Arizona Golf Industry Best Management Practices Guide

May 2019

BMP Best Management Practices

GCSAA USGA

Best Management Practices Planning Guide & Template

In partnership with

PGA TOUR

EIFG | *Funded through the Environmental Institute for Golf*

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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

Arizona Department of Agriculture

The Arizona Department of Agriculture supports and promotes Arizona agriculture in a way that encourages farming, ranching and agribusiness, protects the well-being of people, plants, animals and the environment while safeguarding commerce, consumers and natural resources.

Arizona Departments of Water Resources

The Arizona Department of Water Resources is the steward of Arizona's water future and ensures long-term, reliable water supplies to support the continued economic prosperity of the State. Quality, Integrity, Empowerment, Vigilance, Leadership and Collaboration, Continuous Improvement and Confidence are the guiding values of ADWR.

University of Arizona Turfgrass Research, Education and Extension

The University of Arizona Turfgrass Research, Education and Extension program aims to be the preeminent authority for desert turfgrass science. The foundation for establishing itself as the premier desert research, teaching, and extension center is

concentrated at the University of Arizona Karsten Turfgrass Research Facility in Tucson, AZ. The 8 acre research center built in 1991 through the support of the College of Agriculture and Karsten Manufacturing Corporation is comprised of turfgrass research plots which include the world's largest monolith lysimeters set to turf. A multi-disciplinary research faculty with expertise in plant sciences, weed science, plant pathology, breeding, biometeorology, soil science, irrigation management, water quality and entomology deliver quality teaching and extension to students and turfgrass clientele.

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Maricopa County Environmental Services Department

The mission of the Maricopa County Environmental Services Department is to provide safe food, water, waste disposal and vector borne disease reduction controls to the people of Maricopa County so that they may enjoy living in a healthy and safe community.

BMP Committee

The Cactus & Pine GCSA would like to thank the following individuals for their contributions to the Arizona Golf Industry Best Management Practices Guide:

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Introduction

Introduction

Arizona golf course superintendents are dedicated to protecting the environment and the state's wealth of natural resources. Arizona has the prominent 5 C's - Copper, Cattle, Cotton, Citrus, Climate. The golf industry contributes a sixth C - golf Courses in Arizona. The superintendents strive to achieve economic success with environmental sustainability.

The Arizona chapter Cactus & Pine Golf Course Superintendents Association of the Golf Course Superintendents Association of America (GCSAA) along with the Environmental Institute for Golf (EIFG), the United States Golf Association (USGA), and partnering with The University of Arizona Cooperative Extension Turfgrass Extension and Research program modified and developed a best management practices (BMP's) document for golf course management.

The Arizona Golf Industry BMP's are voluntary guidelines for superintendents in all areas of the state for managing golf facilities in an efficient manner while providing quality playing surfaces and protecting the environment. They also enable the golf course facility to operate where regulatory pressures are mounting from environmental interests and state/federal agencies. They offer the industry a significant platform for advocacy, education, recognition, and demonstration of professional land management.

The Arizona Golf Industry BMP Committee is chaired by White Mountain Country Club superintendent Doug Dykstra, CGCS, and features inputs from Cactus & Pine GCSA members throughout the state as well as agronomy consultants, golf course architects, golf course and landscape construction professionals, irrigation consultants, The University of Arizona Cooperative Extension, and representatives from Arizona's regulatory agencies including the Arizona Department of Agriculture, the Arizona Department of Water Resources, and the Maricopa County Environmental Services Division.

The document is highlighted by 12 sections: Planning, designing and construction; Irrigation; Surface water management; Water quality monitoring and management; Nutrient management; Cultural practices; Integrated pest management; Pesticide management; Pollinator protection; Maintenance operations; Landscape; and Energy.

A focus was placed on the Irrigation, Surface water management, and Water quality management sections. Arizona superintendents are aware of the perception of the golf industry as a large water user and realize that the industry needs to be part of the solution for mandated conservation goals including those being discussed in accordance with the recent Lower Colorado Basin Drought Contingency Plan.

The Arizona golf industry uses only 1.9 percent of the state's freshwater withdrawals while contributing $3.9 billion to the Arizona economy, providing an exceptional economic return on use of a natural resource. Balancing that natural resource with the economic viability of facilities, Arizona golf courses continue to reduce water use through irrigation audits, turfgrass removal, modification of irrigation

systems, use of wetting agents, reduction of overseeded turf areas, and the integration and adoption of water saving technology.

Nearly 40 percent of Arizona golf facilities have a partnership with a conservation organization and superintendents throughout the state continue to manage their lands to provide significant habitats for birds, plants, insects and wildlife. Coyotes, elk, lynx, owls, rabbits, roadrunners, snakes and saguaro cactus are just a few of the unique wildlife and flora species frequently seen on golf courses throughout Arizona.

