Resources for more information.

9.9.2 Container Disposal

- 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 according to the label.

10 Pollinator Protection

Missouri native and cultivated plants alike need pollination to reproduce and grow fruit. While some plants are pollinated by wind, many require assistance from insects and other animals. In the absence of pollinators, many plant species, including the fruits and vegetables we eat, would fail to survive.

Plants and crops depend on a variety of different pollinators, including bees, wasps, butterflies, moths, beetles, ants, flies, spiders, bats, and birds. Over 450 species of native bees reside in Missouri. The western honey bee (*Apis mellifera*) is one of the most important pollinators in the United States. Many native bee species, including the bumble bee (*Bombus spp.*), also serve as important pollinator species in Missouri. Protecting bees and other pollinators is important to the sustainability of agriculture. The non-target effect of products used in golf course management is of increasing concern to pollinator conservation; therefore, pesticide applicators, including those on golf courses, need to be mindful of the impact that pesticides have on pollinator species and their habitat.

10.1 Regulatory Considerations

The U.S. EPA requires pollinator-protection language on pesticide labels. Pesticide applicators must be aware of honey bee toxicity groups and able to understand precautionary statements. More details on record-keeping and integrated pest management (IPM) principles can be found in sections on *Pesticide Management* and *Integrated Pest Management*, respectively.

Best Management Practices

- Proper records of all pesticide applications must be kept for restricted-use pesticides. Record-keeping is encouraged for all non-restricted-use pesticide applications as well. Include the following details in records:
  - Name and license number of certified applicator
  - Name of noncertified applicator or name and license number of the pesticide technician using the pesticide if applicable.
  - Application date
  - Name and address of golf course, with brief description and total area of application site (i.e. hole numbers and area type (i.e. tee, green, etc.)).
  - Target pest(s) controlled or prevented by pesticide use.
  - Complete trade name and EPA registration number from the pesticide label.
  - Total amount and application rate of pesticide used
  - Weather conditions, including wind direction and speed and air temperature, at the time of application
  - Optional records to aid in review of pest control
  - Formulation type, carrier volume, sprayer pressure and application equipment (including nozzle type).
  - Amount applied of adjuvant/surfactant, pH buffer, spray/marking dye or pigment, etc.
  - Additional pest information, such as the severity of the infestation or life stage of the pest
  - Follow-up notes detailing the effectiveness of the application

- Pesticide applicators and those making application decisions are encouraged to have a basic understanding of the following, in order to comply with federal and state regulations:
    - Pollinator protection label statements
    - Life cycles of honey bees, common native bees, and other important pollinators
    - Routes of pesticide exposure to non-target insects and pollinators
    - Direct and indirect effects of pesticides on pollinators and their habitat

10.2 Pollinator Habitat Protection

It is important to minimize the impacts of pesticides on pollinators. Pesticide applicators should use appropriate tools to help manage pests while safeguarding pollinators, the environment, and humans. To be mindful of pollinators when applying pesticides, work to minimize exposure to non-target pollinators in play and non-play course areas. However, a focus on direct exposure may not adequately protect pollinator species. Pesticides can also harm non-target organisms by negatively impacting their habitat.

Various pollinators require a diversity of flowering species to complete their life cycle. Good pollinator habitat will contain several wildflower species of different colors and heights, with blossoms throughout the entire growing season.

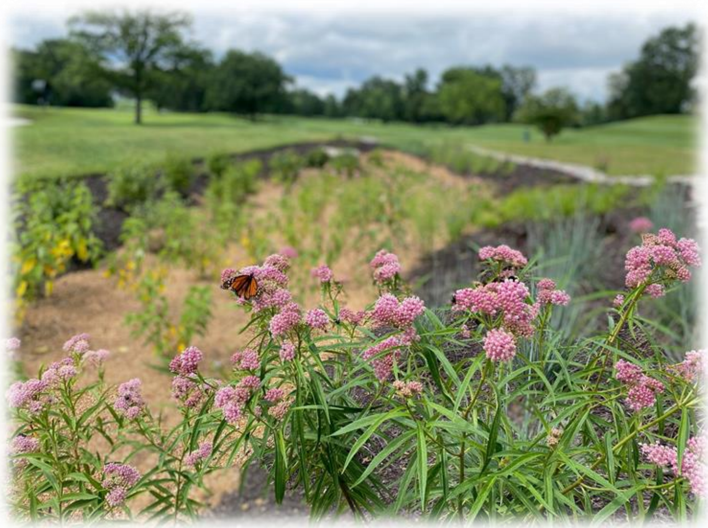

Figure 10-1. Monarch butterfly on native wildflowers at Bellerive Country Club (St. Louis, MO).

