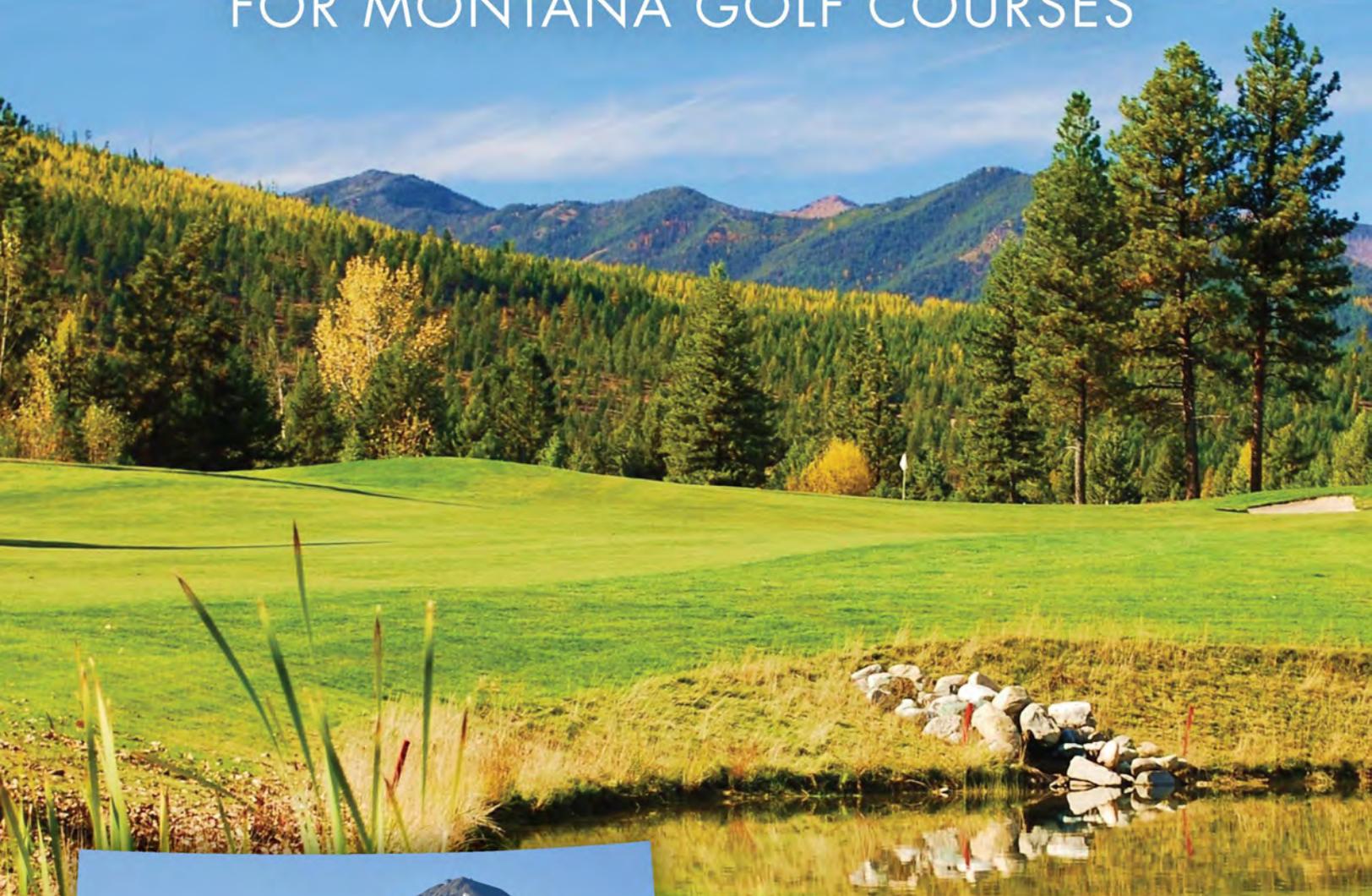


Best Management Practices

FOR MONTANA GOLF COURSES



Peaks & Prairies Golf Course
Superintendents Association



BMP Best Management Practices

Best Management Practices Planning Guide & Template



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 GCSAA, USGA, PGA TOUR.



Copyright free

Permission to copy and distribute content from the Best Management Practices for the Enhancement of Environmental Quality on Florida Golf Courses has been granted by the Florida Department of Environmental Protection, January 2007

Table of Contents

Introduction	4
Acknowledgement	5
Additional Acknowledgement.....	7
BMP Index	8
Planning, Design and Construction	11
Irrigation.....	21
Surface Water Management.....	45
Water Quality Monitoring and Management	55
Nutrient and Soils Management	64
Cultural Practices.....	76
Integrated Pest Management	81
Pesticide Management	93
Pollinator Protection.....	101
Maintenance Operations.....	104
Landscape	112
Energy	116
References	123

Introduction



Introduction

The golf course maintenance industry has long recognized environmental stewardship as playing a vital role in the short and long-term success of managing golf properties. The GCSAA (Golf Course Superintendents Association of America) has offered environmental programs and education as part of its member services for decades. After a few of GCSAA's affiliated chapters developed golf course BMPs (Best Management Plans) for their states, it became apparent to GCSAA's leadership that it was important for this to be completed in all 50 states. The USGA (United States Golf Association) leadership also saw the need for development of this type of information to serve the game of golf and the properties on which it is played.

Working together to fund the BMPs were the USGA, EIFG (Environmental Institute for Golf) and the PGA Tour. All of these entities are committed to the long-term health of the game and the environment. The development of the BMP template serves as the tool for GCSAA affiliated chapters to either develop new, or refine an existing, BMPs for the state(s) of their members. The goal is to have a BMP in place for all 50 states by the end of 2020.

The Peaks & Prairies GCSA is an affiliated chapter of GCSAA with members primarily from Montana and Wyoming. A committee of 12 PPGCSA members (six from each state) volunteered to help develop the content for the Montana/Wyoming BMPs. Using the GCSAA developed template, information was customized to practices relevant in this geographic region. Consideration was given, but not limited, to Montana/Wyoming weather, plant materials, soils, water resources and features, regulatory requirements, weeds, disease and insect problems.

After this information was cross reviewed by all members of the committee, a draft was produced and distributed to several groups and individuals for review and feedback. Primarily, these included the Montana Department of Environmental Quality, Montana Department of Agriculture, the Montana State Golf Association and the Northern Plains Resource Council.

Our goal is to provide a resource helping to guide golf facilities as environmental stewards in their development, maintenance, and management of their recreational property.

Acknowledgement



Who We Are/ Acknowledgments

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.

Acknowledgments

The GCSAA and EIFG wish to thank the **University of Florida**, Institute of Food and Agricultural Sciences, faculty, Dr. J. Bryan Unruh, Dr. Travis Shaddox, Dr. Jason Kruse, and Mr. Don Rainey, who worked on this project, providing their knowledge and expertise to help the golf course industry; the **USGA** for their grant to fund this important project; the **volunteers who served on the task group** to review BMP and provide technical assistance; and the **Florida Department of Environmental Protection** for permission to copy its publication, "Best Management Practices for the Enhancement of Environmental Quality on Florida Golf Courses



Additional Acknowledgement



Thanks to the following Peaks & Prairies GCSA BMP Steering Committee members for their time and effort to develop this document.

Tom Bengtson - Glacier View Golf Club, West Glacier, MT

Jason Busch - The Powder Horn Golf Club, Sheridan, MT

Dwayne Dillinger, CGCS - Bell Nob Golf Course, Gillette, WY

Dane Gamble - Bridger Creek Golf Course, Bozeman, MT

Peter Grass, CGCS - Hilands Golf Club, Billings, MT

Stephen Grass - Hilands Golf Club, Billings, MT

Rick Hathaway - Rock Creek Cattle Company, Deer Lodge, MT

Jory Horsley - The Powder Horn Golf Club, Sheridan, MT

Jason Lamb - Sidney Country Club, Sidney, MT

Zac Leader - Sidney Country Club, Sidney, MT

Dan Tolson, CGCS - 3 Creek Ranch Golf Club, Jackson, WY

Garrett Turner - The Reserve at Moonlight Basin, Big Sky, MT

BMP Index

Planning, Design and Construction	11
Introduction	11
Planning	11
Design	12
Construction	13
Grow-in.....	14
Erosion and Sediment Control	14
Wetlands	15
Drainage.....	16
Surface Water: Stormwater, Ponds, Lakes	17
Maintenance Facilities.....	17
External Certification Programs	19
Wildlife Considerations.....	19
Irrigation.....	21
Water Management Approaches	21
Regulatory Considerations.....	22
Irrigation Water Suitability	22
Water Conservation and Efficient Use Planning	23
Irrigation System Design.....	24
Irrigation Pumping System.....	26
Irrigation System Program and Scheduling	27
Turf Drought Response.....	28
Irrigation System Quality	29
Pond Location and Design.....	30
Pond Use and Maintenance.....	32
Pond Water-Level Monitor	33
Metering	34
Irrigation Leak Detection	34
Sprinkler Maintenance	35
System Maintenance.....	36
Winterization and Spring.....	38
Sensor Technology	39
Maintained Turf Areas.....	40
Non-Play and Landscape Areas	41
Wellhead Protection	42
Fertigation	43
Surface Water Management.....	45
Stormwater Capture.....	45
Regulatory Considerations.....	46
Water Quality Protection	47
Dissolved Oxygen	49
Aquatic Plants	51
Human Health Concerns.....	52
Floodplain Restoration	52

Stormwater, Ponds, and Lakes	53
Water Quality Monitoring and Management	55
Regulatory Considerations.....	55
Local Involvement	55
Site Analysis.....	56
Water Quality Sampling Program.....	56
Sampling Parameters, Collection, and Analysis	57
Buffer Zones.....	58
Wetland Protection.....	60
Stormwater Management.....	60
Sediment.....	61
Sodic/Saline Conditions	61
Nutrient and Soils Management	64
Introduction	64
Soil Health.....	65
Soil Testing	66
Plant Tissue Analysis	67
Fertilizers Used in Golf Course Management	67
Soil pH.....	73
Nutrient Management.....	73
Cultural Practices.....	76
Mowing.....	76
Cultivation	78
Shade and Tree Management	79
Integrated Pest Management	81
Introduction	81
IPM Overview.....	82
Written Plan.....	83
Pest Thresholds	84
Monitoring	84
Record Keeping	85
Turfgrass Selection	86
Biological Controls	87
Pollinators	87
Conventional Pesticides.....	88
Disease	89
Weeds.....	90
Nematodes.....	91
Pesticide Management	93
Introduction	93
Human Health Risks	93
Environmental Fate and Transport.....	94
Pesticide Transportation, Storage, and Handling	94
Emergency Preparedness and Spill Response	95
Pesticide Record Keeping.....	95
Sprayer Calibration	96

Types of Sprayers	96
Inventory	97
Shelf Life	97
Leaching Potentials.....	97
Mixing/Washing Station.....	98
Disposal	98
Personal Protective Equipment.....	99
Pesticide Container Management	99
Pollinator Protection.....	101
Introduction	101
Pollinator Habitat Protection.....	102
Maintenance Operations.....	104
Introduction	104
Storage and Handling of Chemicals	104
Waste Handling.....	105
Equipment Storage and Maintenance.....	106
Equipment Washing.....	107
Fueling Facilities	107
Pollution Prevention	107
Landscape	112
Species Selection and Size Considerations	112
Design and Function	113
Planting Methods	114
Energy	116
Energy Conservation.....	116
Evaluation	117
Efficiency.....	117
Design and Renovation.....	119
Implementation Plan	119
Infrastructure.....	119
Alternative products, operations, and practices	120
Course Management Plan	120
Irrigation	121

Planning, Design and Construction

Introduction



The construction phase of any industry's infrastructure poses the greatest risk of ecosystem alteration. With proper planning and design, golf facilities can be constructed and maintained with minimal impact to existing wildlife and their habitat. Facilities should be designed and constructed to maximize energy efficiency.

Regulatory Issues

Local and state regulations may be in place in your location. Early engagement among developers, designers, local community groups, and permitting agencies is essential to designing and constructing a golf facility that minimizes environmental impact and meets the approval process.

Planning

Proper planning will minimize expenses resulting from unforeseen construction requirements. Good planning provides opportunities to maximize/integrate environmentally favorable characteristics into the property. This often requires the involvement of golf course architects, golf course superintendents, state and local agencies, civil engineers, soil scientists, agronomists, irrigation designers, ecologists, etc.

Best Management Practices

- Assemble a qualified team
 - Golf course architect
 - Golf course superintendent
 - Clubhouse architect
 - Irrigation engineer
 - Environmental engineer
 - Energy analyst
 - Economic consultant
 - Civil engineer

- Soil scientist
 - Geologist
 - Golf course builder
 - Legal team
- Determine objectives
- Complete a feasibility study
 - Are needs feasible given existing resources?
 - Financial
 - Environmental
 - Water
 - Energy
 - Labor
 - Materials
 - Governmental regulatory requirements/restrictions
- Consider ADA compliance during planning phase. The ADA Accessibility Guidelines (ADAAG) is the standard applied to buildings and facilities. Recreational facilities, including golf courses, are among the facilities required to comply with the ADA. Reference: <https://www.access-board.gov/guidelines-and-standards/recreation-facilities/guides/golf-courses>
- Select an appropriate site that is capable of achieving the needs of stakeholders.
- Identify strengths and weakness of the selected site.
- Identify any rare, protected, endangered or threatened plant or animal species on the site
- Identify any water quality impaired waterbodies on/adjacent to the site. Impaired waterbodies in Montana can be found through the Clean Water Information Center. <http://deq.mt.gov/water/resources/cwaic>

Design

Principles

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 golf course superintendent/project manager at the beginning of the design and construction process to integrate sustainable maintenance practices in the development, maintenance, and operation of the course.
- Design the course to minimize the need to alter or remove existing native landscapes including streams/rivers. The routing should identify the areas that provide opportunities for restoration.
- Design the course to retain as much natural vegetation as possible. Where appropriate, consider enhancing existing vegetation through the supplemental

- planting of native vegetation/materials next to long fairways, out-of-play areas, and along water sources supporting fish and other water-dependent species.
- Design out-of-play areas to retain or restore existing native vegetation where possible. Nuisance, invasive, and exotic plants should be removed and replaced with native species that are adapted to that particular site.
 - Greens
 - Select a location that has adequate sunlight to meet plant specific needs and provides sufficient drainage.
 - Choose a green size and sufficient number of hole locations that are large enough to accommodate traffic and play damage, but not so large that they are not sustainable with your resources.
 - Select an appropriate root-zone material as designated by the USGA.
 - Consider the number of bunkers as it relates to resources available for daily maintenance.
 - Irrigate greens separately from surrounding turf.
 - Select a turf species/variety that meets the desired playing conditions while suitable for the site's growing conditions.
 - Plant only certified turfgrass.
 - Decide whether bunkers will contain drainage.
 - Consider bunker entry and exit points. Consider wear patterns and create adequate space for ingress/egress points on greens, tees, fairways, and bunkers.
 - Select the proper color, size, and shape of bunker sand that meets your needs.
 - Define play and non-play maintenance boundaries.

Construction

Principles

Construction should be completed with care to minimize environmental impact and financial ramifications.

Best Management Practices

- Conduct a pre-construction conference with stakeholders and permitting entities. Reference: <http://dnrc.mt.gov/licenses-and-permits>
- Schedule construction to maximize turfgrass establishment and site drainage.
- Use environmentally sound construction techniques.
- Use soil stabilization techniques to minimize soil erosion and maximize sediment containment.
- Identify any environmentally sensitive areas such as streams, ponds, lakes, or wetlands on the site and construct sediment & stormwater control barriers prior to disturbing any soil around these areas.
- Maintain a construction progress report and communicate the report to the 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 of the work, while optimizing environmental conservation and resource management.
- Build temporary construction compounds in a way that minimizes environmental impacts.

Grow-in

Principles

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

- Prepare the area to be established and clear the area of pests (weeds, pathogens, etc.).
- Ensure erosion and sediment control devices are in place and properly maintained.
- Topdress the sod to fill in the gaps between sod pieces. This promotes quicker establishment and provides a smoother surface.
- Use appropriate seeding methods for your conditions. When using sod, nutrient applications should be delayed until sod has sufficiently rooted.
- Use slow-release nitrogen or light, frequent soluble-nitrogen sources during grow-in.
- Apply nutrients — in either foliar or granular formulations — to the turf surface. Incorporating nutrients into the root zone does not result in more rapid establishment and increases environmental risk.
- Mow as soon as sod has knitted-down or seedlings have reached a height of one-third greater than intended height-of-cut. This will hasten establishment.