The Arizona Golf Industry BMP has been produced in a digital format that allows superintendents at facilities around the state to freely download the document. They have the option to further edit the document to make it more specific to their agronomic practices within their regions whether in the low desert or the higher elevation mountains. The digital document also allows the flexibility to revise and edit components for addressing ever changing turf management practices as well as state, tribal, and federal laws and regulations.

The BMP's state-level agronomic and environmental information should be incorporated or referenced accordingly to ensure compliance and healthy turfgrass landscapes. The mission of this project was to provide a platform for developing practical and functional BMP's that we hope will be useful for superintendents to operate in an environmentally and economically sustainable facility.

We thank all of volunteers for their time to make the Arizona Golf Industry BMP a reality. Your selfless efforts have created an environmental legacy that will be passed down to future generations of superintendents and golf course operators.

Doug Dykstra, CGCS

White Mountain Country Club

President, Cactus & Pine GCSA

BMP Index

Planning, Design and Construction

Regulatory Issues

The renovations or 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. Furthermore, facilities should be designed and constructed to maximize energy and resource efficiency

Local, state, and tribal 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

Principles

There is no substitution for the proper planning of any project. Many existing golf facilities today are preparing a master plan to help manage the future of their property. We have to remember that golf courses are for the most part, a living, functional property that through time have been impacted by unforeseen changes, both natural and unnatural. 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, 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
    - Horticulturist, arborist
    - 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

- 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.

Design

Principles

Proper design will meet the needs of the stakeholders, protect the locations 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. 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 is large enough to accommodate traffic and play damage, but not so large that it is not sustainable with your resources.
    - Select an appropriate root-zone material as designated by the USGA. Periodic testing of this greens mix with a certified laboratory throughout the process keeps the material within specs and consistent. This will protect stakeholders in the end with respect to the value of the asset.
    - Greens should be irrigated separately from surrounding turf.
    - Select a turf species/variety that meets the needs of the stakeholders while adhering to the principle of “right plant, right place.”
    - Plant only certified turfgrass.
- Bunkers

    - Consider the number of bunkers as it relates to resources available for daily maintenance.
    - 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. Test throughout the project with a certified laboratory to make sure you are getting what you intended. This, again, protects stakeholders and the value of the golf course as an asset.
    - Consider steepness of faces of bunkers and the appropriate sand to handle the angle of repose so as not to sluff off the slopes.
    - Due diligence and research will be needed to choose the appropriate bunker liner for faces and/or bases of bunkers to fit budget, shape, drainage, look and long-term maintenance concepts. The current construction standards do encourage a quality bunker liner to be installed.

- Define play and non-play maintenance boundaries.

Construction

Principles

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

Best Management Practices

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

Best Management Practices

- Conduct a pre-construction conference with stakeholders.
- Construction should be scheduled to maximize turfgrass establishment and site drainage.
- Use environmentally sound construction techniques.
- Use soil stabilization techniques to minimize soil erosion and maximize sediment containment.
- 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.
- Temporary construction compounds should be built 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

- The soil in the area to be established should be properly tilled, prepared and cleared of pests (weeds, pathogens, etc.).
- Laboratory soil test results should provide fertility levels - sufficiencies and deficiencies. Nutrients can be applied using either liquid or granular formulations. Liquid foliar can be absorbed by the turfgrass more rapidly. Granules dissolve with irrigation and absorbed by the roots. Incorporating fertilizers into the root zone may not necessarily result in more rapid establishment but can be accessible for root absorption.
- Ensure erosion and sediment control devices are in place and properly maintained.
- Sprigs should be “knifed-in” and rolled to hasten root establishment. When using sprigs, application rates for nitrogen, phosphorous, and potassium should

correspond to percent ground cover (i.e., increasing rate as ground coverage increases.)

- Sod should be topdressed to fill in the gaps between sod pieces. This hastens establishment and provides a smoother surface. When using sod, nutrient applications should be delayed until sod has sufficiently rooted.
- Use appropriate seeding methods for your conditions. Ensure proper seed-soil contact for optimum germination and establishment.
- Slow-release nitrogen or light, frequent soluble-nitrogen sources should be used during grow-in.
- Mow as soon as the sod has knitted-down, when sprigs have rooted at the second to third internode, and seedlings have reached a height of one-third greater than intended height-of-cut. This will hasten establishment.

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.
- Monsoon winds can cause significant soil movement in the desert.