Best Management Practices

- Follow label information directing the application of pesticide when the plant may be in bloom. Avoid applying pesticides during bloom season.
- Stay on target by using coarse-droplet nozzles, and monitoring wind to reduce drift.
- Avoid applying pesticides when pollinators are active.
- Before applying a pesticide, scout/inspect the area for both harmful and beneficial insect populations, and use pesticides only when a threshold of damage has been indicated.
- Mow flowering plants (weeds) before insecticide application.
- If flowering weeds are prevalent, control them before applying insecticides.
- Use insecticides that have a lower impact on pollinators.
- Use the latest spray technologies, such as drift-reduction nozzles to prevent off- site (target) translocation of pesticide.
- Avoid applications during unusually low temperatures or when dew is forecast.
- Use granular formulations of pesticides that are known to be less hazardous to bees.
- Consider lures, baits, and pheromones as alternatives to insecticides for pest management.
- Develop new pollinator habitat and/or enhance existing habitat.

11 Maintenance Operations

Equipment maintenance, fueling, and chemical storage can have an impact on water quality on-site and off-site during the maintenance of existing golf courses. One of the key principles of pollution prevention is to reduce the unnecessary use of potential pollutants. With proper planning, golf course superintendents can prevent pollution events and reduce the likelihood that potentially hazardous materials will be discharged into the environment.

Office paper, recyclable plastics, glass, and aluminum should be recycled. Place containers for recycling aluminum cans and glass or plastic soft drink bottles at convenient locations on the golf course.

11.1 Regulatory Considerations

Regulations are in place at the local, state, and national levels that impact maintenance operations on Missouri's golf courses. These laws are in place to minimize the environmental impact. Missouri golf course superintendents should maintain ongoing contact with relevant regulatory agencies and experts to stay up to date on proper compliance protocol.

Federally, the Army Corps of Engineers or Environmental Protection Agency may have jurisdiction of projects impacting local surface waters. Local permitting agencies include the Missouri Department of Agriculture, Missouri Department of Natural Resources, and Missouri Department of Conservation. A stormwater pollution prevention plan (SWPPP) is required under all Missouri land disturbance general permits. The Missouri Pesticide Use Act and Missouri Pesticide Registration Act further guide pesticide use and registration in Missouri and are overseen by the Missouri Department of Agriculture. See Pesticide Laws and Regulations by University of Missouri Extension for a comprehensive overview of regulatory considerations.

The Missouri Solid Waste Disposal Law restricts major appliances, whole tires, oil, and lead-acid batteries from being disposed of in landfills. Be sure to familiarize yourself with all state and local laws related to disposal/recycling of these waste materials. The Missouri Department of Natural Resources developed a publication for Used Oil Generators and Burners and a guide titled *What to do with items banned from landfills.* The Missouri DNR regulates petroleum and hazardous substance underground storage tanks (10 CSR 26-2). Aboveground storage tanks are also subject to inspection by the Missouri Department of Agriculture through the Petroleum/Propane/Anhydrous Ammonia Program.

11.2 Storage and Handling of Chemicals

Proper handling and storage of 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. 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 water bodies. Wash water from pesticide application equipment must be managed properly, since it contains pesticide residues. This applies to wash water from both the inside and the outside of the application equipment. Material should be collected and used as a pesticide in accordance with the label instructions for that pesticide. Any product which cannot be used per label directions must be disposed of properly, refer to the Missouri Department of Natural Resources publication Managing Pesticide Waste for guidance.

The proper handling and storage of pesticides is important. Failure to do so correctly may lead to the serious injury or death of an operator or bystander, fires, environmental contamination that may result in large fines and cleanup costs, civil lawsuits, the destruction of the turf you are trying to protect, and wasted pesticide product.

The Bureau of Pesticide Control under the Missouri Department of Agriculture regulates pesticide use and application in Missouri. University of Missouri Extension has assembled *Safe Use, Storage, and Disposal of Pesticides* as a guide for users.

For valuable information about constructing chemical mixing facilities, reference the Midwest Plan Service book, Designing Facilities for Pesticide and Fertilizer Containment (revised 1995); the Tennessee Valley Authority (TVA) publication, Coating Concrete Secondary Containment Structures Exposed to Agrichemicals (Broder and Nguyen, 1995); and USDA–NRCS Code 703.