Erosion and Sediment Control

Principles

- Soil carried by wind and water erosion transports contaminants with it. Contaminants can dislodge, especially on entering water bodies, where they can cause pollution.
- Erosion and sediment control is a critical component of construction and grow-in of a golf course. Many types of construction in or near water will require a MPDES storm water permit from DEQ.

Best Management Practices

- Develop a working knowledge of erosion and sediment control management.
- Reference the Montana Department of Environmental Quality field guide for best management practices for storm water management during construction to ensure erosion control measures are being constructed properly.
- 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.
- Use seeding, erosion control blankets, straw mulch & hydro-seeding to offer soil stabilization.

Wetlands

Principles

- Montana considers wetlands as “waters of the state,” a designation that carries significant legal ramifications. Furthermore, permitting requirements for wetlands can have multiple overlapping jurisdictions of federal, state, and local agencies. At the federal level alone, the U.S. Army Corps of Engineers (USACOE), EPA, U.S Fish and Wildlife Service (FWS), National Oceanic and Atmospheric Administration (NOAA), and maritime agencies may all be involved.
- Wetlands act both as filters for pollutant removal and as nurseries for many species of birds, insects, fish, and other aquatic organisms. The biological activity of plants, fish, animals, insects, and especially bacteria and fungi in a healthy, diverse wetland is the recycling factory of our ecosystem.
- When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turf areas with native vegetation or structural buffers. Constructed or disturbed wetlands may need to be permitted to be an integral part of the stormwater management system.

Best Management Practices

- Ensure that proper permitting has been obtained before working on any wetlands.
- Ensure that wetlands have been properly delineated before working in and around any wetlands.



Whitefish Lake Golf Club - Whitefish, MT

Drainage

Principles

- Adequate drainage is necessary for growing healthy turfgrass.
- 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.
- Drainage of the golf course features is only as good as the system's integrity. Damaged, improperly installed, or poorly maintained drainage systems will result in inferior performance that negatively impacts play and increases risks to water quality.

Best Management Practices

- Pay close attention to engineering details such as subsoil preparation, the placement of gravel, slopes, and backfilling when constructing drainage systems.
- Discharge internal golf course drains through pre-treatment zones and/or vegetative buffers, rather than directly into an open waterbody, in order to help remove nutrients and sediments.
- Discharge drainage through proper drainage and stormwater management devices, for example, vegetative buffers, swales, etc.
- Inspect the drainage system routinely to ensure proper function.
- Drain cart paths away from areas in play and follow hard surface runoff guidelines.

Surface Water: Stormwater, Ponds, Lakes

Principles

- 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.
- In general, construction activities which disturb more than one acre may require a National Pollutant Discharge Elimination System (NPDES) Permit. Contact the Montana Department of Environmental Quality to determine any requirements.

Best Management Practices

- Create stormwater treatment, 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.
- Include a Storm Water Pollution Prevention Plan (SWPPP) which will consider all sources & remedies of storm water pollution that should be monitored in all construction activities.
- 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.

Maintenance Facilities

Principles

The maintenance facilities must incorporate BMP to minimize the potential for contamination of soil and water resources. The pesticide mixing and storage facility, the equipment wash pad, and the fuel center are focal points.

Best Management Practices

- 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.
- Avoid storing 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.
- Place dry materials above liquids, never liquids above dry materials.
- Prevent placing liquids above eye level.
- Locate operations well away from groundwater wells and areas where runoff may carry spilled pesticides into surface waterbodies.
- Avoid building new facilities on potentially contaminated sites.
- Build an open building with a roof with a substantial overhang (minimum 30° from vertical, 45° recommended) on all sides.
- Construct a concrete mixing and loading pad, paying critical attention to the water-to-cement ratio (no higher than 0.45:1 by weight).
- Use a sump that is 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.
- Determine any material that collects on the pad as a pesticide, according to the label, or dispose of as a potentially hazardous waste, according to Montana state law and regulations.
- Clean up spills immediately!
- 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.
- 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.
- Avoid washing 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.
- Use a closed-loop recycling system for wash water.
- Recycle system filters, treat sludge and dispose of appropriately.
- Give each piece of equipment 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.
- Design pesticide storage to keep pesticides secure and isolated from the environment.

External Certification Programs

Principles

- Golf-centric environmental management programs or environmental management systems can help golf courses protect the environment and preserve the natural heritage of the game.
- These programs help people enhance 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 facility decision makers about the certification program.

Wildlife Considerations

Principles

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

Best Management Practices

- Identify the different types of 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.
- 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 pollinator 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.



Wilderness Club - Eureka, MT

Irrigation

Water Management Approaches



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 sustaining optimal course playability, aesthetics, marketability, and golfer participation.

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

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

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

Several benefits of adopting BMP are:

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

Conservation and Efficiency

Conservation and efficiency considers the strategic use of appropriate course and irrigation design, plant selection, computerized and data-integrated scheduling, and alternative water quality/supply options that maximize plant health benefits and reduce the potential for negative impacts on natural resources.

Resource Protection

Resource protection is an integrated approach that includes irrigation practices as part of the course design, pesticide and nutrient practices, and regulatory compliance plus structural measures as they concern environmental stewardship and policy.

Regulatory Considerations

Principles

- Golf course owners are responsible for contacting federal, state, and local water use authorities at the pre-and post-construction phase to determine annual or specific water consumption (water rights), permitting guidelines, and other requirements allowed by regulators.
- Superintendents have a responsibility to adhere to water-quality standard rules regarding groundwater and surface water flows resulting from the removal of water for irrigation use.

Best Management Practices

- Design and/or maintain a system to meet site's peak water requirements under normal conditions and also be flexible enough to adapt to various water demands and local restrictions.
- Develop an annual water budget for the golf course.
- Look for ways to increase efficiency and reduce energy use associated with irrigation systems and practices.
- Demonstrate good stewardship practices by supplementing watering only for the establishment of new planting and new sod, hand watering of critical hot spots, and watering-in of chemicals and fertilizers (if permissible).
- Protect aquatic life and impairment of water systems by adhering to state and local water withdrawal allocations (gallons/day).
- Design an irrigation system that delivers water with maximum efficiency.

Irrigation Water Suitability

Principles

- Golf course designers and managers should endeavor to identify and use alternative supply sources to conserve freshwater drinking supplies, promote plant health, and protect the environment.

- The routine use of potable water 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.
- When necessary, sodic water system treatment options should be included in the budget to address water quality and equipment maintenance.

Best Management Practices

- Use alternative water supplies/sources that are appropriate and sufficiently available to supplement water needs.
- 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.
- Monitor sodium and bicarbonate buildup in the soil using salinity sensors.
- Monitor shallow groundwater table for contamination of heavy metals and nutrients.
- Guarantee reclaimed, effluent, and other non-potable water supply mains have a thorough and correctly operating cross-connection and backflow prevention device in place.
- 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. Excess nutrients are more likely to runoff.
- Monitor reclaimed water tests regularly for dissolved salt content.
- Use, where practical, reverse-osmosis filtration systems to reduce chlorides (salts) from saline groundwater.
- Monitor the quantity of water withdrawn to avoid aquatic life impairment.
- Identify appropriate water supply sources that meet seasonal and bulk water allocations for grow-in and routine maintenance needs.

Water Conservation and Efficient Use Planning

Principles

- Document actual watering practices, especially to show savings in water use over averages. Communication should be maintained with water managers, ownership, golfers and the public to explain what you are doing and why.

- Potable water supplies in many areas of the United States 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 make an effort 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

- Select drought-tolerant varieties of turfgrasses to help maintain an attractive and high-quality playing surface, while minimizing water use.
- Plant non-play areas with drought-resistant native or other well-adapted, noninvasive plants that provide an attractive and low-maintenance landscape.
- Provide native plant species which are important in providing wildlife with habitat and food sources. After establishment, site-appropriate plants normally require little to no irrigation.
- Operate the system to provide only the water that is actually needed by the plants, or to meet occasional special needs such as salt removal.
- Design properly, so 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.
- Monitor soil moisture levels closely during a drought. Whenever practical, irrigate at times when the least amount of evaporative loss will occur.
- Control invasive plants or plants that use excessive water.

Irrigation System Design

Principles

- A well designed irrigation system should operate at peak efficiency to reduce energy, labor and natural resources.
- 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.

Best Management Practices

- Design a system with optimal distribution efficiency and effective root-zone moisture coverage. Target 80% or better Distribution Uniformity (DU).
- Design a system to allow the putting surface and slopes and surrounds to be watered independently.

- Include in the design package a general irrigation schedule with recommendations and instructions on modifying the schedule for local climatic soil and growing conditions. It should include the base ET rate for the particular location.
- Conduct saturated hydraulic conductivity tests periodically. The application rate must not exceed the infiltration rate (ability of the soil to absorb and retain the water applied during any one application).
- Establish a procedure where the design operating pressure is not greater than the available source pressure.
- Account for peak-use times and supply line pressures at final buildout for the entire system, using proper design operating pressure.
- Create a system flexible enough to meet a site's peak water requirements and allow for operating modifications to meet seasonal irrigation changes or local restrictions.
- Zone turf and landscape areas separately. Specific use areas zoned separately; greens, tees, primary roughs, secondary roughs, fairways, native, trees, shrubs, etc.
- Design an irrigation system to account for the need to leach out salt buildup from poor-quality water sources by providing access to freshwater.
- Install the irrigation system using only qualified specialists.
- Keep construction consistent with the design.
- Seek approval from the designer for any design changes before construction.
- Ensure construction and materials meet existing standards and criteria.
- Identify, prior to construction, all underground cables, pipes, and other obstacles, and flag their locations.
- Space permanent irrigation sprinklers and other distribution devices according to the manufacturer's recommendations.
- Base spacing on average wind conditions during irrigation. For variable wind directions, triangular spacing is more uniform than square spacing.
- Design distribution devices and pipe sizes for optimal uniform coverage.
- Ensure the first and last distribution device has no more than a 10% difference in flow rate. This usually corresponds to about a 20% difference in pressure.
- Ensure distribution equipment (such as sprinklers, rotors, and micro-irrigation devices) in a given zone has the same precipitation rate.
- Space heads for turf areas for head-to-head coverage.
- Design water supply systems (for example, wells, and pipelines) for varying control devices, rain shutoff devices, and backflow prevention.
- Design water conveyance systems with thrust blocks and air-release valves.
- Ensure flow velocity is 5 feet per second or less.
- Design pipelines to provide the system with the appropriate pressure required for maximum irrigation uniformity.
- Use pressure-regulating or compensating equipment where the system pressure exceeds the manufacturer's recommendations.
- Use equipment with check valves in low areas to prevent low head drainage.
- Install isolation valves in a manner that allows critical areas to remain functional.

- Install manual quick-coupler valves near greens, tees, and bunkers so these can be hand-watered to conserve when automated irrigation is not warranted.
- Install part-circle heads along lakes, ponds, and wetlands margins.
- 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.



Meadow Lark Country Club - Great Falls, MT

Irrigation Pumping System

Principles

- 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 as spikes and surges) are infrequent, and if the superintendent has access to qualified technical support.
- Design pumping systems for energy conservation.

Best Management Practices

- Ensure the design operating pressure is not greater than the available source pressure.
- Ensure the design operating pressure accounts 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 valves.
- Install VFD systems to lengthen the life of older pipes and fittings until the golf course can afford a new irrigation system.
- Operate an irrigation system with high-and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- Size pumps to provide adequate flow and pressure.
- Equip pumps with control systems to protect distribution piping.
- Follow system checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers, based on the manufacturer's recommendations.
- Monitor pumping station power consumption.
- Monitor monthly bills 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.
- Check amperage quarterly. Qualified pump personnel may more accurately indicate increased power usage and thus potential problems.

Irrigation System Program and Scheduling

Principles

- Irrigation scheduling must take plant water requirements and soil intake capacity into account to prevent excess water use that could lead to leaching and runoff.
- Plant water needs are determined by 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.
- Responsible irrigation management conserves water, reduces nutrient and pesticide movement.
- 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.

Best Management Practices

- Calibrate the reliability of older clock-control station timing devices. This should be done periodically, but at least seasonally.

- Monitor rain sensors on an irrigation system 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.
- Minimize runoff by making sure the granular fertilizer applications receive 0.25 inch of irrigation to move the particles off the leaves.
- Ensure irrigation quantities do not exceed the available moisture storage in the root zone.
- Ensure irrigation rates do not exceed the maximum ability of the soil to absorb and hold the water applied at any one time.
- Coordinate the irrigation schedule to coincide with other cultural practices (for example, the application of nutrients, herbicides, or other chemicals).
- Account for nutrients in effluent supply when making fertilizer calculations.
- Use irrigation in the early morning hours before air temperatures rise and relative humidity drops.
- Determine base plant water needs 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.
- Monitor visually localized dry conditions or hot spots to identify poor irrigation efficiency or a failed system device.
- Use predictive models to estimate soil moisture and the best time to irrigate.
- Avoid use of a global setting; make adjustments to watering times per head.
- Base water times on actual site conditions for each head and zone.
- 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. Adjust automated ET data to reflect wet and dry areas on the course.
- Use soil moisture sensors to assist in scheduling or to create on-demand irrigation schedules.
- Use multiple soil moisture sensors to reflect soil moisture levels.
- Install soil moisture sensors in the root zone for each irrigation zone to enhance scheduled timer-based run times.
- Place soil moisture sensors in a representative location within the irrigation zone. Install a soil moisture sensor in the driest irrigation zone of the irrigation system.
- Install wired soil moisture systems to prevent damage from aerification.
- Perform catch-can uniformity tests periodically.
- Improve water infiltration by reducing dry spots and soil compaction, which in turn reduces water use and runoff in other areas.
- Install emergency shutdown devices to address line breaks.

Turf Drought Response

Principles

- The presence of visual symptoms of moisture stress is a simple way to determine when irrigation is needed.
- Use a soil moisture meter to determine irrigation needs of in play areas.
- Managers of golf greens cannot afford to wait until symptoms occur, because unacceptable turf quality may result.
- Be prepared for extended drought/restrictions by developing a written drought management plan.
- For golf greens and tees, the majority of roots are in the top several inches of soil.

Best Management Practices

- Wait until visual symptoms appear before irrigating - 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.
- Avoid irrigating too shallowly, which encourages shallow rooting, increases soil compaction, and favors pest outbreaks.
- For golf greens and tees, the majority of roots are in the top several inches of soil.
- Use infrequent, deep irrigation for fairways and roughs, to supply sufficient water for plants and to encourage deep rooting.
- Employ proper cultural practices, such as mowing height, irrigation frequency and irrigation amounts 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.
- Use appropriate turfgrass species adapted to the location of the golf course being managed.

Irrigation System Quality

Principles

- Irrigation system maintenance on a golf course involves four major efforts: calibration or auditing, preventive maintenance (PM), corrective maintenance, and record keeping.
- Personnel charged with maintaining any golf course irrigation system face numerous challenges. This is particularly true for courses with older or outdated equipment.
- Good system management starts with good preventive maintenance (PM) procedures and recordkeeping. Maintaining a system is more than just fixing heads.
- Corrective maintenance is simply the act of fixing what is broken. It may be as simple as cleaning a clogged orifice, or as complex as a complete renovation of the irrigation system.

- As maintenance costs increase, the question of whether to renovate arises. Renovating a golf course irrigation system can improve system efficiencies, conserve water, improve playability, and lower operating costs.

Best Management Practices

- Respond to day-to-day failures in a timely manner, maintain the integrity of the system as designed, and keep good records.
- Follow the manufacturer's recommendations for system checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers.
- Inspect the system 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.
- Observe systems in operation at least weekly. This can be done during maintenance programs such as fertilizer or chemical applications where irrigation is required, or the heads can be brought on-line for a few seconds and observed for proper operation. This process detects controller or communications failures, stuck or misaligned heads, and clogged or broken nozzles.
- Check filter operations frequently. An unusual increase in the amount of debris may indicate problems with the water source.
- Keep filters operating properly to prolong the life of an existing system and reduce pumping costs.
- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.
- Check application/distribution efficiencies annually. Implement a PM program to replace worn components before they waste fertilizer, chemicals, and water.
- 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.
- Gather together all of the documentation collected as part of the PM program, along with corrective maintenance records for analysis.
- Identify problems and their costs help determine what renovations are appropriate.
- Collect information on the cost of maintaining the system as part of system overall evaluation, which allows for planning necessary upgrades, replacement, etc. Compare after changes are made.