Best Management Practices

- Develop a working knowledge of erosion and sediment control management. Each state has its own specifications including types of acceptable structures, materials, and design features.
- Staying within compliance of all federal, state, tribal, and local protective measures is critical.
- Substantial projects should hire or designate a certified Stormwater Pollution Prevention Plan (SWPPP) third party representative.
- Develop and implement strategies to effectively control sediment, minimize the loss of topsoil, protect water resources, and reduce disruption to wildlife, plant species, and designed environmental resource areas.
- Hydro-seeding or hydro-mulching offer soil stabilization. Non-turf areas should be stabilized to prevent severe wind erosion.

Wetlands

Principles

- Most states consider 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, tribal, and local agencies. At the federal level alone, the U.S. Army Corps of Engineers (USACOE), U.S. 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.

Drainage

Principles

- Adequate drainage is necessary for growing healthy grass.
- A high-quality BMP 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

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

Surface Water: Stormwater, Ponds, Lakes

Principles

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

Best Management Practices

- Stormwater treatment is best accomplished by a "treatment train" approach, in which water is conveyed from one treatment to another by conveyances that also contribute to the treatment.
- Eliminate or minimize as much directly connected impervious area (DCIA) as possible.

- Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms.
- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, instead of letting it run off. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediments, while allowing the overflow to drain away.
- Maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass. Special high-permeability concrete is available for cart paths or parking lots.
- Disconnect runoff from gutters and roof drains from impervious areas, so that it flows onto permeable areas that allow the water to infiltrate near the point of generation.

Maintenance Facilities

Principles

The maintenance facilities must incorporate BMP's to minimize the potential for contamination of soil and water sources. 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.
- Do not store pesticides near burning materials or hot work (welding, grinding), or in shop areas.
- Provide storage for personal protective equipment (PPE) where it is easily accessible in the event of an emergency, but do not store in the pesticide storage area.
- Provide adequate space and shelving to segregate herbicides, insecticides, and fungicides.
- Use shelving made of plastic or reinforced metal. Keep metal shelving painted.
- Provide appropriate exhaust ventilation and a nearby emergency wash area.
- Always place dry materials above liquids, never liquids above dry materials.
- Never place liquids above eye level.
- Locate operations well away from groundwater wells and areas where runoff may carry spilled pesticides into surface waterbodies.
- Do not build new facilities on potentially contaminated sites.

- An open building must have a roof with a substantial overhang (minimum 30° from vertical, 45° recommended) on all sides.
- In constructing a concrete mixing and loading pad, it is critical that the concrete have a water-to-cement ratio no higher than 0.45:1 by weight.
- The sump should be small and easily accessible for cleaning.
- Ensure that workers always use all personal protection equipment (PPE) as required by the pesticide label and are provided appropriate training.
- Assess the level of training and supervision required by staff. Follow appropriate federal Worker Protection Safety (WPS) regulations and appropriately train employees.
- Any material that collects on the pad must be applied as a pesticide according to the label or disposed of as a (potentially hazardous) waste according to federal and state laws and regulations.
- Clean up spills immediately! Keep proper absorptive materials, brooms, dustpans, buckets, etc. readily available.
- Sweep up and contain any spilled fertilizer immediately.
- Always store nitrogen-based fertilizers separately from solvents, fuels, and pesticides, since many fertilizers are oxidants and can accelerate a fire.
- Ideally, fertilizer should be stored separately in a concrete building with a metal or other type of flame-resistant roof.
- Always store fertilizers in an area that is protected from rainfall. The storage of dry bulk materials on a concrete or asphalt pad may be acceptable if the pad is adequately protected from rainfall and from water flowing across the pad.
- Store pesticide and fertilizer products only long enough until its intended use.
- Do not wash equipment unnecessarily.
- Clean equipment over an impervious area, and keep it swept clean.
- Brush or blow equipment with compressed air before, or instead of, washing.
- Use spring shutoff nozzles.
- Use a closed-loop recycling system for wash water.
- Recycle system filters and sludge should be treated and disposed of appropriately.
- Each piece of equipment should have an assigned parking area. This allows oil or other fluid leaks to be easily spotted and attributed to a specific machine so that it can be repaired.
- Use solvent-recycling machines or water-based cleaning machines to cut down on the use of flammable and/or toxic solvents.
- Use a service to remove the old solvents and dispose of them properly.
- **See also Section 8: Pesticide Management and Section 10: Maintenance Operations**

External Certification Programs

Principles

- Golf-centric environmental management programs or environmental management systems,, such as Audubon International or Golf Environment Organization, 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.
- Engage and work with an organization prior to starting the project. This will make the application process for the certification much easier.