Best Management Practices

11.2.1 Proper Warning Signs and Personal Protection

- Storage buildings should have appropriate warning signs and placards.
- Follow all personal protective equipment (PPE) statements on pesticide labels.
- Store PPE away from pesticide storage areas in an area that is easily accessible.
- Develop an emergency response plan and educate all golf course personnel regarding emergency procedures on a regular basis.
- Individuals conducting emergency chemical cleanups should be properly trained under requirements of federal Occupational Safety and Health Administration (OSHA).
- Maintain detailed records of current pesticide inventory in the storage facility. Safety Data Sheets (SDS) for the chemicals stored on-site should be stored separate from the storage room, but readily accessible on-site.

11.2.2 Storing Chemicals

- Store pesticides in a lockable concrete or metal building.
- Locate pesticide storage separately from fertilizer storage, preferably in a different building.
- If possible, floors of chemical storage buildings should be impervious and sealed with chemical-resistant paint.
- If possible, floors of chemical storage buildings should have a continuous sill to contain spills and should not have a drain. A sump is acceptable.
- Shelving should be fabricated from plastic or reinforced metal. Metal shelving should be painted to avoid corrosion. Wood shelving should never be used because of its ability to absorb spilled pesticides.
- Automatic exhaust fans and an emergency wash area may be installed to mitigate spills.
- Explosion-proof lighting may be required. Ensure proper ventilation in case of volatile compounds being released.
- Do not store large quantities of pesticides or chemicals for long periods of time. Follow a “first in, first out” principle to rotate products into use to ensure products do not expire.
- Store chemicals in original containers. Never store them in containers that might be mistaken as packaging for food or drink.
- Arrange containers so the labels are clearly visible. Securely fasten loose labels to ensure containers and associated labels are kept together.

- Damaged labels should be replaced immediately.
- Store flammable pesticides separate from those that are nonflammable.
- Store liquid materials below dry materials to prevent leaks from contaminating dry products.
- Ensure that oil containers and small fuel containers (service containers) are properly labeled and stored within the facility.

11.2.3 Handling Chemicals

- If possible, use a chemical mixing center (CMC) as a place for performing all operations where pesticides are likely to be spilled in concentrated form—or where even dilute formulations may be repeatedly spilled in the same area—over an impermeable surface. (A CMC is a concrete pad treated with a sealant and sloped to a liquid-tight sump where all of the spilled liquids can be recovered.)
- Keep spill cleanup equipment available when handling pesticides or their containers.
- If a spill occurs of a pesticide covered by certain state and federal laws, you may need to report any accidental release if the spill quantity exceeds the "reportable quantity" of active ingredient specified in the law. Refer to the SDS sheets for any reportable quantities.
- Large spills or uncontained spills involving hazardous materials/waste may best be remediated by hazardous material cleanup professionals.
- For emergency (only) information on hazards or actions to take in the event of a spill, call CHEMTREC, at (800)424–9300. CHEMTREC is a service of the Chemical Manufacturers Association. For information on whether a spilled chemical requires reporting, call the CERCLA/RCRA help line at (800) 424–9346.

11.2.4 Washing Chemical Mixing Pads

- Flush mixing pad with clean water after the equipment is washed. Captured wash water can be used as a dilute pesticide per labeled site, or it may be pumped into a rinsate storage tank for use in the next application (FIFRA, Section 2 (ee)), allows the applicator to apply a pesticide at less than the labeled rate).
- The sump should be cleaned of any sediment before another type of pesticide is handled.
- Discharge to a treatment system that is permitted under industrial wastewater rules.
- Never discharge to a sanitary sewer system without written permission from the utility.
- Never discharge to a septic tank.
- Use non-containment wash water for field irrigation.
- Do not discharge non-contaminated wastewater during or immediately after a rainstorm, since the added flow may cause the permitted storage volume of the stormwater system to be exceeded.