Pond Location and Design

Principles

- Understanding natural lake processes and accommodating them in the design and management of a pond can create significant aesthetic value and reduce operational costs.

- Lakes and ponds have several distinct defining characteristics. Their size, shape, and depth may all affect how they respond to various environmental inputs.
- Most golf courses plan their lakes and water hazards to be a part of the stormwater control and treatment system. This usually works well for all concerned. However, natural waters may not be considered treatment systems and must be protected.
- Lakes and ponds may be used as a source of irrigation water. It is important to consider these functions when designing and constructing the ponds.
- Careful design may significantly reduce future operating expenses for lake and aquatic plant management.

Best Management Practices

- Consult with a qualified golf course architect, working in conjunction with a stormwater engineer, to develop an effective stormwater management system that complies with the requirements of the water management district/department or other permitting agency. There are additional permitting requirements for pond construction within a floodplain.
- Consider engineering details such as subsoil preparation, the placement of gravel, slopes, and backfilling when constructing drainage systems.
- Create, where practical, internal golf course drains that discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- Perform studies of water supplies needed for irrigation systems. Studies of waterbodies or flows on, near, or under the property are needed to properly design a course's stormwater systems and water features, and to protect water resources.
- Prevent peninsular projections and long, narrow fingers into ponds that may prevent water mixing.
- Ponds that are too shallow may reach high temperatures, leading to low oxygen levels and promoting algal growth and excess sedimentation.
- Use aeration equipment in shallow or nutrient-impacted ponds to maintain acceptable dissolved oxygen (DO) levels in the water.



Stock Farm Club - Hamilton, MT

Pond Use and Maintenance

Principles

- Successful pond management should include a clear statement of goals and priorities to guide the development of the BMP necessary to meet those goals. Some of the challenges facing superintendents in maintaining the quality of golf course ponds are as follows:
 - Low dissolved oxygen
 - Sedimentation
 - Changes in plant populations
 - Nuisance vegetation
 - Maintenance of littoral shelves
 - Vegetation on the lakeshore
- Each pond has regions or zones that significantly influence water quality and are crucial in maintaining the ecological balance of the system. It is important for the manager to understand their function and how good water quality can be maintained if these zones (riparian zone, littoral zone, limnetic zone, and benthic zone) are properly managed.

- Surface water sources can present problems with algae and bacteria growth. Algal cells and organic residues of algae can pass through irrigation system filters and form aggregates that may plug emitters.
- Pond leaks should be controlled and managed properly.
- Use an expert in aquatic management to help develop and monitor pond management programs.

Best Management Practices

- Use leak controls in the form of dike compaction, natural-soil liners, soil additives, commercial liners, drain tile, or other approved methods.
- Maintain a riparian buffer to filter the nutrients and sediment in runoff.
- Reduce the frequency of mowing at the lake edge and collect or direct clippings to upland areas.
- Prevent overthrowing fertilizer into ponds. Practice good fertilizer management to reduce nutrient runoff into ponds, which causes algae blooms and ultimately reduces dissolved oxygen levels.
- Establish a special management zone around pond edges.
- Dispose of grass clippings where runoff will not carry them back to a water body.
- Encourage clumps of native emergent vegetation at the shoreline.
- Maintain water flow through lakes, if they are interconnected.
- Establish wetlands where water enters lakes to slow water flow and trap sediments.
- Maintain appropriate silt fencing and BMP on projects upstream to reduce erosion and the resulting sedimentation.
- Manipulate water levels to prevent low levels that result in warmer temperatures and lowered dissolved oxygen levels.
- Aerate ponds and dredge or remove sediment before it becomes a problem.

Pond Water-Level Monitor

Principle

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

Best Management Practices

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

Metering

Principles

- Rainfall may vary from location to location on a course; the proper use of rain gauges, rain shut-off devices, flow meters, soil moisture sensors, and/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.

Best Management Practices

- Calibrate equipment periodically to compensate for wear in pumps, nozzles, and metering systems.
- Manage irrigation using properly calibrated flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods.
- Prevent turbulence and bad readings by using flow meters that have a run of pipe that is straight enough — both downstream and upstream.
- Use flow meters to determine how much water is applied.
- For electromagnetic flow meters, if fertigation is used, ensure that injection ports are downstream of the flow meter.

Irrigation Leak Detection

Principle

- 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.
- Install in an irrigation system high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- Monitor the system daily for malfunctions and breaks. Also 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.
- Install automated emergency control systems to shut down pumps in the event of a line break. They must be tested and serviced on a regular schedule.

Sprinkler Maintenance

Principles

- Good system management starts with good preventive maintenance (PM) procedures and record keeping. This can be done during maintenance programs such as fertilizer or chemical applications where irrigation is required, or the heads can be brought on-line for a few seconds and observed for proper operation.
- Maintaining a system is more than just fixing heads. It also includes documenting system- and maintenance-related details so that potential problems can be addressed before expensive repairs are needed. It also provides a basis for evaluating renovation or replacement options.
- Be proactive; if the system requires frequent repairs, it is necessary to determine why these failures are occurring.
 - Pipe failures may be caused not only by material failure, but also by problems with the pump station.
 - Wiring problems could be caused by corrosion, rodent damage, or frequent lightning or power surges.
 - Control tubing problems could result from poor filtration.

Best Management Practices

- Follow the manufacturer's recommendations for system checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers.
- Inspect the system routinely for proper operation by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads.
- Inspect the system visually for leaks, misaligned or inoperable heads, and chronic wet or dry spots, so that adjustments can be made or replaced.
- Flush irrigation lines regularly to minimize emitter clogging. To reduce sediment buildup, make flushing part of a regular maintenance schedule. If fertigating, prevent microbial growth by flushing all fertilizer from the lateral lines before shutting down the irrigation system.
- Clean and maintain filtration equipment.
- Observe systems in operation at least weekly. This process detects controller or communication failures, stuck or misaligned heads, and clogged or broken nozzles.
- Check filter operations frequently. An unusual increase in the amount of debris may indicate problems with the water source.

- Keep filters operating properly, even under routine conditions. This 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.
- Check application/distribution efficiencies annually. Conduct a periodic professional irrigation audit at least once every five years. Implement a PM program to replace worn components before they waste fertilizer, chemicals, and water.
- Document equipment run-time hours.
- Ensure that all lubrication, overhauls, and other preventive maintenance are completed according to the manufacturer's schedule.
- Monitor pump station power consumption. Monthly bills should be monitored over time to detect a possible increase in power usage. Compare the power used with the amount of water pumped. Requiring more power to pump the same amount of water may indicate a problem with the pump motor(s), control valves, or distribution system. Quarterly checks of amperage by qualified pump personnel may more accurately indicate increased power usage and thus potential problems.
- Monitor and record the amount of water being applied, including system usage and rainfall. By tracking this information, you can identify areas where minor adjustments can improve performance. Not only is this information essential in identifying places that would benefit from a renovation, but it is also needed to compute current operating costs and compare possible future costs after a renovation.
- Document and periodically review the condition of infrastructure (such as pipes, wires, and fittings).

System Maintenance

Principles

- 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

- Perform irrigation audits by trained technicians.
- Identify necessary repairs or corrective actions by visual inspection. It is essential to make repairs before carrying out other levels of evaluation.
- Evaluate pressure and flow to determine that the correct nozzles are being used and that the heads are performing according to the manufacturer's specifications.

- Check pressure and flow rates at each head to determine the average application rate in an area.
- Run catch-can tests to determine the uniformity of coverage and to accurately determine irrigation run times.
- Conduct catch-can testing 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.
- Inspect for broken and misaligned heads.
- Check that the rain sensor is present and functioning.
- Inspect the backflow device to determine that it is in place and in good repair.
- Examine 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.

Preventive Maintenance

- Inspect irrigation pipe in older systems and look for fitting breaks caused by surges in the system.
- Install thrust blocks to support conveyances.
- Inspect the system 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.
- Observe systems 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.
- Check application/distribution efficiencies 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.
- Perform quarterly checks of amperage to accurately identify increased power usage that indicates potential problems. This should be done by qualified pump personnel.

- Monitor and record the amount of water being applied, including system usage and rainfall. By tracking this information, areas where minor adjustments can improve performance can be identified.
- 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.

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.
- Document all corrective actions; record keeping is an essential practice.

System Renovation

- Use appropriate golf course renovations to 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.
- Document system performance to maximize the effectiveness of the renovation routinely.
- Evaluate cost of renovation and its return on benefits, both financial and management.

Winterization and Spring

Principle

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

Best Management Practices

- Conduct a visual inspection of the irrigation system: inspect for mainline breaks, low pressure at the pump, and head-to-head spacing.
- Conduct a catch-can test to audit the system.
- Flush and drain above-ground irrigation system components that could hold water.

- Remove water at the lowest point on the system, from all conveyances and supply and distribution devices that may freeze, with compressed air or open drain plugs.
- Clean filters, screens, and housing; remove drain plug and empty water out of the system.
- Secure systems and close and lock covers/compartments 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.
- Perform pump and engine servicing/repair during winter, if possible.
- Recharge irrigation in the spring with water and inspect for corrective maintenance issues.
- Ensure proper irrigation system drainage design.

Sensor Technology

Principles

- To prevent excess water use, irrigation scheduling should take into account plant water requirements, recent rainfall, recent temperature extremes, and soil characteristics.
- Irrigation management and control devices need to be installed correctly for proper irrigation management.
- Soil moisture sensors and other irrigation management tools should be installed in representative locations and maintained to provide the information necessary for making good irrigation management decisions.
- Rain gauges are necessary measurement tools to track how much rain has fallen at a specific site on the golf course. On some courses, more than one station may be necessary to get a complete measure of rainfall or evaporation loss. The use of soil moisture probes and inspections for visual symptoms such as wilting turf, computer models, and tensiometers may supplement these measurements. Computerized displays are available to help visualize the system.
- Predictive models based on weather station data and soil types are also available. These are relatively accurate and applicable, especially as long-term predictors of annual turf water requirements.
- Weather data such as rainfall, air and soil temperature, relative humidity, and wind speed are incorporated into certain model formulas, and soil moisture content is estimated. Models, however, are only as effective as the amount of data collected and the number of assumptions made.
- It is best to have an on-site weather station to daily access weather information and ET to determine site specific water needs.

Best Management Practices

- Reset irrigation controllers/timers as often as practically possible to account for plant growth requirements and local climatic conditions.
- Calibrate flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods to manage irrigation.
- Ensure irrigation rates do not exceed the maximum ability of the soil to absorb and hold the water applied in any one application.
- Base irrigation on ET rates and soil moisture replacement. It should not occur on a calendar-based schedule.
- Install computerized control systems on all new course irrigation systems to help ensure efficient irrigation application. These allow for timing adjustments at every head.
- Place rain shut-off devices and rain gauges in open areas to prevent erroneous readings.
- Use multiple soil moisture sensors/meters for accuracy and to reflect soil moisture levels.

Maintained Turf Areas

Principle

Courses should use well-designed irrigation systems with precision scheduling based on evapotranspiration (ET), soil infiltration rates, soil water-holding capacity, plant water-use requirements, the depth of the root zone, and the desired level of turfgrass appearance and performance in order to maximize efficient watering.

Best Management Practices

- Design and install the irrigation system so that the putting surface, slopes, and surrounding areas can be watered independently.
- Account for nutrients in effluent water supply when making fertilizer calculations.
- Install part-circle heads that conserve water and reduce unnecessary stress to greens and surrounds.
- Avoid use of a global setting; make adjustments to watering times per head.
- Base water times on actual site conditions for each head and zone.
- 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.
- Adjust automated ET data manually to reflect wet and dry areas on the course.
- Install rain switches to shut down the irrigation system if enough rain falls in a zone.
- Use soil moisture sensors to bypass preset or to create on-demand irrigation schedules.
- Space permanent irrigation sprinklers and other distribution devices according to the manufacturer's recommendations.
- Base spacing on average wind conditions during irrigation.
- Evaluate triangular spacing. It is more uniform than square spacing.

- Perform catch-can uniformity tests periodically.
- Reduce dry spots and soil compaction to improve water infiltration, which in turn reduces water use and runoff in other areas.
- Use irrigation in the early morning hours before air temperatures rise and relative humidity drops.
- Base plant water needs on evapotranspiration rates, recent rainfall, recent temperature extremes and soil moisture.
- Use mowing, verticutting, aeration, wetting agents, nutrition, and other cultural practices to control water loss and to encourage conservation and efficiency.
- Use solid-tine aeration equipment in place of verticutting, depending on physical soil characteristics and turf type.
- Use slicing and spiking to help relieve surface compaction and promote better water penetration and aeration.
- Monitor for localized dry conditions or hot spots visually to identify poor irrigation efficiency or a failed system device.
- Use predictive models to estimate soil moisture and the best time to irrigate.
- Install in-ground (wireless) soil moisture sensors or use hand-held moisture meters in the root zone for each irrigation zone to enhance scheduled timer-based run times.
- Ensure an irrigation system has high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- Place soil moisture sensors in a representative location of the irrigation zone.
- Install soil moisture sensors in the driest irrigation zone of the irrigation system.
- Install wireless soil moisture systems to prevent damage from aeration.



Non-Play and Landscape Areas

Principles

- 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.
- Natural vegetation should be retained and enhanced for non-play areas to conserve water.
- The most efficient and effective watering method for non-turf landscape 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.
- Inspect non-play irrigation systems routinely for problems related to emitter clogging, filter defects, and overall system functionality.

Wellhead Protection

Principles

- Wellhead protection is the establishment of protection zones and safe land-use practices around water supply wells in order to protect aquifers from accidental contamination. It also includes protecting wellheads from physical impacts, keeping them secure, and sampling wells according to the monitoring schedule required by the regulating authority, which is often a local health department or state department of environmental quality.
- When installing new wells, contact the 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.
- 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.

Fertigation

Principles

- Fertigation is the practice of adding nutrients and/or amendments directly into an irrigation supply system.

Best Management Practices

- Calibrate fertigation systems on a regular basis.
- Keep accurate records, which are essential for proper fertigation.
- Apply materials through fertigation as accurately as the irrigation system will allow. Practice the highest standards of system performance to distribute products used as calibrated and does not allow them to be applied to unintended areas.



Yellowstone Club - Big Sky, MT

Surface Water Management

Stormwater Capture



Although golf courses are typically large properties ranging in size from 40 to 200 acres, 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 proper, 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. In some instances, golf courses and other recreational facilities are mandated to be designed to handle a 20-, 50- or 100-year rain event, which means the golf course must detain more water for perhaps a longer period of time. 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.

Principles

- 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.
- Natural storage of early season runoff and other stormwater runoff events is an important element in drought mitigation and maintaining/restoring water quality.
- It is important to ensure that captured water returns to streams/other surfaces in good condition by ensuring BMP's are in place to protect captured water.

Best Management Practices

- Install berms and swales 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.
- Incorporate a backup source of water into the management plan.
- Inspect irrigation pumps, filtration systems, conveyances and control devices to prevent/correct system issues.

Regulatory Considerations

Principle

Course owners and superintendents should investigate regulatory requirements that apply to the golf facility to protect surface and groundwater quality.

Best Management Practices

- Regulate aquatic management of plants under construction permitting and regulatory licensing requirements. Consult with federal, state, and local water management agencies before managing golf course lakes and wetland areas.
- Consult with federal, state, and local water management agencies, and/or consult an approved management plan before performing cultural practices: fertilization, installation of plants, hand removal of plants, or mechanical harvesting.
- Approve the introduction of aquatic triploid grass carp, biological controls, aeration, and chemical controls (herbicide/algaecide), and monitor according to permit and licensing protocols and compliance.
- Understand the disposal of sediments from surface water ponds (stormwater detention) may be subject to regulation.
- Observe Total Maximum Daily Load (TMDL), mitigation, and watershed basin management action plans (BMAP) for golf course management.

- Consult with federal and state agencies before altering natural aquatic areas; wetlands are protected areas.
- Ensure constructed wetlands have an impervious bottom to prevent groundwater contamination.
- Check studies of water supplies needed for irrigation systems, including studies of waterbodies or flows on, near, and under the property to properly design a course's stormwater system and water features to protect water resources.