Best Management Practices

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

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, state, or tribal government, including any species “of special concern.”
- Preserve critical habitat.
- Identify and preserve regional wildlife and migration corridors.

- Design and locate cart paths to minimize environmental impacts. Construct the paths of permeable materials, if possible.
- Avoid or minimize crossings of wildlife corridors. Design unavoidable crossings to accommodate wildlife movement.
- Remove nuisance and noxious/invasive plants and replace them with native species that are adapted to a particular site.
- Maintain clearance between the ground and the lowest portion of a fence or wall to allow wildlife to pass, except in areas where feral animals need to be excluded.
- Retain dead tree snags for nesting and feeding sites, provided they pose no danger to people or property.
- Construct and place birdhouses, bat houses, and nesting sites in out-of-play areas.
- Plant butterfly gardens or pollinator habitats around the clubhouse and out-of-play areas.
- Retain riparian buffers along waterways to protect water quality and provide food, nesting sites, and cover for wildlife.
- Minimize stream or river crossings to protect water quality and preserve stream banks.
- Retain riparian buffers along waterways to protect water quality, provide food, nesting sites, and cover for wildlife.

Irrigation

Water Management Approaches

Water is a precious commodity in the desert and golf courses judiciously manage this important resource. Arizona golf courses are dependent upon surface waters from the Colorado River through the Central Arizona Project (CAP); from snowmelt in the region's mountains that are stored, conserved, and shared with residential, agricultural, and industrial users; protected groundwater; and reclaimed waters. Course owners and superintendents protect surface and groundwater quality and quantity by optimizing turfgrass management and water conservation practices. The golf community partners with all municipalities, counties, tribes, and state and federal agencies to proactively address delicate regulatory and environmental issues, especially with respect to water.

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

BMP's are identified and described to conserve and protect water resources. Important principles are presented to help understand and implement protecting water quality and quantity and surrounding natural resources. The irrigation BMP's provide guidance for economic advantages, regulatory compliance, and environmental stewardship when implemented. BMP's are not intended to increase labor or place an undue burden on the owner/superintendent. It is important to keep in mind that new technologies may make many tasks easier or less labor-intensive. If applied appropriately, BMP's can help

stabilize labor cost, extend equipment life and limit repairs, and provide overall improved personal and public liability.

The monetary investment is minimal to implement non-structural BMP’s in a daily golf course water-use plan. Other advantages for implementing BMP’s include: reduced administrative management stress; improved employee communications and directions; and effective facilities training procedures.

Several benefits of adopting BMP's are:

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

Water Management Approaches

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 measures and 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.
- Industrial water conservation requirements, monitoring, and reporting requirements for turf-related facilities in five (5) Active Management Areas (AMA’s) designated by the Arizona Department of Water Resources (AZDWR) are listed below. **Click on the individual links** to access details:

    - Phoenix AMA
    - Pinal AMA
    - Prescott AMA
    - Santa Cruz AMA
    - Tucson AMA
- 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 the 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. Please refer to the AZDWR AMA's for application rates.
- 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 system, 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.
- Amend sodic water systems appropriately (with gypsum or an appropriate ion amendment) to minimize sodium buildup in soils.
- Flush with freshwater or use amending materials regularly to move salts out of the root zone and/or pump brackish water to keep salts moving out of the root zone. Golf courses may apply for a water allotment addition for leaching purposes if the water supply contains at least 1,000 milligrams per liter of total dissolved solids.
- Monitor sodium and bicarbonate buildup in the soil using salinity sensors.
- Routinely monitor shallow groundwater table of freshwater for saltwater intrusion or contamination by heavy metals and nutrients.
- Monitor reclaimed water tests regularly for dissolved salt content.
- Reclaimed, effluent, and other non-potable water supply mainlines must have a thorough cross-connection and backflow prevention, or air gap device in place and operating correctly.
- Where practical, use reverse-osmosis filtration systems to reduce chlorides (salts) from saline groundwater.
- Monitor the quantity of water withdrawn to avoid aquatic life impairment.
- 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.

- 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, golf course members, regulatory agencies, 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 courses while using less water.
- BMP's and educational programs are necessary to deliver and instill a positive perception by the public that golf course superintendents are stewards of water management and are at the forefront of water-related issues.
- Some courses are designed to use 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 environmentally adapted native plants, grasses, or ground covers to reduce water use and augment the site's aesthetic appeal.

Best Management Practices

- Selecting drought-tolerant varieties of turfgrasses minimize water use yet provide an attractive and high-quality playing surface.