11.3 Waste Disposal

Proper disposal of waste materials is critical for protection of water and natural resources. Some pesticides can interfere with local stormwater treatment processes and should never be dumped directly in a drain or stormwater outlet. The Missouri Solid Waste Disposal Law restricts major appliances, whole tires, oil, and lead-acid batteries from being disposed of in landfills. The Missouri Department of Natural Resources developed a guide for getting rid of these items: *What to do with items banned from landfills*. In order to minimize potentially hazardous waste, 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

11.3.1 Disposing of Pesticides

- Pesticides that have been mixed that cannot be legally applied to a site in accordance with the label must be disposed of and may be classified as hazardous waste depending on the materials involved. Contact local waste officials or the Missouri Department of Natural Resources. Refer to Managing Pesticide Waste publication for specific disposal information.
- Ensure that all containers are sealed, secured, and properly labeled. Use only regulatory agency-approved, licensed contractors for disposal.
- Rinse pesticide containers as soon as they are empty. Pressure rinse or triple- rinse containers, and add the rinse water to the sprayer. If rinsate cannot be used per label directions it must be disposed of properly, see the Missouri Department of Natural Resources' Pesticide Rinsate Management document.
- Shake or tap non-rinseable containers, such as bags or boxes, so that all dust and material fall into the application equipment.
- After cleaning them, puncture the pesticide containers to prevent reuse (except glass and refillable mini-bulk containers).
- Keep the rinsed containers in a clean area, out of the weather, for disposal or recycling.
- Storing the containers in large plastic bags/tubs to protect the containers from collecting rainwater.
- Recycle rinsed containers in counties where an applicable program is available, or take them to a landfill for disposal. Even though it is legal to place properly rinsed pesticide containers in the trash, check with your local landfill before discarding containers into the trash, as not all landfills will accept them.

11.3.2 Disposing of Other Hazardous Materials

- Collect used oil, oil filters, antifreeze, solvents, and degreasers in separate marked containers and recycle them as directed by local and state authorities.
- Arrange pickup of used oil, or deliver to a hazardous waste collection site. Refer to the Missouri Department of Natural Resources' Licensed Hazardous and Infectious Waste Transporter List for companies who can legally haul used oil in Missouri.
- Do not mix used oil with used antifreeze or sludge from used solvents.
- Antifreeze is considered hazardous if it contains metals, such as lead (see Antifreeze Waste Management Guide). Commercial services are available to collect and recycle antifreeze.
- Solvent contaminated wipes may need to be managed as hazardous waste depending on the type of solvent used. Contact the Missouri Department of Natural Resources at 573-751-5401 for the proper management of solvent contaminated wipes.
- Lead-acid batteries are classified as hazardous waste and should be properly managed (see The Universal Waste Rule in Missouri publication).
- Store old batteries on impervious services where they are protected from rainfall and recycle as soon as possible.
- Recycle used tires by contacting local tire dealers. Retailers and storage sites accepting scrap tires may charge a fee to cover disposal costs.
- Recycle or dispose of fluorescent tubes/lamps and other lights according to state requirements. Fluorescent lamps should be managed under the Universal Waste Rule in Missouri.

11.4 Equipment Storage and Maintenance

Storing and maintaining equipment properly will extend useful life and reduce repairs. Ideally, equipment should be stored in a covered area complete with a sealed impervious surface to limit risk of fluid leaks contaminating the environment. If this is not possible, golf course superintendents can reduce risks of contamination by washing equipment on an impervious surface prior to storing, closely monitoring for fluid leaks, and quickly repairing equipment when leaks occur.

Over time, the routine discharge of even small amounts of solvents can result in serious environmental and liability consequences, because of the accumulation of contaminants in soil or groundwater. Generating as little as 25 gallons per month of used solvents for disposal can qualify you as a "small-quantity generator" of hazardous waste, triggering EPA and state reporting requirements. Prevent solvents from draining onto pavement or soil, or discharging into water bodies, wetlands, storm drains, sewers, or septic systems, even in small amounts. The Missouri Department of Natural Resources' Handbook for Small Quantity Generators outlines hazardous waste management in Missouri.

Best Management Practices

11.4.1 Equipment Storage

- Store and maintain equipment in a covered area complete with a sealed impervious surface, if possible, 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 turf 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 (VOC).
- When possible, replace solvent baths with recirculating water-based 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.