Water Quality Protection

Principle

- 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 should include the presence of invasive or weedy species, aesthetics, watershed and groundwater assessments, and other environmental considerations.
- One of the key elements of any suite of practices to protect and maintain water quality is having a good riparian buffer that generally consists of woody vegetation or wetland plant communities. These help filter pollutants, provide shade and stabilize banks.
- Another key element is providing stream access to its floodplain along with good shape/pattern/profile of the channel. With access to its floodplain, a stream will generally maintain a stable shape/pattern/profile. A good sized buffer allows some channel movement without affecting course infrastructure.
- Only licensed individuals or contractors should be allowed to select and apply aquatic pesticides.

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) strategies 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 prevent turfgrass injury and to protect water quality and wildlife habitat.
- Ensure irrigation does not directly strike or run off to waterbodies, and maintain no-fertilization buffers along water edges.
- Outline goals and priorities to guide the development of the BMP necessary to support the lake/aquatic management plan.
- Monitor, by superintendents, all waterbodies in their area for the persistence of toxic herbicides and algaecides in the environment.

- Monitor and record secondary environmental effects on surface water and groundwater from the chemical control of vegetation.
- Apply fertilizer and reclaim (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, with special consideration to fish, aquatic life and grazing wildlife present in the area, which are sensitive to bio-accumulation of copper in plant communities.
- Identify position of property in relation to its watershed.
- Identify 50 and 100 year flood zones and properly locate structures or improvements, working with local and federal agencies.
- Identify overall goals and validate concerns of the local watershed.
- Identify surface water and flow patterns to be able to monitor any changes.
- Indicate stormwater flow, as well as existing and potential holding capacity to document any potential changes.
- Indicate impervious surfaces, such as buildings, parking lots, or pathways.
- Indicate major drainages and catch basins that connect to local surface water bodies as an area to record water quality measurements.
- Identify and understand depth to water tables and soil types to help manage any activities that may impact them.
- Locate and protect wellheads.



Bridger Creek Golf Course - Bozeman, MT

Dissolved Oxygen

Principles

- 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 should be determined based on golf course operation and basin-specific parameters of concern (these may be identified by DEQ Water Quality 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. If water quality monitoring cannot be conducted monthly, target strategic times that are relevant to the water quality parameter being measured, for example times of peak temperatures, runoff, pesticide applications, etc.
- 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.
- 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.
- 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.
- 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.

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 algacides containing natural biological enzymes or 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 algacides 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, or reseed, bare or thinning turf areas.
- Mulch areas under tree canopies to cover bare soil.
- Avoid allowing grass clippings and other biological waste products to be deposited in open water.
- 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 water quality data values appropriately, based on the associated BMP used to protect water quality.
- Record observations of fish, wildlife, and general pond conditions.

Aquatic Plants

Principles

- 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 (emersed plants), rooted to the bottom with their leaves floating on the water surface (floating-leaved plants), or free-floating on the water surface (floating plants). 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

- Design ponds properly with a narrow fringe of vegetation along the edge. These are more resistant to problems than those with highly maintained turf.
- Control problem plants in ponds with littoral plantings selectively, without damaging littoral shelves.
- Encourage clumps of native emergent vegetation at the shoreline.
- Include in a comprehensive lake management plan, strategies to control the growth of nuisance vegetation that can negatively affect a pond's water quality and treatment capacity.
- Remove filamentous algae by hand frequently, and/or frequently apply algaecide to small areas of algae (spot treatment).
- Use natural algaecides whenever possible, including enzymes which consume excess nutrients in pond water, to limit algae growth.
- Identify undesirable or noxious aquatic weeds and create an IPM for their control.

Human Health Concerns

Principles

- 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 IPM.
- Address areas where standing water may provide habitat for nuisance organisms.

Best Management Practices

- Use IPM principles to address insects that may pose a hazard to human health.
- 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.

Floodplain Restoration

Principles

- Reestablishment of natural stream/river 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.

Stormwater, Ponds, and Lakes

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.

Principles

- 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.
- 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 nutrients and contamination. Stormwater should run through at least 30' of vegetation before entering any body of water.
- 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. Construct drainage pipes to discharge into a sump containing filter media before it can overflow into a body of 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.
- Include in golf course stormwater management “natural systems engineering” or “soft engineering” approaches that maximize the use of natural systems to treat water.
- Institute buffers and special management zones.



Cabinet View Golf Club - Libby, MT

Water Quality Monitoring and Management

Regulatory Considerations



Principles

- Golf course owners and superintendents should know and understand the state regulations that govern them regarding water quality.
- Owners and superintendents should know what activities require permitting to perform.
- Owners and superintendents should make every attempt to stay in contact with those administering regulatory considerations and stay in the loop of possible future regulatory considerations.
- Owners and superintendents should have a general baseline knowledge of local water rights, and should consider other water rights holders who could be effected by future decisions.

Best Management Practices

- Dispose of sediments from surface-water ponds (stormwater detention), subject to regulation.
- Consult with federal and state agencies before altering natural aquatic areas, as wetlands are protected areas.
- Maintain an impervious bottom in constructed wetlands to prevent groundwater contamination.
- Perform studies of water supplies needed for irrigation systems, including studies of waterbodies or flows on, near, and under the property. These studies are needed to properly design a course's stormwater system and water features to protect water resources.

Local Involvement

Principles

- Citizen science refers to the practice of engaging the general public in scientific projects that can produce reliable data and information.

- Incorporation of citizen perspectives can be a conduit to other scientific research programs, as citizens involved in the research development process provide important cross-connections, perspectives and relationships with other community and government programs.
- Golf course owners can obtain a broader public support since community members who participate in the development and decision making process are partially responsible for the program.
- Citizens are more likely to take a more active role in implementation if their opinions are considered in the development of goals and decisions.
- The DEQ Nonpoint Source Program works with local groups to implement BMPs and is a good option to engage citizens.

Site Analysis

Principle

Identify 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

- Use Integrated Pest Management (IPM) and native or naturalized vegetation wherever practical.
- Apply appropriate herbicides to minimize damage to non-target littoral plantings.
- Use appropriate aquatic herbicides to avoid turfgrass injury.
- Maintain no-fertilization buffers along edges.
- Monitor, by superintendents, the designated waters on their property.
- Monitor and record environmental effects on surface water and groundwater from the chemical control of vegetation.
- Apply fertilizer and reclaim (reuse) irrigation/fertigation appropriately to avoid surface and groundwater contamination.
- Identify position of property in relation to its watershed.
- Identify overall goals and qualify concerns of the local watershed.
- Indicate 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, active and inactive.

Water Quality Sampling Program

Principles

- 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. It also provides a body of evidence on the golf course's environmental impact.
- Sampling parameters are determined based on golf course operation and basin-specific parameters of concern from local regulators and watershed interest groups. Typically, samples should be analyzed for nutrients, pH and alkalinity, sediments, 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.
- Should there be 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.
- Golf courses should also sample for macroinvertebrates as determined useful by water quality specialists.

Best Management Practices

- Reduce stress on fish; when feasible provide aeration as needed for oxygenation.
- 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.
- Provide turf or mulch to reduce sediments.

Sampling Parameters, Collection, and Analysis

Principles

- A water quality monitoring program must include monitoring of surface water, groundwater, and pond sediments.

- 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 quality assurance/quality control (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. Golf course management must have good data to make good decisions, and if a golf course should ever want to produce data for an agency or in court to defend the facility from unwarranted charges, those data must meet QA/QC standards to be defensible as evidence.

Best Management Practices

- Seek cooperation with local watershed interest groups.
- 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.

Buffer Zones

Principles

- Buffers around the shore of a waterbody or other sensitive areas filter and purify runoff as it passes across the buffer. Ideally, plant buffers with native species provide a triple play of water quality benefits, pleasing aesthetics, and habitat/food sources for wildlife.
- Effective BMP 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.

Best Management Practices

- Ensure riparian buffer areas are above the high-water mark and should be unfertilized and left in a natural state.
- Institute buffers and special management zones.
- 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.

- 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.
- Use plant buffers with native species to provide pleasing aesthetics, habitat, and food sources for wildlife when possible.
- Establish special management zones around pond edges.
- Plant all or most of the out-of-play water bodies with shoreline buffers planted with native or well-adapted noninvasive vegetation to provide food and shelter for wildlife.
- Practice good fertilizer management to prevent the nutrient runoff into ponds.
- Dredge or remove sediment when needed, and with proper permitting, to protect beneficial organisms that contribute to the lake's food web and overall lake health.
- If maintaining turf grass to edge of artificial ponds, reduce the frequency of mowing.



Glacier View Golf Course - West Glacier, MT

Wetland Protection

Principles

- When present, wetlands are critical components of a landscape and are closely regulated.
- Wetlands are protected as waters of the state by rule of law. Wetlands act both as filters for pollutant removal and as nurseries for many species. Many people do not realize the vital role they play in purifying surface waters.
- 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.
- Constructed or disturbed wetlands may be permitted to be an integral part of the stormwater management system.

Best Management Practices

- Maintain appropriate silt fencing and BMP on projects upstream to prevent erosion and sedimentation.
- Protect natural waters, which cannot be considered treatment systems and must be protected. Natural waters do not include treatment wetlands.
- Consult appropriate regulatory agencies when planning management or construction activity that may impact wetlands.

Stormwater Management

Principle

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. 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

- 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.
- Use special high-permeability concrete available for cart paths or parking lots.

- Design stormwater control structures to hold stormwater for appropriate residence times, in order to remove total suspended solids.
- Eliminate or minimize directly connected impervious areas as much as possible.
- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, instead of letting it run off.

Sediment

Principle

- Sediment is the leading cause of impairment to stream beneficial uses. The source is often from excessive streambank erosion caused by alterations to riparian vegetation and the stream channel's shape/pattern/profile. Courses should ideally be designed to leave a large buffer along a stream corridor in order to allow some channel movement.
- During construction and/or renovation, temporary barriers and traps must be used to prevent sediments from being washed off-site into water bodies. Wherever possible, keep a vegetative cover on the site until it is actually ready for construction, and then plant, sod, or otherwise cover it as soon as possible to prevent erosion.
- If any activity will disturb more than one acre, a National Pollutant Discharge Elimination System (NPDES) permit may be required.
- All construction activities should include a Storm Water Pollution Prevention Plan (SWPPP) which will consider all sources & remedies of storm water pollution that should be monitored.

Best Management Practices

- Use turfgrass or vegetation to prevent bank erosion and sediment movement into water bodies.
- Use dry detention basins/catchments to buffer flooding and excessive runoff that may contain sediment.
- Pay close attention to engineering details such as subsoil preparation, the placement of gravel, slopes, and backfilling when constructing drainage systems.
- Ensure that internal golf course drains not drain directly into an open water body, but discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.

Sodic/Saline Conditions

Principles

- All natural waters contain soluble salts; however, the amount and type of salts they contain vary greatly.

- Irrigation water can degrade when 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 TDS.

Best Management Practices

- Monitor water quality routinely 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.
- Base management plan on routine soil tests to determine sodium adsorption ratio (SAR), exchangeable sodium percentage (ESP), electrical conductivity saturated paste method/unit (EC), and free calcium carbonate content.
- Select alternative turfgrass and landscape plants that are more salt-tolerant if problems exist.
- Reduce salt accumulations in the soil by flushing soils as needed.
- Amend soil and water to remove salt ions from affected areas.



Hilands Golf Club - Billings, MT

Nutrient and Soils Management

Introduction



Proper nutrient and soils management play a key role in the reduction of environmental risk while also potentially helping to reduce inputs and overall expenditures. Maintaining appropriate nutrient levels along with managing soil physical and biological health ultimately produce the most efficient turf system possible. This will allow turfgrass to not only survive under stress conditions but be as healthy as possible during the variety of seasonal changes that occur in our climate.

Nutrients may move beyond the turfgrass via leaching or runoff, which may directly impact our environment. The goal of a proper nutrient management plan should be to apply the minimum necessary nutrients with the help of a vibrant microbial population to achieve an acceptable playing surface. A key benefit of healthy biology is the higher efficiency of the system with reduced inputs.

Soils are a dynamic, living entity that encompass what some refer to as a 'three legged stool'. The legs, all of which interact with each other are what support the stool, or in this case, healthy soils. The chemical leg is addressed through soil testing and adjusting nutrient levels per the results shown or applying corrective amendments such as lime or gypsum. The physical leg comprises things like soil amendments and sand topdressing to correct poor physical soil structure. The biological leg addresses the bacterial and fungal populations in the soil that are responsible for many important functions in turf management such as thatch breakdown, nutrient cycling, buffering of salts and bicarbonates and the efficient use of water. This also can be tested doing direct microscopy and mitigated with soil inoculants and food for the biology if tests indicate the need.



Regulatory Considerations

Principles

- Manage nutrient risks based on the unique conditions that exist in your location and unique ecosystem.
- Depending on your location, regulatory agencies may include federal, state, or local policies.
- Understand the importance of nutrient licensing.
- There are currently no regulatory policies regarding nutrient management in Montana.

Best Management Practices

- Identify who must be licensed.
- Describe differing licenses, if applicable.
- Provide the minimum requirement.
- Detail the Continued Education Unit required to maintain the license.
- Understand the value of training programs.
- Contact local and state organizations for regulatory restrictions.

Soil Health

Principles

- Understand that many of the important processes we undertake on a seasonal basis have an impact on the health of the soil microbiology.
- Understanding the dynamic relationships going on in the soil and how we impact them, can make golf courses a haven for a healthy microbial system.

- Devise ways to maintain a healthy microbial system using as part of your overall management plan, biologically friendly inputs such as humic acids and naturally derived Nitrogen sources (ex: kelp, composts, other organic sources).

Best Management Practices

- Minimize potentially harmful inputs to the microbial population when possible but if they are necessary, work to rebuild those populations through inoculants and testing.
- There are many regenerative land companies that can assist in this effort and are easy to locate.

Soil Testing

Principles

- Soil testing may or may not provide the appropriate answers to your nutrient management questions. Consult with your local land-grant university to get the most current information and to better understand which soil test values are relevant in your location.
 - Montana State University Extension - <https://www.msuextension.org/>
- Through proper sampling, laboratory analysis, interpretation of results, recommendations, and record keeping, soil testing can be used to manage nutrients more efficiently.

Best Management Practices

- Sample accurately and consistently as an essential part to providing useful soil test information over time.
- Divide the course into logical components such as greens, fairways, tees, roughs, etc., for each hole.
- Take ten to 15 soil samples randomly from each section and blend together to provide a representative, uniform soil sample.
- Take each soil sample from the same depth.
- Use an extractant appropriate for your soils.
 - Most Montana soils have a pH of 7 or higher. For high pH soils, the Olsen method of phosphorus extraction is preferred. Acidic soils are extracted with the Bray method (MSU Extension Document 4449-4).
- Use the same extractant for each test in order to compare soil test results over time.
- Use a soil test to provide the grower with a prediction of a plant's response to an applied nutrient.
- Observe 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.

- Note that if your location does not have correlation data, then soil test recommendations may be of little value.
- Keep soil tests from prior years. This will allow you to observe changes over time. This practice can provide good evidence of the impact of your nutrient management plan.
- Extensive information on soil testing in Montana can be found in Montana State University Extension's Nutrient Management Model 1 - <http://landresources.montana.edu/nm/>

Plant Tissue Analysis

Principles

- 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.
- Through proper sampling, consistent intervals, and record keeping, tissue sampling may be used to measure existing turf health.

Best Management Practices

- Collect tissue samples during regular mowing.
- Avoid collecting 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.
- Allow tissue samples, if possible, to air-dry at your facility before mailing them.
- Sample poor-quality turfgrass that is of concern separately from higher-quality turfgrass.
- Collect a sample immediately when turfgrass begins to show signs of nutrient stress.
- Sample tissue more frequently to allow a more accurate assessment of your turfgrass nutrient status changes over time.
- Choose the quantity of tissue analysis depending on 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.
- Keep tissue tests from prior years, allowing you to observe changes over time.
- Use tissue testing to provide good evidence of the impact of your nutrient management plan.

Fertilizers Used in Golf Course Management

Principles

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

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.
- A complete fertilizer contains N, P_2O_5 , and K_2O .
- The laws governing the labeling of fertilizer vary greatly among states.

Label

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

Macronutrients

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

Understanding the role of each macronutrient within the plant should provide a greater understanding of why these nutrients play such a key role in proper turfgrass management.

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, proteins and nucleic acids.