- Non-play areas may be planted with drought-resistant native or other well-adapted, noninvasive plants that provide an attractive and low-maintenance landscape.
- Native plant species are important in providing wildlife with habitat and food sources. After establishment, site-appropriate plants normally require little to no irrigation.
- The system should be operated to provide only the water that is actually needed by the plants, or to meet occasional special needs such as salt removal.
- If properly designed, rain and runoff captured in water hazards and stormwater ponds may provide supplemental water under normal conditions, though backup sources may be needed during severe drought.

- During a drought, closely monitor soil moisture levels. Whenever practical, irrigate at times (night, early morning) when the least amount of evaporative loss will occur.

- Selectively hand water as needed any critical turf areas that exhibit observable stress or as indicated by use of a moisture meter.

- Control and reduce 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 should account for optimal distribution efficiency and effective root-zone moisture coverage. Target 80% or better Distribution Uniformity (DU).
- Design should allow the putting surface and slopes and surrounds to be watered independently.
- The design package should include a general irrigation schedule with recommendations and instructions on modifying the schedule for local climatic, soil, and growing conditions. It should include the base evapotranspiration (ET) rate for the particular location.
- The application rate must not exceed the infiltration rate, ability of the soil to absorb and retain the water applied during any one application. Conduct saturated hydraulic conductivity tests periodically.
- The design operating pressure must not be greater than the available source pressure.
- The design operating pressure must account for peak-use times and supply line pressures at final buildout for the entire system.
- The system should be flexible enough to meet a site's peak water requirements and allow for operating modifications to meet seasonal irrigation changes or local restrictions.
- Turf and landscape areas should be zoned separately. Specific use areas should be zoned separately: greens, tees, primary roughs, secondary roughs, fairways, native areas, trees, shrubs, etc.
- Design should account for the need to leach out salt buildup from poor-quality water sources by providing access to freshwater.
- Only qualified irrigation specialists should install the irrigation system.
- Construction must be consistent with the design.
- The designer must approve any design changes before construction.
- Construction and materials must meet existing standards and criteria.
- Prior to construction, all underground cables, pipes, and other obstacles must be identified and their locations flagged.
- Permanent irrigation sprinklers and other distribution devices should be spaced according to the manufacturer's recommendations.
- Spacing should take into account the average or typical wind conditions during the day or night during irrigation events.
- For variable wind directions, triangular spacing is more uniform than square spacing.

- Distribution devices and pipe sizes should be designed for optimal uniform coverage.
- The first and last distribution device should have no more than a 10% difference in flow rate. This usually corresponds to about a 20% difference in pressure.
- Distribution equipment (such as sprinklers, rotors, and micro-irrigation devices) in a given zone must have the same precipitation rate.
- Heads for turf areas should be spaced for head-to-head coverage.
- Water supply systems (i.e. wells, and pipelines) should be designed for varying control devices, rain shutoff devices, and backflow prevention.
- Water conveyance systems should be designed with thrust blocks and air-release valves.
- Flow velocity must be 5 feet per second or less.
- Pipelines should be designed to provide the system with the appropriate pressure required for maximum irrigation uniformity.
- Pressure-regulating or compensating equipment must be used where the system pressure exceeds the manufacturer's recommendations.
- Equipment with check valves must be used in low areas to prevent low head drainage.
- Isolation valves should be installed in a manner that allows critical areas to remain functional.
- Manual quick-coupler valves should be installed near greens, tees, and bunkers so these can be hand-watered during severe droughts.
- 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.

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 spikes and surges) are infrequent, and if the superintendent has access to qualified technical support. When applied properly, a variable frequency drive is perhaps the single largest energy-saving measure available to golf course pump stations.

- Design pumping systems for energy conservation. A pump station can account for up to 50 percent of a golf facilities energy use.

Best Management Practices

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

Irrigation System Program and Scheduling

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 be on a calendar-based schedule but should be based on ET rates and soil moisture replacement.
- An irrigation system should be operated based on the moisture needs of the turfgrass, or to water-in a fertilizer or incorporate a chemical application as directed by the label.
- Responsible irrigation management can conserve water, reduce 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

- The reliability of older clock-control station timing depends on the calibration of the timing devices; this should be done periodically, but at least seasonally.