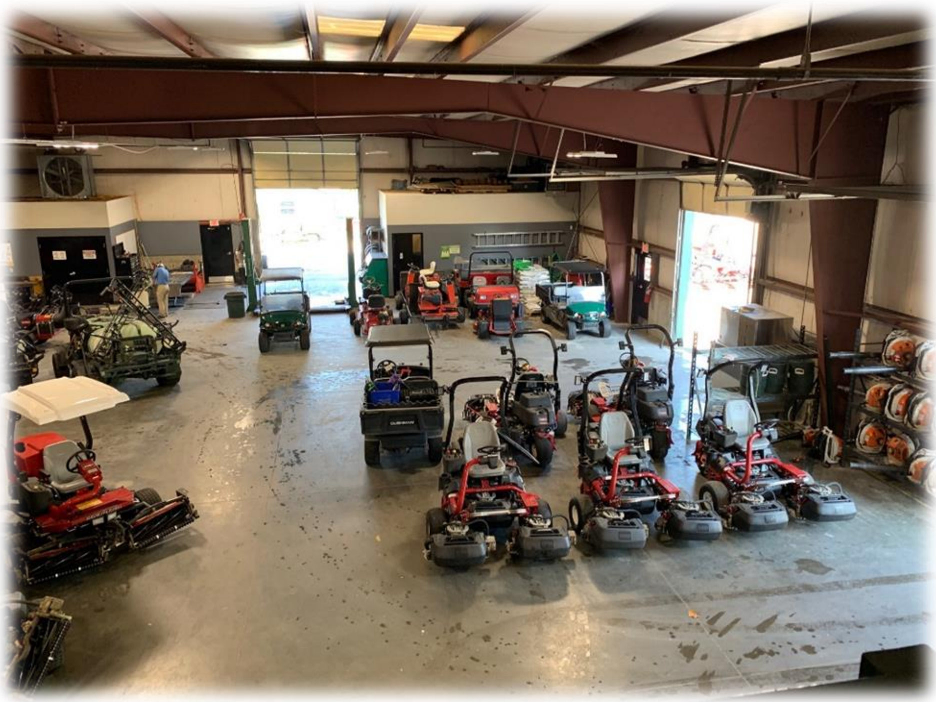

Figure 11-1. Equipment storage facility at the National Golf Club of Kansas City (Kansas City, MO).

11.4.2 Equipment Maintenance

- Always use appropriate PPE when working with solvents.
- Prevent solvents or degreasers from draining onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.
- Collect used solvents and degreasers, place them into containers marked with the contents and the date, and then have them picked up by a service that properly recycles or disposes of them. Never mix used oil or other liquid material with the used solvents.

11.5 Equipment Washing

An equipment-washing facility can be a source of both surface water and groundwater pollution, if the wash water generated is not properly handled. All equipment used in the maintenance of golf courses and associated developments should be designed, used, maintained, and stored in a way that eliminates or minimizes the potential for pollution.

Best Management Practices

- Wash equipment over a concrete or asphalt pad that allows the water to be collected. After the residue dries on the pad, collect, compost, or spread in the field.
- If possible, use a closed-loop wash-water recycling system and follow appropriate BMP.
- If applicable, allow runoff onto a grassed area to soak into the ground, but never into a surface water body or canal.
- 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 can be used to minimize water usage. Reduce direct wastewater flow into surface waters or storm drains.
- Blow off all equipment with compressed air to reduce damage to hydraulic seals.
- Avoid washing equipment in the vicinity of wells or surface water bodies.
- Minimize the use of detergents. Use only biodegradable non-phosphate detergents.
- Do not conduct equipment wash operations on a pesticide mixing and loading pad. (This keeps grass clippings and other debris from becoming contaminated with pesticide).
- Oil/water separators can be used but must be managed properly to avoid problems. Do not wash equipment used to apply pesticides on pads with oil/water separators.

11.6 Fueling Facilities

Safe storage of fuel, including use of above-ground tanks and containment facilities, is critical to the protection of the environment. The Missouri Department of Agriculture regulates petroleum and hazardous substance aboveground storage tanks. Aboveground storage tanks are also subject to inspection by the Missouri Department of Agriculture through the Petroleum/Propane/Anhydrous Ammonia Program.

Best Management Practices

- Locate fueling facilities on roofed areas with a concrete (not asphalt) pavement. Areas should be equipped with spill-containment and recovery facilities.
- Store small gas and diesel cans in flammable safety cabinets.

12 Landscape

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.

12.1 Species Selection and Size Considerations

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, and light patterns, insects, and other pests, and endemic nutrient levels over thousands of years. It is important to understand the ultimate sizes and growth rates of trees, shrubs, and ground covers in order to reduce the need for pruning and debris removal. 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 BMP 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 lower nutritional input requirements once 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 or low-maintenance plant material that requires little to no maintenance after establishment. Additionally, it is beneficial if 50% to 70% of the non-play areas 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 to provide wildlife habitat in non-play areas, along water sources to support fish and other water-dependent species. By leaving dead trees (snags) where they do not pose a hazard, a well-developed understory (brush and young trees), and native grasses, the amount of work needed to prepare a course is reduced while habitat for wildlife survival is maintained.