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

- *Mineralization*: the microbial mediated conversion of organic N into plant-available NH_4
 - *Nitrification*: the microbial-mediated conversion of NH_4 to NO_3
 - *Denitrification*: the microbial mediated conversion of NO_3 to N gas; this primarily occurs in low-oxygen environments and is enhanced by high soil pH
 - *Volatilization*: the conversion of NH_4 to NH_3 gas
 - *Leaching*: the downward movement of an element below the rootzone
 - *Runoff*: the lateral movement of an element beyond the intended turfgrass location
- The release mechanism and factors influencing N release from available N 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 date, location, and turfgrass species all should be included in your nutrient application decision.

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

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

These include:

- Sulfur-coated urea
- Polymer/resin-coated

- Isobutylidene diurea
- Urea-formaldehyde/ureaformaldehyde reaction products
- Natural organic

- *Urease and nitrification inhibitors*
 - Urease inhibitors reduce the activity of the urease enzyme, resulting in a reduction of volatilization and an increase in plant-available N.
 - Nitrification inhibitors reduce the activity of *Nitrosomonas* bacteria, which are responsible for the conversion of NH₄ to NO₂. This reduced activity results in a reduction of N lost via denitrification and an increase in plant-available N.

The role of phosphorous (P)

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

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

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

- *P sufficiency ranges*

- Consult your land-grant university for sufficiency ranges in your location.

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

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 1/2 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.

- *K deficiency symptoms*

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

- *K sufficiency ranges*

Consult your land-grant university for sufficiency ranges in your location.

- *K fertilizer sources*
 - Potassium sulfate
 - Potassium chloride
 - Potassium nitrate

Secondary Macronutrients

Secondary macronutrients are essential to plant function and are required in quantities less than N, P, and K, but more than micronutrients. These include calcium (Ca), magnesium (Mg), and sulfur (S)

The role of calcium (Ca)

- Primarily a component of cell walls and structure
- Consult your land-grant university for sufficiency ranges in your location
- Found in gypsum, limestone, and calcium chloride

The role of magnesium (Mg)

- Central ion in the chlorophyll molecule and chlorophyll synthesis
- Consult your land-grant university for sufficiency ranges in your location
- Found in S-Po-Mg, dolomitic limestone, and magnesium sulfate

The role of sulfur (S)

- Metabolized into the amino acid, cysteine, which is used in various proteins and enzymes
- Consult your land-grant university for sufficiency ranges in your location
- Found in ammonium sulfate, elemental sulfur, gypsum, potassium sulfate

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 Chlorine (Cl).

Consult your land-grant university for micronutrient sufficiency ranges in your location.

The role of iron (Fe)

- Is part of the catalytic enzymes and is required for chlorophyll synthesis
- Affects photosynthesis, nitrogen fixation, and respiration

The role of manganese (Mn)

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

The role of boron (B)

- Found in the cell wall; probably required for the structural integrity of the cell wall

The role of copper (Cu)

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

The role of zinc (Zn)

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

The role of molybdenum (Mo)

- Primarily related to nitrogen metabolism
- Structural and catalytical functions of enzymes

The role of chlorine (Cl)

- Required for the oxygen-evolving reactions of photosynthesis

- Also appears to be required for cell division in both leaves and shoots

Soil pH

Principle

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. Soil pH adjustments may occur slowly and are temporary.

Best Management Practices

- Apply a liming material (calcium carbonate, calcium oxide, dolomitic limestone) that contains Ca^{2+} and neutralizes acidity to increase soil pH.
- Apply products containing elemental sulfur in order to lower soil pH.
- Utilize injection pumps into irrigation water to address pH. This can be beneficial in some cases.

Nutrient Management

Principles

- Within Montana, 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.
- Understanding the importance of application timing for effective use of applied nutrients is critical to nutrient management.
- The objective of all nutrient applications is plant uptake and the corresponding desirable response.
- 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 less nutrient inputs than other locations because of their increased height of cut, less damage, and clipping return.

Best Management Practices

- Apply nutrients when turfgrass is actively growing.
- Apply slow-release N fertilizers at the appropriate time of year to maximize the products' release characteristics. Many fertilizer manufacturers and distributors have software available to help predict N release from their various products.
- Follow N application rate recommendations from your local land-grant university.

- Consider N application rates from slow-release materials, taking into consideration the release rate of the chosen material. If insufficient material is applied, the desired response may not be observed.
- 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
- Understand the different types of spreaders and the advantages and disadvantages of each.
- Use the correct spreader with fertilizers. 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
- Use calibration to reduce environmental risk and increases profitability.
- Use proper fertilizer storage, loading, and clean-up to reduce environmental risk.
- Avoid applying fertilizer to soils that are at, or near, field capacity or following rain events that leave the soils wet. Avoid applying fertilizer to frozen soils.
- Understand fertilizer should NOT be applied when the National Weather Service has issued a flood or severe storm warning, or if heavy rains are likely.



The Reserve at Moonlight Basin - Big Sky, MT

Cultural Practices

Mowing



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 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 destroying the playing surface.

Principles

- Mowing is the most basic yet most important cultural practice to consider when developing a management plan.
- The mowing practices implemented on a facility will 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. Other factors influencing mowing height include mowing frequency, shade, mowing equipment, time of year, root growth, and abiotic and biotic stresses.
- 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.

Best Management Practices

- Increase mowing frequency during periods of rapid growth and decrease during dry, stressful periods.
- Avoid mowing down tall turf to the desired height 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.
- Know that 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. Because of this, increase mowing height by at least 30% to improve the health of turf grown in a shaded environment.
- Use the plant growth regulator trinexapac-ethyl, which has been shown to improve overall turf health when used as a regular management tool for grasses growing in shaded environments.
- Understand that 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.
- Use proper mowing equipment.
- Use reel mowers that 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. Dull or improperly adjusted reels will result in shredding of leaf tissue, increasing water loss and the potential for disease development.
- Use rotary mowers, that when sharp and properly adjusted, deliver acceptable cutting quality for turf that is to be cut above 1 inch in height. Dull blades will result in shredding of leaf tissue, increasing water loss and the potential for disease development.
- Use flail mowers to maintain utility turf areas that are mowed infrequently and do not have a high aesthetic requirement.
- Understand mowing patterns influence both the aesthetic and functional characteristics of a turf surface.
- Be aware that 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.
- Handle nutrients contained in clippings properly as they can be sources of pollution.

- Return clippings 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 amount of clippings is so large that it could smother the underlying grass or on golf greens where clippings might affect ball roll.
- Dispose of collected clippings 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 maintained rough areas where mowers can aid the natural decomposition without accumulating in piles.
- Consider reducing or eliminating mowing on turf areas close to waterbodies to provide a filter strip that will reduce runoff.

Cultivation

Principles

- 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 is effective at managing soil compaction and aiding in improvement of soil drainage.
- 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.

Best Management Practices

- Design core aerification by 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.
- Conduct core aerification 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.
- Use solid tines, which cause less disturbance to the turf surface, 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.

- Create deep aerification holes in the soil profile. If removing soil, it can be brought to the surface and distributed into the canopy or removed. 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.
- Reduce surface compaction and promote water infiltration with minimal surface damage by using slicing and spiking.
- Observe that slicing is faster than core aerification but is less effective. Slicing is best accomplished on moist soils.
- Use a spiker to break up crusts on the soil surface, disrupt algae layers, and improve water infiltration.
- Incorporate vertical mowing (verticutting) into a cultural management program to achieve a number of different goals. The grain of a putting green can be reduced by setting a verticutter to a depth that just nicks the surface of the turf. Deeper penetration of knives will stimulate new growth by cutting through stolons and rhizomes while removing accumulated thatch.
- Ensure verticutting depth for thatch removal reaches the bottom of the thatch layer and extends into the surface of the soil beneath the thatch.
- Complete shallow vertical mowing at least monthly on putting greens, during active growing periods when turf is not under heat or drought stress, to prevent excessive thatch accumulation.
- Use groomers, or miniature vertical mowers attached to the front of reels, which are effective at improving management of grain and improving plant density through cutting of stolons.
- Topdress the playing surface with sand following core aerification and heavy vertical mowing to aid in recovery of turf. Rates will vary from 0.08 to 0.5 inch in depth and will depend on the capacity of the turf canopy to absorb the material without burying the plants.
- Aid in the management of thatch accumulation by making light, frequent applications of topdressing sand on putting greens to smooth out minor surface irregularities.
- Use only weed-free topdressing materials with a particle size similar to that of the underlying root zone.
- Understand the use of finer materials can result in layering and can have a negative impact on water infiltration.
- Increase putting speeds by roughly 10%, allowing for improved ball roll without lowering height of cut, by daily rolling of putting surfaces following mowing.
- Use light weight rollers to minimize potential for compaction caused by rolling.

Shade and Tree Management

Principles

- In general, most turfgrasses perform best in full sun.
- Excessive shade reduces photosynthesis and air circulation, thus 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.
- Remove, when possible, trees located near closely mowed areas such as tees and greens, or thin their canopy 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.
- Understand thoroughly the growth characteristics, and water and space requirements of each tree species before planting, to help eliminate future problems and competition with desired turf and other beneficial trees.



Iron Horse Golf Club - Whitefish, MT

Integrated Pest Management

Introduction



The philosophy of integrated pest management (IPM) was developed in the 1950s because of concerns over increased pesticide use, environmental contamination, and the development of pesticide resistance. The objectives of IPM include reducing pest management expenses, conserving energy, and reducing the risk of pesticide exposure to people, animals, and the environment. Its main goal, however, is to reduce pesticide use by using a combination of tactics to control pests, including cultural, biological, genetic, and chemical controls.

Pest management on golf courses results in significant inputs of time, labor, and financial resources. To grow healthy turfgrass, it is important for golf course superintendents to know what IPM is and how to implement it for each pest group (arthropods, nematodes, diseases, and weeds). They must be well-versed in pest identification, understand pest life cycles and/or conditions that favor pests, and know about all possible methods of controlling pests.

Regulatory Considerations

Principles

- Some federal or state regulations cover practically anyone who manufactures, formulates, markets, and uses pesticides.
- Record keeping of pesticide use is required by law. 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

- Keep proper records of all pesticide applications according to local, state, or federal requirements.
- Keep at least one trained and licensed applicator on staff.
- Use records to establish proof of use and follow-up investigation of standard protocols regarding:

- Date and time of application
- Name of applicator
- Person directing or authorizing the application
- Weather conditions at the time of application
- Target pest
- Pesticide used (trade name, active ingredient, amount of formulation, amount of water)
- Adjuvant/surfactant and amount applied, if used
- Area treated (acres or square feet) and location
- Total amount of pesticide used
- Application equipment
- Additional remarks, such as the severity of the infestation or life stage of the pest
- Follow-up to check the effectiveness of the application

Noxious Weeds

Definition - Any weed designated by an agricultural authority or lawmaking body that has or may have the potential to cause harmful effects on agricultural crops, horticultural crops, natural habits, ecosystems, humans, or livestock.

With each state designating a variety of plant species as noxious, it is important for golf courses to consider noxious weed management as part of the regulatory considerations for weed management.

Terrestrial Noxious Weeds

- Blueweed, Canada Thistle, Common Tansy, Dalmatian Toadflax, Diffuse Knapweed, Dyer's Woad, Field Bindweed, Hoary Alyssum, Houndstongue, Knotweed Complex, Leafy Spurge, Meadow Hawkweed Complex, Orange Hawkweed, Oxeye Daisy, Perennial Pepperweed, Purple Loosetrife, Rush Skeletonweed, Russian Knapweed, Saltcedar, Scotch Broom, Spotted Knapweed, St. Johnswort, Sulfur Cinquefoil, Tall Buttercup, Tansy Ragwort, Whitetop, Yellow Starthistle, Yellow Toadflax, Yellowflag Iris

Aquatic Noxious Weeds

- Curly-Leaf Pondweed, Eurasian Water Milfoil, Flowering Rush

Regulated Plants (Not Montana listed noxious weeds, but regulated because of the potential to have significant negative impacts)

- Cheatgrass, Hydrilla, Russian Olive

IPM Overview

Principles

- The fundamental basis of an environmentally sound pest control program is a process called IPM.
- IPM focuses on the basics of identifying the pests, choosing pest-resistant varieties of grasses and other plants, enhancing the habitat for natural pest predators, scouting to determine pest populations and determining acceptable thresholds, and applying biological and other less toxic alternatives to chemical pesticides whenever possible.
- Chemical controls should have minimal effect on beneficial organisms and the environment and minimize the development of pesticide resistance.

Best Management Practices

- Choose chemical pesticide applications carefully for effective and site-specific pest control with minimal environmental impact.
- Identify key pests on key plants.
- Determine the pest's life cycle, and know which life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).
- Use cultural, mechanical, or physical methods to prevent problems from occurring (for example, prepare the site, select resistant cultivars), reduce pest habitat (for example, practice good sanitation, carry out pruning and dethatching), or to help promote biological control (for example, provide nectar or honeydew sources).
- Decide which pest management practice is appropriate and carry out corrective actions. Direct control where the pest lives or feeds.
- 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. Record and use this information when making similar decisions in the future.

Written Plan

Principles

- IPM is an overall pest management strategy that includes biological controls, cultural methods, pest monitoring and other applicable preventative practices.
- A pest-control strategy should be used only when the pest is causing or is expected to cause more damage than what can be reasonably and economically tolerated. A control strategy should be implemented that reduces the pest numbers to an acceptable level while minimizing harm to non-targeted organisms.
- When a pesticide application is deemed necessary, its selection should be based on effectiveness, toxicity to non-target species, cost, and site characteristics, as well as its solubility and persistence.

Best Management Practices

- Decide which pest management practice(s) are appropriate and carry out corrective actions. Direct control where the pest lives or feeds. Use properly timed preventive chemical applications only when your professional judgment indicates they 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. Record and use this information when making similar decisions in the future.
- 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.

Pest Thresholds

Principles

- IPM is commonly used in agricultural crop production, where the economic thresholds for key pests have been determined. Pest levels exceeding the site's threshold warrant treatment.
- Using IPM is more challenging on golf courses than in an agricultural setting. The golf industry is sensitive to aesthetic damage, and golfers are often intolerant of anything that could affect the appearance of turfgrass and ornamental plants. Increased education of golfers and maintenance personnel could raise their tolerance of minor aesthetic damage without compromising plant health, play, and aesthetics.

Best Management Practices

- Use available pest thresholds to guide pesticide application decisions (see IPM Guide).
- Use preventive chemical applications only when professional judgment indicates that properly timed preventive applications are likely to control the target pest effectively while minimizing the economic and environmental costs.
- Record and use this information when making similar decisions in the future.

Monitoring

Principles

- Monitoring, or scouting, is the most important element of a successful IPM program. Monitoring documents the presence and development of pests, or the conditions that are conducive for pest outbreak throughout the year.

- It is essential to record the results of scouting in order to develop historical information, document patterns of pest activity, and document successes and failures.

Best Management Practices

- Train personnel to 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 they are and what control strategies are necessary.
- Train personnel to determine the pest's life cycle, and know which life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).
- 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.
- Train personnel to document, identify, and record key pest activities on key plants.
- Identify signs of the pest. These may include mushrooms, animal damage, insect frass, or webbing.
- Identify the symptoms of the pest. Look for symptoms such as chlorosis, dieback, growth reduction, defoliation, mounds, or tunnels.
- Determine the damage. Problem areas might include the edges of fairways, shady areas, or poorly drained areas.
- Document when the damage occurred. Note the time of day, year, and flowering stages of nearby plants.
- Map pest outbreak locations to identify patterns and susceptible areas for future target applications and ultimate pesticide reductions.

Record Keeping

Principles

- It is essential to record the results of scouting in order to develop historical information, document patterns of pest activity, and document successes and failures.
- Record keeping is required to comply with the federal Superfund Amendments and Reauthorization Act (SARA, Title III), which contains emergency planning and community right-to-know legislation.
- Certain pesticides are classified as restricted-use pesticides (RUPs). Very few pesticides in this category are routinely used in turf maintenance, but if you happen to use one of them, certain record-keeping requirements apply.

Best Management Practices

- Document, identify, and record key pest activities on key plants and locations.

- Determine the pest's life cycle, and know which life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).
- 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.
- 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 they are and what control strategies are necessary.

Turfgrass Selection

Principles

- Selecting pest-resistant cultivars or plant species is a very important part of IPM, and it leads to reduced pesticide usage. Species grown outside of their zone of adaptation are more prone to pest problems.
- Species and cultivars should be managed under conditions similar to their intended use (for example, not exceeding mowing height limitations that a grass was bred for or selected for).
- Educate builders, developers, golf course and landscape architects, sod producers, golfers and others on which plants are best suited to their areas.
- Turfgrasses must be scientifically selected for the eco-region of the golf course, resulting in minimized irrigation requirements, fertilization needs, and pesticide use.