- An irrigation system should have rain sensors to shut off the system after 0.25 to 0.5 inch of rainfall. 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.
- Generally, granular fertilizer applications should receive 0.25 inch of irrigation to move the particles off the leaves while minimizing runoff.
- Irrigation quantities should not exceed the available moisture storage in the root zone.
- Irrigation rates should not exceed the maximum ability of the soil to absorb and hold the water applied following an irrigation event.
- Irrigation scheduling should coincide with other cultural practices (e.g. the application of nutrients, herbicides, or other chemicals).
- Account for nutrient supply content in effluent when making fertilizer calculations.
- Irrigation should occur in the early morning hours before air temperatures rise and relative humidity drops.
- Plant water needs should be determined by ET rates, recent rainfall, recent temperature extremes, and soil moisture.
- Use mowing, verticutting, aeration, nutrition, and other cultural practices to control water loss and to encourage conservation and efficiency.
- Visually monitor for localized dry conditions or hot spots to identify poor irrigation efficiency or a failed system device.
- Use predictive models to estimate soil moisture and the best time to irrigate.
- Avoid use of a global setting for irrigation timers; 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.
- Manually adjust automated ET data to reflect wet and dry areas on the course.
- Use soil moisture sensors to assist in scheduling or to create on-demand irrigation schedules.
- Use multiple soil moisture sensors to reflect soil moisture levels.
- Install and utilize 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.
- Wired soil moisture systems should be installed to prevent damage from aerification.
- Periodically perform catch-can uniformity tests to audit the irrigation system. Conduct catch-can tests during the morning or day when the system is not at full operation and then at night under normal operating conditions to determine differences due to high flow demands or fluctuating pressure.
- Reducing dry spots and soil compaction improves water infiltration, which in turn reduces water use and runoff in other areas.
- Install emergency shutdown devices to address line breaks.

Photo Courtesy of Toro

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 moisture needs of greens and tees.
- 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.
    - Use a phased approach to cut back 10, 20, 30, 40 percent or greater as subsequent drought level emergencies are reached.
- Communicate the drought management plan to owners, committees, members, employees, water agencies and where appropriate the general public.

Best Management Practices

- Waiting to observe visual symptoms of turfgrass stress would be an indicator to irrigate low-maintenance areas such as golf course roughs and possibly some parts of fairways.
- Use soil moisture meters to determine moisture thresholds and plant needs.
- Irrigating too shallowly encourages shallow rooting, increases soil compaction, and may make the turfgrass stressed and susceptible to pests and diseases.
- For golf greens and tees, the majority of roots are in the top several inches of soil profile.

- For fairways and roughs, use infrequent, deep irrigation to supply sufficient water for plants and to encourage deep rooting.
- Proper cultural practices such as adjusting mowing heights, appropriately timed fertilizer applications, irrigation frequency, and irrigation amounts should be employed to promote healthy, deep root development and reduce irrigation requirements.
- Create a drought management plan for the facility that identifies steps to be taken to reduce irrigation/water use and protects critical areas, etc.
- Use appropriate turfgrass species adapted to the location of the golf course being managed. For complete information on turfgrass research, education and extension in Arizona, visit http://turf.arizona.edu/

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.
- 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. When considering a renovation, facilities should consider future water availability, quality, and source and have a system that is flexible to meet future needs.

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.
- System checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers should follow the manufacturer’s recommendations.
- The system should be inspected daily for proper operation by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads. A visual inspection should be carried out for leaks, misaligned or inoperable heads, and chronic wet or dry spots, so that adjustments can be made.
- Systems should be observed 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.
- Even under routine conditions, keeping filters operating properly prolongs the life of an existing system and reduces pumping costs.
- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.
- Application/distribution efficiencies should be checked 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.
- Correctly identifying problems and their costs helps to determine what renovations are appropriate.
- Collecting information on the cost of maintaining the system as part of system overall evaluation, allows for planning necessary upgrades, replacement etc. and to 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. 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. Information on stormwater management in Arizona is available through the Arizona Department of Environmental Quality.

- When constructing drainage systems, pay close attention to engineering details such as subsoil preparation, the placement of gravel, slopes, and backfilling.
- Where practical, internal golf course drains should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- Studies of water supplies are needed for irrigation systems, and studies of waterbodies or flows on, near, and under the property are needed to properly design a course's stormwater system and water features, and to protect water resources.
- Peninsular projections and long, narrow fingers into ponds 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.
- In shallow or nutrient-impacted ponds, the use of aeration equipment may be required to maintain acceptable dissolved oxygen (DO) levels in the water.