For recommended plant species in Missouri, see:

- Native Plants for Your Landscape - Missouri Department of Conservation
- Native Plant Database - Missouri Prairie Foundation
- Native Landscaping Manual - Missouri Botanical Garden
- Managing Lawns and Turfgrass - University of Missouri Extension

Figure 12-1. Low maintenance grass alongside the course at the National Golf Club of Kansas City (Kansas City, MO).

Best Management Practices

- Base plant selection as close to a natural ecosystem as practical, while meeting the needs of the golf course. It has adapted specifically to the soil, microclimate, rainfall, light patterns, insects and other pests, and endemic nutrient levels over many years.
- 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 map. In Missouri, cold-hardiness zones range from 5b to 7b.
- Select stress-tolerant species or cultivars to manage periodic dry/wet conditions depending on landscape position.
- Choose the most stress-tolerant species or cultivar for a particular area if economically feasible.

12.2 Design and Function

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 turf 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 turf. Garden plants, shrubbery, ground covers, or native plants may provide a pleasing 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 forested buffers should contain a mixture of fast- and slow- growing native trees, shrubs, and grasses to provide a diverse habitat for wildlife.
- Use forested buffers to trap and remove upland sources of sediments, nutrients, and chemicals.
- Use forested buffers to protect fish and wildlife by supplying food, cover, and shade.
- Use forested buffers to maintain a healthy riparian ecosystem and stable stream channel.
- Leave dead tree snags whenever possible for nesting and food source to wildlife. However, make sure that these snags are a safe distance away from playing surfaces should they get blown over.
- Use turf as a landscape element where needed.

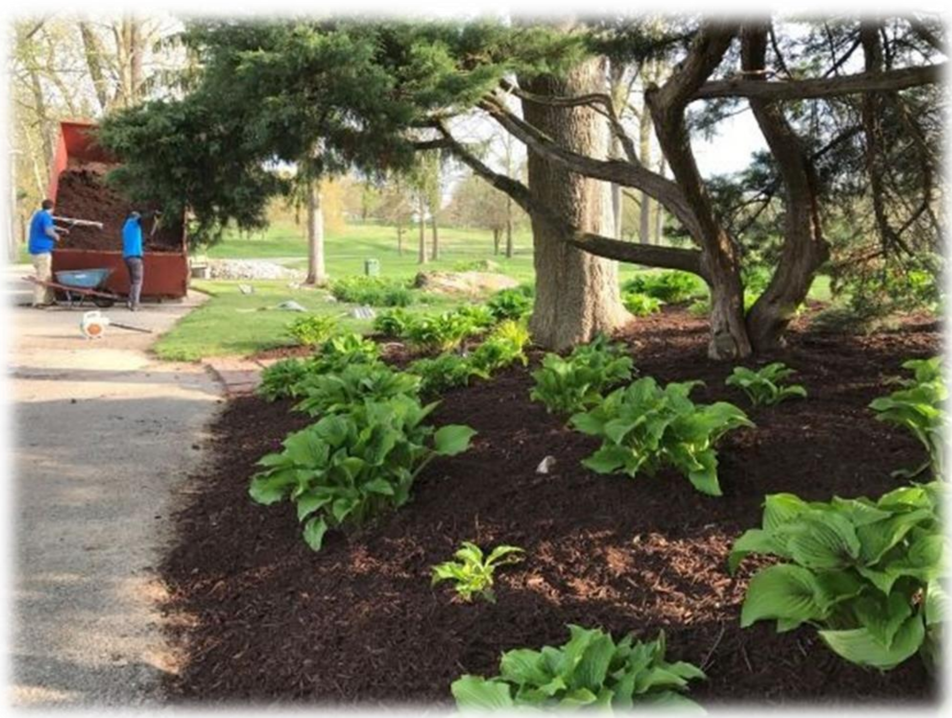

Figure 12-2. Shade-tolerant plants incorporated into the landscape design at Bogey Hills Country Club (St. Charles, MO).

12.3 Planting Methods

The ideal plant from an environmental standpoint is specifically adapted to the soil, microclimate, rainfall, light patterns, insects, and other pests, and endemic nutrient levels of a given location. A BMP goal is to maintain as close to a natural ecosystem as practical, while meeting the needs of the golf course. 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, considering, 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 hydro-zones should be minimized. Local government ordinances often address the percentage of irrigated landscaped area that may be included in high-water-use hydro-zones. These high water-use limits should not apply to landscaped areas requiring large amounts of turf for their primary functions (for example, ball fields and playgrounds).
- 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 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.