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.



Sidney Country Club - Sidney, MT

Biological Controls

Principles

- The biological component of IPM involves the release and/or conservation of natural predators, such as parasites and pathogens, and other beneficial organisms (pollinators).
- Natural enemies (beneficial insects including ladybird beetles, green lacewings, and mantids) may be purchased and released near pest infestations.
- Areas on the golf course can also be modified to better support natural predators and beneficial organisms.

Best Management Practices

- Identify areas on the golf course that can be modified to attract natural predators, provide habitat for them, and protect them from pesticide applications.
- Install flowering plants that can provide parasitoids with nectar, or sucking insects (aphids, mealybugs, or soft scales) with a honeydew source.
- Provide a refuge for beneficial organisms by not applying pesticides to roughs, driving ranges, or other low-use areas.
- Release insect-parasitic nematodes to naturally suppress mole crickets and white grubs.

Pollinators

Principles

- It is important to minimize the impacts on bees and beneficial arthropods. Pesticide applicators must use appropriate tools to help manage pests while safeguarding pollinators, the environment, and humans.
- Pollinator-protection language is a label requirement found on pesticide labels.

- Be mindful of pollinators; when applying pesticides, focus on minimizing exposure to non-target pollinators in play and non-play course areas.
- Pollinators may be negatively impacted when pesticide applications are made based on insufficient information and/or made without regard to the safety of pollinators.

Best Management Practices

- Minimize injury and damage by following label directions when using pesticides.
- 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.
- Prohibit applying pesticides when pollinators are active.
- Scout/inspect area for both harmful and beneficial insect populations before applying a pesticide, and apply only when the indicated threshold of damage has been reached.
- Mow flowering plants (weeds) before insecticide application.
- Control flowering weeds, if prevalent, 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 forecasted.
- 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.

Conventional Pesticides

Principles

- IPM does not preclude the use of pesticides. However, pesticides should be viewed as one of the many tools used to minimize pest problems.
- 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!

Best Management Practices

- 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.
- Note 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).

Disease

Principles

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

Best Management Practices

- Identify the disease pathogen correctly. This often involves sending samples to diagnostic clinics.
- Ensure that 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.)
- Integrate fungicide use into an overall management strategy for a golf course.

- Apply the appropriate (most effective) preventive fungicide to susceptible turfgrasses when unacceptable levels of disease are likely to occur.
- Apply appropriate preventative fungicides where diseases are likely to occur and when conditions favor disease outbreaks.
- 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.

Weeds

Principles

- 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
 - properly selecting and using the appropriate herbicide, if necessary
- Weeds are hosts for other pests such as plant pathogens, nematodes, and insects, and certain weeds can cause allergic reactions in humans.
- Weeds reproduce from seed, root pieces, and special vegetative reproductive organs such as tubers, corms, rhizomes, stolons, or bulbs. People, animals, birds, wind, and water can distribute seeds.
- Weeds complete their life cycles in either one growing season (annuals), two growing seasons (biennials), or three or more years (perennials). Annuals that complete their life cycles from spring to fall are referred to as summer annuals. Those that complete their life cycles from fall to spring are winter annuals.

Best Management Practices

- Use proper weed identification - essential for effective management and control.
- Select appropriate turf species or cultivars that are adapted to the prevalent environmental conditions to reduce weed encroachment that may lead to bare soils.
- Adopt or maintain cultural practices that prevent weed encroachment and protect turfgrass from environmental stresses such as shade, drought, and extreme temperatures.
- Address improper turf management practices to reduce weed infestation, 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.

- Use proper fertilization, which 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.
- Use weed-free materials for topdressing.
- Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to broadleaf weeds.
- Record and map weed infestations to help identify site specific issues for preventative actions.

Nematodes

Principles

- Plant-parasitic nematodes 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.
- Nematodes debilitate the root system of susceptible turfgrasses; plant-parasitic nematodes cause turf to be less efficient at water and nutrient uptake from the soil and make it much more susceptible to environmental stresses. Additionally, weakened turf favors pest infestation, especially troublesome weeds that necessitate herbicide applications.
- Over time, turf in the affected areas thins out and, with severe infestations, may die. The roots of turfgrasses under nematode attack may be very short, with few, if any, root hairs, or they may appear dark and rotten.
- Turfgrasses usually begin showing signs of nematode injury as they experience additional stresses, including drought, high temperatures, low temperatures, and wear.

Best Management Practices

- Assess an assay of soil and turfgrass roots when nematode activity is suspected, to determine the extent of the problem.
- Base the application of a nematicide on golf course turf on assay results.
- Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
- Increase mowing height to reduce plant stress associated with nematodes, root-feeding insects, disease outbreaks, or peak weed-seed germination.
- Reduce/eliminate other biotic/abiotic stresses when nematodes are compromising the root system and plant health.



Pesticide Management

Introduction



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 deemed necessary, its selection should be based on effectiveness, toxicity to non-target species, cost, site characteristics, and its solubility and persistence in the environment.

Regulatory Considerations

Principle

Pesticides contain active ingredients (the component that targets the pest) and inert ingredients such as solvents, surfactants, and carriers. Both active and inert ingredients may be controlled or regulated by federal, state, and local laws because of environmental and health concerns.

Best Management Practices

- Apply only pesticides that are legally registered at all levels of jurisdiction.
- Apply only 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.

Human Health Risks

Principle

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.

Best Management Practices

- Select the least toxic pesticide with the lowest exposure potential within the economic abilities of the facilities.
- Know the emergency response procedure in case excessive exposure occurs.

Environmental Fate and Transport

Principle

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.

Best Management Practices

- Select pesticides that have a low runoff and leaching potential.
- Evaluate the impact of site-specific characteristics before applying a pesticide (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).
- Select pesticides with reduced impact on pollinators.
- Select pesticides that, when applied according to the label, have no known effect on endangered species known to be present on the facility.

Pesticide Transportation, Storage, and Handling

Principle

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.

Best Management Practices

- Store, mix, and load pesticides away from sites that directly link to surface water or groundwater.
- Store pesticides in a lockable concrete or metal building that is separate from other buildings.
- Locate pesticide storage facilities away from other types of structures to allow fire department access.

- Seal storage facility floors, which should be impervious, with a chemical-resistant paint.
- Construct floors with a continuous sill to retain spilled materials and no drains, although a sump may be included.
- Provide sloped ramps at the entrance to allow the use of wheeled handcarts for moving material in and out of the storage area safely.
- Construct shelving made of sturdy plastic or reinforced metal.
- Paint metal shelving to avoid corrosion. Wood shelving should never be used, because it may absorb spilled pesticides.
- Provide automatic exhaust fans and an emergency wash area. 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.
- Make personal protective equipment (PPE) easily accessible and store immediately outside the pesticide storage area.
- Avoid transporting pesticides in the passenger section of a vehicle.
- Prevent pesticides from being left unattended during transport.
- Place a spill containment kit in the storage area, in the mix/load area, and on the spray rig.

Emergency Preparedness and Spill Response

Principle

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

Best Management Practices

- Develop a golf course facility emergency response plan which includes procedures to control, contain, collect, and store spilled materials.
- Post in a prominent location “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.

Pesticide Record Keeping

Principle

Maintaining accurate records of pesticide-related activities (for example, purchasing, storage, inventory, applications, etc.) is essential.

Best Management Practices

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

Sprayer Calibration

Principle

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

Best Management Practices

- Ensure personally that your 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.
- Check equipment daily when in use.
- Use recommended spray volumes for the targeted pest to maximize efficacy.
- Conduct the calibration of walk-behind applicators for each person making the application, to take into consideration their walking speed, etc.

Types of Sprayers

Principle

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.

Best Management Practices

- Use an appropriately sized applicator for the size of area being treated.
- Avoid using equipment too large in size that requires greater volumes to prime the system. This can result in significant waste that must be properly handled.

Inventory

Principle

Do not store large quantities of pesticides for long periods. Adopt the “first in–first out” principle, using the oldest products first to ensure that the product shelf life does not expire.

Best Management Practices

Keep an inventory of the pesticides in the storage building. 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.

Shelf Life

Principle

- Pesticides degrade over time. Do not store large quantities of pesticides for long periods.
- Utilize computer software systems to record inventory and use.

Best Management Practices

- 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.
- Use available Department of Agriculture recycling programs in order to eliminate potential public health and environmental hazards from cancelled, suspended, and unusable pesticides that are being stored.
- 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.

Leaching Potentials

Principle

Weakly sorbed pesticides (compounds with small K_{oc} values) are more likely to leach through the soil and reach groundwater. Conversely, strongly sorbed pesticides (compounds with large K_{oc} values) are likely to remain near the soil surface, reducing the likelihood of leaching, but increasing the chances of being carried to surface water via runoff or soil erosion.

Best Management Practices

- 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.

Mixing/Washing Station

Principle

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

Best Management Practices

- Load pesticides and mix them with water or oil diluents over an impermeable surface (such as lined or sealed concrete), so that spills can be collected and managed.
- Ensure mixing station surface provides 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.
- Use absorbents such as cat litter or sand to clean up small spills and then apply as a topdressing in accordance with the label rates, or dispose of as a waste.
- Sweep up solid materials and use as intended.

Disposal

Principle

Wash water from pesticide application equipment must be managed properly, since it contains pesticide residues.

Best Management Practices

- Collect wash water (from both inside and outside the application equipment) and use it as a pesticide in accordance with the label instructions.

- Apply the rinsate as a pesticide (preferred) or store for use as makeup water for the next compatible application.

Personal Protective Equipment

Principle

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.

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.
- Confirm that PPE is appropriate for the chemicals used.
- Ensure that PPE meets rigorous testing standards and is not just the least expensive.
- Store PPE where it is easily accessible, but not in the pesticide storage area.
- Forbid employees who apply pesticides from wearing facility uniforms home where they may come into contact with children.
- Provide laundering facilities or uniform service for employee uniforms.
- Follow the federal Occupational Safety and Health Administration (OSHA) requirement for employers to fit test workers who must wear tight-fitting respirators.
- Meet requirements for OSHA 1910.134 Respiratory Protection Program.

Pesticide Container Management

Principle

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

- 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.



Old Works Golf Club - Anaconda, MT

Pollinator Protection

Introduction



Most flowering plants 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.

The western honey bee (*Apis mellifera*) is one of the most important pollinators in the United States. Hundreds of other bee species, including the bumble bee (*Bombus* spp.), also serve as important pollinator species. Protecting bees and other pollinators is important to the sustainability of agriculture.

Pesticides are products designed to control pests (for example, insects, diseases, weeds, nematodes, etc.). Pesticides and other plant growth products, including plant growth regulators, surfactants, biostimulants, etc., are used in golf course management. The non-target effect of products used in golf course management is of increasing concern; therefore, pesticide applicators, including those on golf courses, need to be mindful of the impact that pesticides have on pollinator species and their habitat.

Regulatory Considerations

Principles

- Pollinator-protection language is a label requirement found on pesticide labels; follow the label, it is the law.
- Pesticide applicators must be aware of honey bee toxicity groups and able to understand precautionary statements.
- Recordkeeping may be required by law in order to use some products. IPM principles suggest that you keep records of all pest control activity so that you may refer to information on past infestations or other problems to select the best course of action in the future.

Best Management Practices

- Keep proper records of all pesticide applications according to local, state, or federal requirements.
- Use records to establish proof of use and follow-up investigation of standard protocols regarding:
 - Date and time of application
 - Name of applicator
 - Person directing or authorizing the application
 - Weather conditions at the time of application
 - Target pest
 - Pesticide used (trade name, active ingredient, amount of formulation, amount of water)
 - Adjuvant/surfactant and amount applied, if used
 - Area treated (acres or square feet) and location
 - Total amount of pesticide used
 - Application equipment
 - Additional remarks, such as the severity of the infestation or life stage of the pest
 - Follow-up to check the effectiveness of the application
- Understand that pollinator protection label statements should be used by those who make decisions regarding their applications and those applying the pesticides.
- Know honey bee biology when applying pesticides.
- Understand the various routes of exposure (outside the hive and inside the hive) when applying pesticides.
- Understand the effects of pesticides on bees when applying pesticides.

Pollinator Habitat Protection

Principles

- It is important to minimize the impacts of pesticides on bees and beneficial arthropods. Pesticide applicators must use appropriate tools to help manage pests while safeguarding pollinators, the environment, and humans.
- Be mindful of pollinators; when applying pesticides, focus on minimizing exposure to non-target pollinators in play and non-play course areas.
- Pollinators require a diversity of flowering species to complete their life cycle. Pollinator habitat contains a diversity of wildflower species of different colors and heights, with blossoms throughout the entire growing season

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.
- Prohibit applying pesticides when pollinators are active.

- 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.
- Control flowering weeds, if prevalent, 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.



Maintenance Operations

Introduction



Equipment maintenance, fueling, and chemical storage can have an impact on water quality, both on-site and off-site, during construction and during the maintenance of existing golf courses.

Regulatory Considerations

Local and state regulations may be in place in your location. Early engagement among developers, designers, local community groups and permitting agencies is essential to designing and constructing a golf maintenance and storage facility that minimizes environmental impact and meets the needs for the approval process.

Storage and Handling of Chemicals

Principles

- 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.
- Check federal, state, and local regulations for specific requirements related to storage of pesticides.

Best Management Practices

- Post appropriate warning signs and placards at storage buildings.
- 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.
- Train individuals conducting emergency chemical cleanups properly, under requirements of Federal Occupational Safety and Health Administration (OSHA).
- Store pesticides in a lockable concrete or metal building.

- Locate pesticide storage away from other buildings, especially fertilizer storage facilities.
- Seal floors of chemical storage buildings with chemical-resistant paint. These floors should be impervious.
- Equip floors of chemical storage buildings with a continuous sill to contain spills. There should be no drain. A sump is acceptable.
- Construct shelving 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.
- Provide automatic exhaust fans and an emergency wash area.
- Use explosion-proof lighting if required. Locate fan and light switches outside the entrance to the building to facilitate ventilation of building before entrance of staff.
- Maintain detailed records of current pesticide inventory in the storage facility. Safety Data Sheets (SDS) for the chemicals stored on-site should be stored separately from the storage room, but readily accessible on-site.
- Abstain from storing 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.
- Replace damaged labels 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.

Waste Handling

Principles

- Proper disposal of waste materials is critical for protection of water and natural resources. State or local laws and regulations related to disposal of hazardous waste products may vary. Be sure to familiarize yourself with all state and local laws related to disposal/recycling of these waste materials.
- 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

- Dispose as waste pesticides that have been mixed for application. These may be classified as hazardous waste depending on the materials involved. Contact local authorities for guidance regarding proper disposal.
- Collect used oil, oil filters, and antifreeze in separate marked containers and recycle them as directed by local and state authorities.
- Handle antifreeze, which may be considered hazardous waste by state or local laws, appropriately. Commercial services are available to collect and recycle antifreeze.
- Classify lead-acid batteries as hazardous waste unless they are properly recycled.
- Store old batteries on impervious surfaces where they are protected from rainfall and recycle as soon as possible.
- Recycle used tires.
- Recycle or dispose of fluorescent tubes and other lights according to state requirements.

Equipment Storage and Maintenance

Principle

Storing and maintaining equipment properly will extend useful life and reduce repairs.

Best Management Practices

- Store and maintain equipment in a covered area complete with a sealed impervious surface to limit risk of fluid leaks contaminating the environment and to facilitate the early detection of small leaks that may require repair before causing significant damage to the 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).
- Replace solvent baths with recirculating aqueous washing unit when possible. Soap and water or other aqueous cleaners are often as effective as solvent-based products and present a lower risk to the environment.
- Use appropriate PPE when working with solvents.

- Prohibit solvents or degreasers from draining onto pavement or soil, or discharging into waterbodies, wetlands, storm drains, sewers, or septic systems.
- Collect used solvents and degreasers in containers clearly marked with contents and date; schedule collection by a commercial service.
- Blow off all equipment with compressed air to reduce damage to hydraulic seals.

Equipment Washing

Principle

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

Best Management Practices

- Brush or blow off grass-covered equipment with compressed air before being washed.
- Use spring-operated shut-off nozzles.
- Prevent wastewater, including water from equipment washing areas, from flowing directly into surface waters or storm drains.