Pond Use and Maintenance

Principles

- Successful pond management should include a clear statement of goals and priorities to guide the development of the BMP. Some of the challenges facing superintendents in maintaining the quality of golf course ponds are as follows:
    - Low DO
    - Sedimentation
    - Changes in plant populations
    - Nuisance vegetation
    - Maintenance of littoral shelves
    - Vegetation on the lakeshore
    - Nuisance birds
    - Mollusks
- 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 algal 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. Consider installing liners where water loss is a reoccurring issue.
- 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 proven methods.
- Maintain a riparian buffer to filter the nutrients and sediment in runoff. A buffer of at least 15 meters is necessary to protect streams and wetlands under most conditions.
- 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 DO levels.
- Establish a special management zone around pond edges.
- Dispose of grass clippings where runoff will not carry them back to the lake.
- 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.
- Prevent mollusks from entering from surface waters and not allow establishment in ponds and pipes.
- 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 DO 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

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

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

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

Sprinkler Maintenance

Principles

- Good system management starts with good preventive maintenance (PM) procedures and record keeping. This can be done during turf 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

- System checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers should follow the manufacturer's recommendations.
- The system should be inspected routinely 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 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.
- Mollusk shell fragments should be cleared from water lines and nozzles.
- Clean and maintain filtration equipment.
- Systems should be observed 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.
- Even under routine conditions, keeping filters operating properly prolongs the life of an existing system and reduces pumping costs.
- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.

- Application/distribution efficiencies should be checked 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

- Irrigation audits should be performed by trained technicians once every 5 years.
- A visual inspection should first be conducted to identify necessary repairs or corrective actions. It is essential to make repairs before carrying out other levels of evaluation.
- Pressure and flow should be evaluated to determine that the correct nozzles are being used and that the heads are performing according to the manufacturer's specifications.
- Pressure and flow rates should be checked at each head to determine the average application rate in an area.

- Catch-can tests should be run to determine the uniformity of coverage and to accurately determine irrigation run times.
- Catch-can testing should be conducted on the entire golf course to ensure that the system is operating at its highest efficiency.
- Conduct an irrigation audit annually to facilitate a high-quality maintenance and scheduling program for the irrigation system.
- Inspect for interference with water distribution.
- 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 and adheres to code standards.
- 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

- In older systems, inspect irrigation pipe and look for fitting breaks caused by surges in the system.
- Install thrust blocks to support conveyances.
- The system should be inspected daily for proper operation by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads. A visual inspection should be carried out for leaks, misaligned or inoperable heads, and chronic wet or dry spots so that adjustments can be made.
- Maintain air-relief and vacuum-breaker valves.
- Systems need to be observed in operation at least weekly to detect controller or communication failures, stuck or misaligned heads, and clogged or broken nozzles.
- Check filter operations frequently; keeping filters operating properly prolongs the life of an existing system and reduces pumping costs.
- Keep records of filter changes, as this could be an early sign of system corrosion, well problems, or declining irrigation water quality.
- Application/distribution efficiencies should be checked annually.
- Conduct a periodic professional irrigation audit at least once every five years.
- Document equipment run-time hours. Ensure that all lubrication, overhauls, and other preventive maintenance are completed according to the manufacturer’s schedule.
- Monitor the power consumption of pump stations for problems with the pump motors, control valves, or distribution system.
- Qualified pump personnel should perform quarterly checks of amperage to accurately identify increased power usage that indicates potential problems.

- Monitor and record the amount of water being applied, including system usage and rainfall. By tracking this information, you can identify areas where minor adjustments can improve performance.
- Document and periodically review the condition of infrastructure (such as pipes, wires, and fittings). If the system requires frequent repairs, it is necessary to determine why these failures are occurring.
- Increase frequency of routine inspection/calibration of soil moisture sensors that may be operating in high-salinity soils.
- At higher elevations, winterize irrigation system to prevent damage (see Winterization and Spring Startup section).

Corrective Maintenance

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

System Renovation

- Appropriate golf course renovations can improve system efficiencies, conserve water, improve playability, and lower operating costs.
- Correctly identify problems and their cost to determine which renovations are appropriate.
- Determine the age of the system to establish a starting point for renovation. Information on the life cycle of pump stations and various components is available at http://asgca.org/images/stories/publications/qa-life-cycle.pdf
- Identify ways to improve system performance by maximizing the efficient use of the current system.
- Routinely document system performance to maximize the effectiveness of the renovation.
- Evaluate cost of renovation and its return on benefits both financial and management.

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


Pine Canyon Club, Flagstaff, AZ.

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 access daily weather information and ET to determine site specific water needs. The weather station should be properly sited in an area with adequate air movement with turfgrass to simulate the golf course turf conditions.

Best Management Practices

- Irrigation controllers/timers should be reset as often as practically possible to account for plant growth requirements and local climatic conditions.
- Properly calibrated flow meters, soil moisture sensors, rain shut-off devices, and/or other automated methods should be used to manage irrigation.
- Irrigation rates should not exceed the maximum ability of the soil to absorb and hold the water applied in any one application.
- Irrigation should not occur on a calendar-based schedule but should be based on ET rates and soil moisture replacement.
- Computerized control systems should be installed on all new course irrigation systems to help ensure efficient irrigation application. These allow for timing adjustments at every head.
- Rain shut-off devices and rain gauges should be placed in open areas to prevent erroneous readings.
- Use multiple soil moisture sensors/meters for accuracy and to reflect soil moisture levels.
- Use hand-held soil moisture sensors when possible to augment observations of potentially stressed turfgrass.