13 Energy

According to the GCSAA Golf Course Environmental Profile, Vol. IV (GCSAA 2012), golf facility managers must take steps toward identifying options for conservation, efficiency, and cost savings. Golf courses utilize electricity, gasoline, diesel, natural gas, propane and heating oil. Each of these energy sources has various degrees of energy efficiency and carbon footprints. Additionally, golf course managers can strategically improve energy efficiency and reduce energy by using fuel-efficient vehicles, energy efficient building materials, and more.

To address current needs and future energy reduction opportunities, managers should start by assessing current energy conservation performance practices based on the following categories:

- General energy conservation position statements on policy and planning
- Buildings and amenities statements –buildings, infrastructure and facility amenities such as the clubhouse, swimming pool, restaurant, parking lot, kitchen, offices, maintenance building(s), tennis courts, etc.
- Golf course statements – the golf course and surrounding landscapes, pump station, irrigation system and related agronomic operations (playing surfaces, equipment, turfgrass maintenance etc.)

More resources on energy policies and efficiency standards can be found through the Missouri Division of Energy and the Missouri Energy Initiative.

13.1 Energy Principles

13.1.1 Conservation

Energy conservation should be an intentional component of a facility's overall environmental plan. An effective energy management plan for the facility begins with understanding current and projected energy use and identifying areas of improved efficiency. Once established, the energy management plan can be communicated 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. The irrigation pump is the largest user of energy; thus, a well-engineered pump station is critical to reducing energy consumption.

Best Management Practices

- Conduct an energy audit.
- Conduct a lighting audit.
- Conduct a carbon footprint analysis.
- Add insulation, where needed, to improve energy efficiency.
- Charge golf carts, use pumps to acquire water, charge maintenance equipment, and other items later in the day or early in the morning to take advantage of non- demand electrical rates.
- Limit high-consumption activities during periods when demand is high.
- Use alternative energy from natural sources, such as solar, geothermal and wind energy generation where possible.

- Upgrade or install National Electrical Manufacturers Association's (NEMA) premium efficiency-rated pump motors.
- Seek output reduction by watering less area, apply target golf goals.
- Install LED lighting and/or retrofit devices.
- Install motion sensors for lights where appropriate.
- Install a programmable thermostat.
- Install solar/GeoThermal pumps for pools and spa.

13.1.2 Efficiency

Energy efficiency can be optimized by minimizing the total energy consumed to meet a certain goal, such as irrigating the course or heating a building. Efficiency can be increased in a number of ways, such as installing energy efficient lighting and appliances, using proper irrigation scheduling, and planning ahead for maintenance operations.

Increased energy efficiency typically leads to lower overall energy costs, but these rate reductions may not occur immediately. For instance, an initial investment in new energy efficient technologies may immediately reduce energy costs, but it may take several years for the energy savings to pay for the technological investment. Therefore, superintendents should consider various options and understand the return-on- investment of new energy-saving technologies.

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 of infrastructure/hard items and behavioral/process-oriented items.
- Consider alternative equipment, products, and practices.

13.2 Energy Consumption

13.2.1 Infrastructure

Ensure efficient building/facility/amenities and related infrastructure. Consider the materials: used insulation and color selection. Ensure efficient lighting in both interior and exterior areas.

Best Management Practices

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

13.2.2 Irrigation

Ensure efficient design, selection, operation, and maintenance of irrigation pumps, irrigation controls, and other irrigation components to optimize energy use. Assess irrigation pump efficiency; consider alternative equipment, products, and practices; use energy efficiently to maximize the output of the pump station.

Best Management Practices

- Audit irrigation system (see Irrigation BMP).
- Schedule and operate pumps and irrigation in an efficient manner.
- Identify and implement infrastructure and behavioral changes.
- Evaluate technology and upgrades; implement when feasible.

13.3 Management Strategies

13.3.1 Evaluation

Continually track and measure energy use at the facility based on energy assessment units, for example, kilowatt hour. Benchmark practices to evaluate existing facility consumption with other local golf facilities of similar size and monitor energy use monthly.

Best Management Practices

- Monitor energy use: track data, evaluate billing meters.
- Install adequate meters, gauges, etc.
- Develop an equipment inventory incorporating individual equipment's energy use, use / traffic patterns, etc. (maintenance records, operation hours, etc.).
- Establish a baseline for performance parameters to optimize irrigation pumps.
- Consider benchmarking performance against similar-sized facilities.