Fueling Facilities

Principle

Safe storage of fuel, including use of above-ground tanks and containment facilities, is critical to the protection of the environment. State or local laws and regulations related to storage of fuel may vary.

Best Management Practices

- Equip fueling stations with spill-containment and recovery facilities.
- Use above ground fuel tanks, if possible.

Pollution Prevention

Principles

- Plan appropriately to minimize the possibility of an illicit discharge and need for disposal. Monitor the water to be discharged for contamination; never discharge to the environment any contaminated water. If the water is not contaminated, it can be reused or discharged to a permitted stormwater treatment system.
- 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.
- 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.
- One of the key principles of pollution prevention is to reduce the unnecessary use of potential pollutants. 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.
- 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.
- 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.
- Pesticides that have been mixed so they cannot be legally applied to a site in accordance with the label must be disposed of as a waste. Depending on the materials involved, they may be classified as hazardous waste.
- Provide adequate protection from the weather. Rain can wash pesticide and fertilizer residues from the exterior of the equipment, and these residues can contaminate soil or water.
- Never allow solvents to drain onto pavement or soil, or discharge into water bodies, wetlands, storm drains, sewers, or septic systems, even in small amounts.
- 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.

Best Management Practices

- Store pesticides in a lockable concrete or metal building.
- Seal pesticide storage and mixing facility floors with a chemical-resistant paint. These floors should be impervious and have a continuous sill to retain spilled materials. Prohibit drains, although a sump may be included.
- 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 for valuable information about constructing chemical mixing facilities.

- 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.)
- Flush wash 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.
- Allow the applicator to apply a pesticide at less than the labeled rate per FIFRA, Section 2(ee).
- Clean the sump of any sediment before another type of pesticide is handled.
- Discharge to a treatment system that is permitted under industrial wastewater rules.
- Avoid discharging to a sanitary sewer system without written permission from the utility.
- Avoid discharging to a septic tank.
- Use non-containment wash water for field irrigation.
- Avoid discharging 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.
- Replace, whenever practical, solvent baths with recirculating aqueous washing units (which resemble heavy-duty dishwashers).
- Use soap and water or other aqueous cleaners; these products are often as effective as solvent-based ones.
- Clean up spills as soon as possible.
- Keep spill cleanup equipment available when handling pesticides or their containers.
- Report 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.
- Remediate large spills or uncontained spills involving hazardous materials, using hazardous material cleanup professionals.
- Call CHEMTREC, at (800)424-9300 for emergency (only) information on hazards or actions to take in the event of a spill. 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.
- Avoid washing equipment in the vicinity of wells or surface water bodies.
- 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 applicable, allow runoff onto a grassed area to soak into the ground, but never into a surface water body or canal.

- Use compressed air to blow off equipment. This is less harmful to the equipment's hydraulic seals, eliminates wastewater, and produces dry material that is easier to handle.
- Handle clippings and dust separately. After the residue dries on the pad, it can be collected and composted or spread in the field.
- Minimize the use of detergents. Use only biodegradable non-phosphate detergents.
- Minimize the amount of water used to clean equipment. This can be done by using spray nozzles that generate high-pressure streams of water at low volumes.
- Avoid discharging wash water to surface water or groundwater, either directly or indirectly, through ditches, storm drains, or canals.
- Avoid conducting equipment wash operations on a pesticide mixing and loading pad. (This keeps grass clippings and other debris from becoming contaminated with pesticide).
- Use solvents and degreasers over a collection basin or pad that collects all used material.
- Manage oil/water separators properly to avoid problems. Do not wash equipment used to apply pesticides on pads with oil/water separators.
- 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.
- Collect used oil, oil filters, and antifreeze in separate marked containers and recycle them. Arrange pickup of used oil, or deliver to a hazardous waste collection site.
- Avoid mixing used oil with used antifreeze or sludge from used solvents. Antifreeze may be considered hazardous waste by state or local laws and should be handled accordingly. Commercial services are available to collect and recycle antifreeze.
- Store batteries on an impervious surface and preferably under cover. Remember, spent lead-acid batteries must be recycled if they are to be exempt from strict hazardous waste regulations.
- Classify lead-acid storage batteries as hazardous wastes unless they are recycled. All lead-acid battery retailers in Florida are required by law to accept returned batteries for recycling.
- Recycle spent lead-acid batteries if they are to be exempt from strict hazardous waste regulations.
- Store equipment used to apply pesticides and fertilizers in areas protected from rainfall.
- Store pesticide application equipment in the chemical mixing center (CMC), but fertilizer application equipment should be stored separately.
- Blow or wash loose debris off equipment to prevent dirt from getting on the CMC pad, where it could become contaminated with pesticides.

- 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.
- Shake or tap non-rinseable containers, such as bags or boxes, so that all dust and material fall into the application equipment.
- Puncture the pesticide containers, after cleaning them, 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.
- Store 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. Check with your local landfill before taking containers for disposal, as not all landfills will accept them.



The Reserve at Moonlight Basin - Big Sky, MT

Landscape

Species Selection and Size Considerations



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.

Principles

- The fundamental principle for the environmentally sound management of landscapes is “right plant, right place.” The ideal plant from an environmental standpoint is the one that nature and evolution placed there. It has adapted specifically to the soil, microclimate, rainfall, and light patterns, insects, and other pests, and endemic nutrient levels over thousands of years.
- Know the ultimate sizes and growth rates of trees, shrubs, and ground covers. This reduces the need for pruning and debris removal and lowers maintenance costs.
- The addition of proper soil amendments can improve soil’s physical and chemical properties, increase its water-holding capacity, and reduce the leaching of fertilizers. Amendments may be organic or inorganic; however, soil microorganisms rapidly decompose organic amendments such as peat or compost.
- The goal of species-selection 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 plant material that requires little to no maintenance after establishment. Additionally, 50% to 70% of the non-play areas should remain in natural cover. As much natural vegetation as possible should be retained and enhanced through the supplemental planting of

native trees, shrubs, and herbaceous vegetation 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.

Best Management Practices

- Ensure base plant selection is as close to a natural ecosystem as practical, while meeting the needs of the golf course. The natural ecosystem 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.
- Select stress-tolerant species or cultivars to manage periodic dry/wet conditions.
- Choose the most stress-tolerant species or cultivar for a particular area.

Design and Function

Principles

- Aesthetic gardens, window boxes, and container gardens should include a variety of plants of different heights that provide nectar for hummingbirds and butterflies. Again, “right plant, right place” is the key to success.
- When integrating 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

- Ensure well-designed forested buffers 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.

Planting Methods

Principles

- The ideal plant from an environmental standpoint is the one that nature and evolution placed there. It has adapted specifically to the soil, microclimate, rainfall, light patterns, insects, and other pests, and endemic nutrient levels over hundreds or thousands of generations. Where these factors have changed, the challenge is finding other suitable plants. 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

- Ensure the plant palette and irrigation system are appropriate for site conditions, taking into account that, in some cases, soil improvement can enhance water-use efficiency.
- Group plants together based on irrigation demand.
- Minimize the percentage of landscaped area in irrigated high-water-use hydrozones. Local government ordinances should address the percentage of irrigated landscaped area that may be included in high-water-use hydrozones. 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).
- Understand that in most instances, established, drought-tolerant landscape plants have a root system substantial enough to keep them alive with little or no supplemental irrigation.
- Ensure 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.



Rock Creek Cattle Company - Deer Lodge, MT

Energy

Energy Conservation



According to the GCSAA Golf Course Environmental Profile, Vol. IV (GCSAA 2012), six major energy sources were identified for golf course use: electricity, gasoline, diesel, natural gas, propane and heating oil. In addition, operational uses were segmented to meet irrigation, turf maintenance, buildings, clubhouse operations, swimming pools and various amenity needs.

The overall conclusion of the study suggests that golf facility managers must take steps toward identifying options for conservation, efficiency, and cost savings.

To address current needs and future energy reduction opportunities, managers should evaluate 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.)

Principles

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

- Understand that the irrigation pump is the largest user of energy associated with the golf course itself. 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.
- Use non-demand electrical hour rates: charge golf carts, use pumps to acquire water, charge maintenance equipment, and other items later in the day or early in the morning.
- Limit high-consumption activities during periods when demand is high.
- Explore potential use of alternative energy from natural sources, such as solar, geothermal and wind energy generation.
- 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.

Evaluation

Principles

- 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.

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.

Efficiency

Principles

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

Best Management Practices

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



Canyon River Golf Club - Missoula, MT

Design and Renovation

Principles

- Incorporate an analysis of the assessments, audits, and data.
- Incorporate first cost consideration (initial investment and long-term gain).
- Redesign – evaluate future projects with a priority for energy conservation.
- According to system and compliance standards, communicate 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.

Implementation Plan

Principles

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

Best Management Practices

- Evaluate effectiveness of upgrades according to efficiency/conservation goals for energy use.
- 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.

Infrastructure

Principles

- Ensure efficient building/facility/amenities and related infrastructure.
- Consider the materials: which type 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.

Alternative products, operations, and practices

Principles

- Educate and motivate employees, guests, etc.
- Educate, train, and motivate employees on energy efficiency practices pertaining to golf course operations.
- Identify incentives and programs from energy providers.
- Identify state/local programs and certification.
- Consider U.S. Green Building Council's LEED program.
- Consider EPA's EnergyStar, Portfolio Manager, etc.
- Consider energy management software, services, etc.
- Consider national and local programs and programs like the EPA's WaterSense program as it relates to buildings (see Water Conservation BMP).

Best Management Practices

- Evaluate alternative transportation.
- 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 cart equipment/operations and ensure proper selection, operation, charging, and maintenance.
- Incorporate training for employees.
- Incorporate the use of incentives.

Course Management Plan

Principles

- Set energy-use goals for efficiency/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.

Irrigation

Principles

- Ensure efficient design, selection, operation, and maintenance of irrigation pumps, irrigation controls, and other irrigation components.
- 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 Water Conservation BMP).
- Schedule and operate pumps and irrigation in an efficient manner.
- Identify and implement infrastructure and behavioral changes in irrigation.
- Evaluate technology and upgrades; implement when feasible.



References



Selected References

(Note: URLs are as of September 2016)

Aerts, M.O., N. Nesheim, and F. M. Fishel. April 1998; revised September 2015. *Pesticide recordkeeping*. PI-20. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI012>.

Aquatic Ecosystem Restoration Foundation. 2014. *Biology and Control of Aquatic Plants: A Best Management Practices Handbook*: 3rd Ed. Gettys, L.A., W. T. Haller, and D. G. Petty, editors. <http://www.aquatics.org/bmp%203rd%20edition.pdf>

ASCE, January 2005. *The ASCE standardized reference evapotranspiration equation*. Final report of the Task Committee on Standardization of Reference Evapotranspiration, Environmental and Water Resources Institute of the American Society of Civil Engineers. 1801 Alexander Bell Drive, Reston, VA 20191 Available: <http://www.kimberly.uidaho.edu/water/asceewri/ascestzdetmain2005.pdf>

Bohmert, B. 1981. *The new pesticide users guide*. Fort Collins, Colorado: B & K Enterprises.

Brecke, B.J., and J.B. Unruh. May 1991; revised February 25, 2003. *Spray additives and pesticide formulations*. Fact Sheet ENH-82. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/LH061>.

Broder, M.F., and D.T. Nguyen. 1995. *Coating concrete secondary containment structures exposed to agrichemicals*. Circular Z-361. Muscle Shoals, Alabama: Tennessee Valley Authority, Environmental Research Center. Tel. (205) 386-2714.

Broder, M.F., and T. Samples. 2002. *Tennessee handbook for golf course environmental management*. Tennessee Department of Agriculture.

Buss, E.A. January 2002; revised July 2003. *Insect pest management on golf courses*. ENY-351. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/IN410>.

Butler, T., W. Martinkovic, and O.N. Nesheim. June 1993; revised April 1998. *Factors influencing pesticide movement to groundwater*. PI2. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI002>.

California Fertilizer Association. 1985. *Western fertilizer handbook*, 7th ed. Sacramento, California.

Carrow, R.N., R. Duncan, and C. Waltz. 2007. Best Management Practices (BMPs) Water-Use Efficiency/Conservation Plan for Golf Courses. Available: [https://www.gcsaa.org/uploadedfiles/Environment/Get-Started/BMPs/Water-use-efficiency-and-conservation-best-management-practices-\(Georgia\).pdf](https://www.gcsaa.org/uploadedfiles/Environment/Get-Started/BMPs/Water-use-efficiency-and-conservation-best-management-practices-(Georgia).pdf)

Carrow, R.N., R.R. Duncan, and D. Wienecke. 2005. BMPs: Critical for the golf industry. *Golf Course Management*. 73(6):81-84.

Center for Resource Management. 1996. *Environmental principles for golf courses in the United States*. 1104 East Ashton Avenue, Suite 210, Salt Lake City, Utah 84106. Tel: (801) 466-3600, Fax: (801) 466-3600.

Clark, G.A. July 1994. *Microirrigation in the landscape*. Fact Sheet AE254. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/AE076>.

Clark, Mark and Acomb, Glenn; Florida Field Guide to Low Impact Development: Stormwater Reuse. Univ. Florida 2008. http://buildgreen.ufl.edu/Fact_sheet_Stormwater_Reuse.pdf

Colorado Nonpoint Source Task Force. 1996. Guidelines for Water Quality Enhancement at Golf Courses Through the Use of Best Management Practices. Available: <http://www.wrightwater.com/assets/7-golf-course-bmps.pdf>

Connecticut Department of Environmental Protection. 2006. Best Management Practices for Golf Course Water Use. Available: http://www.ct.gov/deep/lib/deep/water_inland/diversions/golfcoursewaterusebmp.pdf

Cromwell, R.P. June 1993; reviewed December 2005. *Agricultural chemical drift and its control*. CIR1105. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/AE043>.

Crow, W.T. February 2001; revised November 2005. *Nematode management for golf courses in Florida*. ENY-008 (IN124). Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/IN124>.

Daum, D.R., and T.F. Reed. n.d. *Sprayer nozzles*. Ithaca, New York: Cornell Cooperative Extension. Available <http://psep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-spray-nozz.aspx>.

Dean, T.W. February 2003. *Pesticide applicator update: Choosing suitable personal protective equipment*. PI-28. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI061>.

———. April 2004; revised November 2004. *Secure pesticide storage: Facility size and location*. Fact Sheet PI-29. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI064>.

———. April 2004; revised November 2004. *Secure pesticide storage: Essential structural features of a storage building*. Fact Sheet PI-30. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI065>.

Dean, T.W., O.N. Nesheim, and F. Fishel. Revised May 2005. *Pesticide container rinsing*. PI-3. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI003>.

Delaware Nutrient Management Commission. 2006. *Water Quality Best Management Practices: Nutrients, Irrigation and Pesticides for Golf Course, Athletic Turf, Lawn Care and Landscape Industries*. Available: <http://dda.delaware.gov/nutrients/forms/BMPnonagforprinter.pdf>

Dodson, R.G. 2000. *Managing wildlife habitat on golf courses*. Sleeping Bear Press. Chelsea, MI.

Elliott, M.L., and G.W. Simone. July 1991; revised April 2001. *Turfgrass disease management*. SS-PLP-14. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/LH040>.

Fishel, F.M. March 2005. *Interpreting pesticide label wording*. Gainesville, Florida: Institute of Food and Agricultural Sciences. Available: <http://edis.ifas.ufl.edu/PI071>.

Fishel, F.M., and Nesheim, O.N. November 2006. *Pesticide safety*. FS11. Gainesville, Florida: Institute of Food and Agricultural Sciences. Available: <http://edis.ifas.ufl.edu/pdf/CV/CV10800.pdf>.

Florida Department of Agriculture and Consumer Services. n.d. *Pesticide recordkeeping—benefits and requirements*. Available: <http://www.flaes.org/pdf/Pesticide%20Recordkeeping%20Pamphlet%205-05.pdf>.

Florida Department of Agriculture and Consumer Services. Division of Agricultural Environmental Services. *Suggested pesticide recordkeeping form*. Available: <https://www.freshfromflorida.com/content/download/2990/18861/Suggested%20Pesticide%20Recordkeeping%20Form.pdf>

———. Division of Agricultural Environmental Services. *Suggested pesticide recordkeeping form for organo-auxin herbicides*. Available: <http://forms.freshfromflorida.com/13328.pdf>.

Florida Department of Agriculture and Consumer Services and Florida Department of Environmental Protection. 1998. *Best management practices for agrichemical handling and farm equipment maintenance*. Available:

<http://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/agbmp3p.pdf>

Florida Department of Environmental Protection. 2008. *Florida stormwater, erosion, and sedimentation control inspector's manual*. Tallahassee, Florida: Nonpoint Source Management Section, MS 3570, 3900 Commonwealth Blvd., Tallahassee, Florida 32399-3000. Available: <http://www.dep.state.fl.us/water/nonpoint/docs/erosion/erosion-inspectors-manual.pdf>.

———. December 27, 2002. *Environmental risks from use of organic arsenical herbicides at south Florida golf courses*. FDEP white paper. Available:

<http://fdep.ifas.ufl.edu/msma.htm>.

———. April 2002. *Florida water conservation initiative*. Available:

http://www.dep.state.fl.us/water/waterpolicy/docs/WCI_2002_Final_Report.pdf.

———. 2015. "Florida-friendly Best Management Practices for Protection of Water Resources by the Green Industries", Florida Department of Environmental Protection. Revised December 2008, 3rd printing 2015. <https://fyn.ifas.ufl.edu/pdf/grn-ind-bmp-en-12-2008.pdf>

———. 2012. *Best Management Practices for The Enhancement of Environmental Quality on Florida Golf Courses*. Florida Department of Environmental Protection. 3rd printing, September 2012.

<http://www.dep.state.fl.us/water/nonpoint/docs/nonpoint/glfbmp07.pdf>

———. Revised August 2009. *A guide on hazardous waste management for Florida's auto repair shops*. Available:

http://www.dep.state.fl.us/waste/quick_topics/publications/shw/hazardous/business/Pain_t_and_Body8_09.pdf.

———. October 2005. *Checklist guide for 100% closed loop recycle systems at vehicle and other equipment wash facilities*. Available:

<http://www.dep.state.fl.us/water/wastewater/docs/ChecklistGuideClosed-LoopRecycleSystems.pdf>.

———. October 2005. *Guide to best management practices for 100% closed-loop recycle systems at vehicle and other equipment wash facilities*. Pollution Prevention Program and Industrial Wastewater Section. Available:

<http://www.dep.state.fl.us/water/wastewater/docs/GuideBMPClosed-LoopRecycleSystems.pdf>.

———. 2006. *State of Florida erosion and sediment control designer and reviewer manual*. Nonpoint Source Management Section. Available: <http://www.dep.state.fl.us/water/nonpoint/erosion.htm>.

———. 2016. Operation Cleansweep for Pesticides Web site. Available: <http://www.dep.state.fl.us/waste/categories/cleansweep-pesticides>.

———. December 1, 2005. *Standards and specifications for turf and landscape irrigation systems*, 5th Ed. Available: <http://ufdc.ufl.edu/UF00076845/00001>.

———. December 2006. *Landscape Irrigation & Florida-Friendly Design Standards*. Florida Department of Environmental Protection, Office of Water Policy, 3900 Commonwealth Blvd., MS 46, Tallahassee, FL 32399-3000. Available: <http://www.dep.state.fl.us/water/waterpolicy/docs/LandscapeIrrigationFloridaFriendlyDesign.pdf>

Gilman, E. 2006. *Pruning shade trees in landscapes*. Available: <http://hort.ufl.edu/woody/pruning/index.htm>.

Golf Course Superintendents Association of America. 2012. *Golf Course Environmental Profile; Volume IV; Energy Use and Energy Conservation Practices on U.S. Golf Courses*. Available: <https://www.gcsaa.org/Uploadedfiles/Environment/Environmental-Profile/Energy/Golf-Course-Environmental-Profile--Energy-Use-and-Conservation-Report.pdf>

Golf Course Water Resources Handbook of Best Management Practices (Pennsylvania). 2009. Available: <http://pecpa.org/wp-content/uploads/Golf-Course-Water-Resources-Handbook-of-Best-Management-Practices.pdf>

Havlin, J.L., et al. 2004. *Soil fertility and fertilizers*, 7th Ed. Prentice Hall.

Haydu, J.J., and A.W. Hodges. 2002. *Economic impacts of the Florida golf course industry*. UF–IFAS Report EIR 02-4. Available: <http://economicimpact.ifas.ufl.edu/publications/EIR02-4r.pdf>.

Helfrich, L.A., et al. June 1996. *Pesticides and aquatic animals: A guide to reducing impacts on aquatic systems*. Virginia Cooperative Extension Service. Publication Number 420-013. Available: <http://www.ext.vt.edu/pubs/waterquality/420-013/420-013.html>.

Hornsby, A.G., T.M. Buttler, L.B. McCarty, D.E. Short, R.A. Dunn, G.W. Simone. Revised September 1995. *Managing pesticides for sod production and water quality protection*. Circular 1012. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/SS053>.

Insecticide Resistance Action Committee Web site. Available: <http://www.irac-online.org/>.

King, K.W., and J.C. Balogh. 2001. Water quality impacts associated with converting farmland and forests to turfgrass. In: *Transactions of the ASAE, Vol. 44(3): 569-576*.

Lehtola, C.J., C.M. Brown, and W.J. Becker. November 2001. *Personal protective equipment. OSHA Standards 1910.132-137. AE271*. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/OA034>.

McCarty, L.B., and D.L. Colvin. 1990. *Weeds of southern turfgrasses*. Gainesville, Florida: University of Florida.

Midwest Plan Service. Revised 1995. *Designing facilities for pesticide and fertilizer containment*. MWPS-37. Midwest Plan Service, 122 Davidson Hall, Iowa State University, Ames, IA 50011-3080. Tel.: (515) 294-4337. Available: <http://infohouse.p2ric.org/ref/50/49471.pdf>.

Mitra, S. 2006. *Effects of recycled water on turfgrass quality maintained under golf course fairway conditions*. WateReuse Foundation, 1199 North Fairfax Street, Suite 410, Alexandria, VA 22314. Available: <http://www.watereuse.org/Foundation/documents/wrf-04-002.pdf>.

National Pesticide Telecommunications Network. December 1999. *Signal words*. Fact Sheet. Available: <http://npic.orst.edu/factsheets/signalwords.pdf>.

Nesheim, O.N., and F.M. Fishel September 2007, reviewed August 2013. *Interpreting PPE statements on pesticide labels*. P116. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <https://edis.ifas.ufl.edu/pdffiles/CV/CV28500.pdf>.

Nesheim, O.N., and F.M. Fishel. March 1989; revised November 2005. *Proper disposal of pesticide waste*. PI-18. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/PI010>.

Nesheim, O.N., F.M. Fishel, and M. Mossler. July 1993. *Toxicity of pesticides*. PI-13. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/pdffiles/PI/PI00800.pdf>.

O'Brien, P. July/August 1996. Optimizing the turfgrass canopy environment with fans. *USGA Green Section Record, Vol. 34(4), 9-12* Available: <http://gsrpdf.lib.msu.edu/ticpdf.py?file=/1990s/1996/960709.pdf>.

O'Brien, P., and C. Hartwiger. March/April 2003. Aerification and sand topdressing for the 21st century. *USGA Green Section Record*, Vol. 41(2), 1-7. Available: <http://turf.lib.msu.edu/2000s/2003/030301.pdf>.

Olexa, M.T., A. Leviten, and K. Samek. December 2008, revised December 2013. *Florida solid and hazardous waste regulation handbook: Table of contents*. FE758. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/fe758>.

Otterbine Barebo, Inc. 2003. *Pond and lake management*. 3840 Main Road East, Emmaus, PA 18049. Available: <http://www.otterbine.com/assets/base/resources/PondAndLakeManual.pdf>.

Peterson, A. 2000. *Protocols for an IPM system on golf courses*. University of Massachusetts Extension Turf Program.

Pennsylvania Department of Environmental Protection, LandStudies, Inc., The Pennsylvania Environmental Council. *Golf Course Water Resources Handbook of Best Management Practices*. June 2009. <http://pecpa.org/wp-content/uploads/Golf-Course-Water-Resources-Handbook-of-Best-Management-Practices.pdf>

Pettinger, N.A. 1935. Useful chart for teaching the relation of soil reaction to availability of plant nutrients to crops. *Virginia Agri. Ext. Bul.* 136, 1-19.

Portness, R.E., J.A. Grant, B. Jordan, A.M. Petrovic, and F.S. Rossi. 2014. *Best Management Practices for New York State Golf Courses*. Cornell Univ. Available: http://nysgolfbmp.cals.cornell.edu/ny_bmp_feb2014.pdf

Rao, P.S.C., and A.G. Hornsby. May 1993; revised December 2001. *Behavior of pesticides in soils and water*. Fact Sheet SL40. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/SS111>.

Rao, P.S.C., R.S. Mansell, L.B. Baldwin, and M.F. Laurent. n.d. *Pesticides and their behavior in soil and water*. Ithaca, New York: Cornell Cooperative Extension. Available: <http://psep.cce.cornell.edu/facts-slides-self/facts/gen-pubre-soil-water.aspx>.

Rodgers, J. n.d. *Plants for lakefront revegetation*. Invasive Plant Management, Florida Department of Environmental Protection, 3900 Commonwealth Blvd., MS 705, Tallahassee, FL 32399. Available: <http://myfwc.com/media/2518526/LakefrontRevegetation.pdf> .

Sartain, J.B. 2000. *General recommendations for fertilization of turfgrasses on Florida soils*. Fact Sheet SL-21. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/LH014>.

———. 2001. *Soil testing and interpretation for Florida turfgrasses*. SL-181. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/SS317>.

———. 2002. revised October 2006. *Recommendations for N, P, K, and Mg for golf course and athletic field fertilization based on Mehlich-I extractant*. SL-191. Available: <http://edis.ifas.ufl.edu/SS404>. Gainesville, Florida.

Sartain, J.B., and W.R. Cox. 1998. *The Florida fertilizer label*. SL-3. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/SS170>.

Sartain, J.B., G.L. Miller, G.H. Snyder, and J.L. Cisar. 1999a. Plant nutrition and turf fertilizers. In: J.B. Unruh and M. Elliott (Eds.). *Best management practices for Florida golf courses*. SP-141 2nd ed. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida.

———. 1999b. Liquid fertilization and foliar feeding. In: J.B. Unruh and M. Elliott (Eds.), *Best management practices for Florida golf courses*. SP-141 2nd ed. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida.

Sartain, J.B., G.L. Miller, G.H. Snyder, J.L. Cisar, and J.B. Unruh. 1999. Fertilization programs. In: J.B. Unruh and M. Elliott (Eds.). *Best management practices for Florida golf courses*. SP-141 2nd ed. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida.

Schueler, T.R. 2000. Minimizing the impact of golf courses on streams. Article 134 in: *The practice of watershed protection*. T. R. Schueler and H. K. Holland (Eds.). Ellicott City, Maryland: Center for Watershed Protection. Available: <http://www.stormwatercenter.net/>.

Schumann, G.L., et al. January 1998. *IPM handbook for golf courses*. Indianapolis, Indiana: Wiley Publishing, Inc.

Seelig, B. July 1996. *Improved pesticide application BMP for groundwater protection from pesticides*. AE-1113. Fargo, North Dakota: North Dakota State University Extension Service. Available: <http://www.ext.nodak.edu/extpubs/h2oqual/watgrnd/ae1113w.htm>.

Smajstrla, A.G., and B.J. Boman. April 2000. *Flushing procedures for microirrigation systems*. Bulletin 333. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/WI013>.

Staples, A.J. 2. Golf Course Energy Use Part 2: Pump Stations. Golf Course Management, July 2009.

<https://www.gcsaa.org/Uploadedfiles/Environment/Resources/Energy-Conservation/Golf-course-energy-use-Part-2-Pump-stations.pdf>

Tennessee Department of Agriculture. Tennessee Handbook for Golf Course Environmental Management. Available: <http://tennesseeturf.utk.edu/pdf/golfcourseenvironmgmt.pdf>

Thostenson, A., C. Ogg, K. Schaefer, M. Wiesbrook, J. Stone, and D. Herzfeld. 2016. Laundering pesticide-contaminated work clothes. PS 1778. Fargo, ND. North Dakota State Univ. Cooperative Extension. <https://www.ag.ndsu.edu/pubs/plantsci/pests/ps1778.pdf>

Trautmann, N.M., K.S. Porter, and R.J. Wagenet. n.d. *Pesticides and groundwater: A guide for the pesticide user*. Fact Sheet. Ithaca, New York: Cornell Cooperative Extension. Available: <http://psep.cce.cornell.edu/facts-slides-self/facts/pest-gr-gud-grw89.aspx>

University of Florida—Institute of Food and Agricultural Sciences. Center for Aquatic and Invasive Plants Web site. Available: <http://plants.ifas.ufl.edu/>.

———. Insect Identification Service Web site. Available: <http://edis.ifas.ufl.edu/SR010>.

———. Nematode Assay Laboratory Web site. Available: <http://edis.ifas.ufl.edu/SR011>.

———. Pesticide Information Office Web site. Available: <http://pested.ifas.ufl.edu/>

———. Plant Disease Clinic Web site. Available: <http://plantpath.ifas.ufl.edu/extension/plant-diagnostic-center/>

———. Rapid Turfgrass Diagnostic Service Web site. Available: <http://turfpath.ifas.ufl.edu/rapiddiag.shtml>.

Unruh, J.B. November 1993. *Pesticide calibration formulas and information*. Fact Sheet ENH-90. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://edis.ifas.ufl.edu/WG067>.

Unruh, J.B. 2006. *2006 University of Florida's pest control guide for turfgrass managers*. Gainesville, Florida: Institute of Food and Agricultural Sciences, University of Florida. Available: <http://turf.ufl.edu>.

Unruh, J.B., and B.J. Brecke. Revised January 1998. *Response of turfgrass and turfgrass weeds to herbicides*. ENH-100. Gainesville, Florida: Department of Environmental Horticulture, University of Florida. Available: <http://edis.ifas.ufl.edu/WG071>.

Unruh, J.B., and M. Elliot. 1999. *Best management practices for Florida golf courses*, 2nd ed. UF–IFAS Publication SP-141. Gainesville, Florida.

Unruh, J.B., J.L. Cisar, and G.L. Miller. 1999. Mowing. In: J.B. Unruh and M.L. Elliot (Eds.). *Best management practices for Florida golf courses*, 2nd ed. Gainesville, Florida: University of Florida Institute of Food and Agricultural Sciences.

Unruh, J.B., A.E. Dudeck, J.L. Cisar, and G.L. Miller. 1999. Turfgrass cultivation practices. In: J.B. Unruh and M.L. Elliot (Eds.). *Best management practices for Florida golf courses*, 2nd ed. Gainesville, Florida: University of Florida Institute of Food and Agricultural Sciences.

U.S. Environmental Protection Agency. 2005. *GreenScapes: Environmentally beneficial landscaping*; Washington, D.C. Office of Solid Waste and Emergency Response. Available: <https://archive.epa.gov/greenbuilding/web/pdf/brochure.pdf>

United States Golf Association. 2004. *Recommendations for a method of putting green construction*. Available: <http://www.usga.org/content/dam/usga/images/course-care/2004%20USGA%20Recommendations%20For%20a%20Method%20of%20Putting%20Green%20Cons.pdf>.

van Es., H.M. October 1990. *Pesticide management for water quality: Principles and practices*. October 1990. Ithaca, New York: Cornell Cooperative Extension. Available: <http://psep.cce.cornell.edu/facts-slides-self/facts/pestmgt-water-qual-90.aspx>.

Virginia Golf Course Superintendents Association. 2012. Environmental Best Management Practices for Virginia's Golf Courses. https://pubs.ext.vt.edu/ANR/ANR-48/ANR-48_pdf.pdf

White, C.B. 2000. *Turfgrass manager's handbook for golf course construction, renovation, and grow-in*. Sleeping Bear Press. Chelsea, MI.

Witt, J.M. n.d. *Agricultural spray adjuvants*. Ithaca, New York: Cornell Cooperative Extension. Available: <http://pmep.cce.cornell.edu/facts-slides-self/facts/gen-peapp-adjuvants.html>.

Yergert, M.B. Austin, and R. Waskom. June 1993. *Best management practices for turfgrass production*. Turf BMP Fact Sheet. Colorado Department of Agriculture. Agricultural Chemicals and Groundwater Protection Program. Available: http://hermes.cde.state.co.us/drupal/islandora/object/co%3A3063/datastream/OBJ/download/Best_management_practices_for_turfgrass_production.pdf.