13.3.2 Design and Renovation

Once evaluations, assessments, and audits are complete, these analyses can inform design and renovation decisions. Consider the initial investment compared to short- and long-term gains. Redesign – evaluate future projects with a priority for energy conservation. According to system and compliance standards, communicate plans with utility provider, insurance company, 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.

13.3.3 Implementation Plan

Develop an implementation plan by setting goals for buildings/amenities and the golf course operation. 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 as part of purchase/decision-making process for HVAC, food service, laundry, swimming pools, etc.
- Consider other devices as part of the plan; do research on building, pumps, and power generation.

13.3.4 Course Management Plan

Set energy-use goals for efficiency/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/ conservation practices.

Best Management Practices

- Work with energy providers and evaluate existing programs, resources, etc.
- Consider long-term costs in addition to acquisitions.
- Schedule reviews to evaluate future technology and fuel types.
- Evaluate upgrades.
- Evaluate use of alternative energy/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.

13.3.5 Certification Programs

Incentives and programs from energy providers may assist with implementing the energy management plan. Additionally, consider U.S. Green Building Council's LEED program or EPA's EnergyStar, Portfolio Manager, etc. to obtain energy efficiency certificates or credits.

Best Management Practices

- Evaluate alternative transportation and energy sources.
- Evaluate cleaning practices (dry vs. wet).
- Consider local vs. distant purchases, product selection, etc.
- 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.

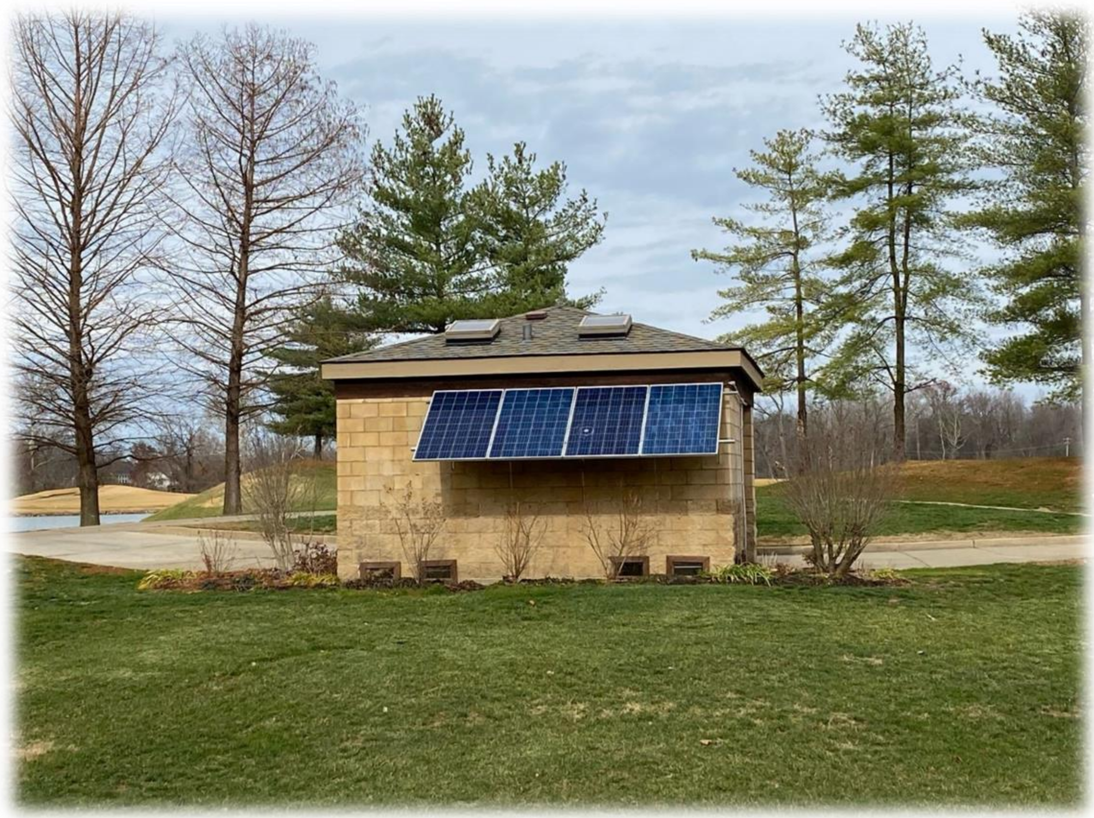

Figure 13-1. Solar panel used to power water and ice machine at Old Hickory Golf Club (St. Peter's, MO).

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(Note: URLs are as of December 2020)

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