Photo Courtesy of Toro

Maintained Turf Areas

Principle

Courses should use well-designed irrigation systems with precision scheduling based on 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. Current weather conditions data contribute to the application timing and rates.

Best Management Practices

- The irrigation system should be designed and installed so that the greens putting surface, slopes, and immediate surrounding areas are watered independently.
- Account for nutrients in effluent supply when making fertilizer calculations.
- Install part-circle heads that conserve water, enhance efficiency, 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.
- Manually adjust automated ET data 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.

- Permanent irrigation sprinklers and other distribution devices should be spaced according to the manufacturer's recommendations.
- Sprinkler head spacing should take into consideration the average wind conditions (speed and direction) during irrigation events.
- Sprinkler heads should be level.
- Triangular spacing is more uniform than square spacing.
- Periodically perform catch-can uniformity tests.
- Reducing dry spots and soil compaction improves water infiltration, which in turn reduces water use and wasted runoff.
- Irrigation should occur in the early morning hours before air temperatures rise and relative humidity drops.
- Base plant water needs on evapotranspiration (ET) rates, recent rainfall, recent temperature extremes and soil moisture conditions.
- Use mowing, verticutting, aeration, wetting agents, nutrition, and other cultural practices to control water loss and to encourage conservation and efficiency.
- Surface slicing and spiking help relieve surface compaction and promote better water penetration and aeration.
- Visually monitor for localized dry conditions or hot spots to identify poor irrigation efficiency or a failed system device.
- Use a hand-held soil moisture sensor to confirm observed localized dry spots.
- 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 efficiency of scheduled timer-based run times.
- An irrigation system should have 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.
- Wireless soil moisture systems should be installed to avoid damage from aeration.

Non-Play and Landscape Areas

Principles

- Map any environmentally sensitive areas such as sinkholes, wetlands, washes, or flood-prone areas.
- Identify any species classified as endangered, threatened, or of concern by federal and state government agencies. Information about endangered and threatened species in Arizona is through the U.S. Fish & Wildlife Service.
- Natural vegetation should be retained and enhanced for non-play areas to conserve water.
- Be aware of noxious or invasive weeds that can threaten landscapes.
- 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 should be evaluated and transitioned into non-play areas. Turfgrass transitioned into non-play areas may achieve a significant decrease in water use.

Best Management Practices

- Strive to designate 50 - 70% of the non-play area to have natural vegetation cover according to “right-plant, right-place,” a principle of plant selection that favors limited supplemental irrigation and on-site cultural practices. Refer to the

Arizona Municipal Water Users Association for a complete list of landscape plants.
- Incorporate natural vegetation in non-play areas.
- Use micro-irrigation and low-pressure emitters in non-play areas for supplemental irrigation.
- Routinely inspect non-play area irrigation systems for problems related to emitter clogging, rodent or animal chewing lines, 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 to protect aquifers from accidental contamination. It 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 Arizona Department of Water Resources 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. Licensing information is available by clicking here.

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. Information on well abandonment is available at: Well Abandonmenthttp://www.azwater.gov/azdwr/WaterManagement/Wells/documents/AbandonmentHandbook2008.pdf.
- 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.
- Never apply a fertilizer or pesticide next to a wellhead.
- Never mix and load pesticides next to a wellhead if not on a pesticide mix/load pad.

Surface Water Management

Regulatory Considerations

Principle

Water is a precious commodity in the desert and golf courses judiciously manage this important resource. Surface waters from snowmelt in the region's mountains are conserved and shared with residential, agricultural, and industrial users. The Colorado River provides surface water through the CAP. The Verde and Salt Rivers with a series of reservoirs provides much of the surface water for the metropolitan Phoenix area. Groundwater is protected and water conservation practices are implemented by all users. Surface waters and reclaimed waters contribute to recharging. Course owners and superintendents protect surface and groundwater quality and quantity by optimizing turfgrass management and water conservation practices. The golf community partners with all municipalities, counties, tribes, and state and federal agencies to proactively address regulatory and delicate environmental issues, especially with all aspects related to water.

Best Management Practices

- Aquatic management of plants may be regulated under construction permitting and regulatory licensing requirements. Consult with federal, state, and local water management agencies before managing golf course lakes and wetland areas. Arizona does not have a wetlands regulatory program separate from the federal §404 permitting program under the CWA, but state law does outline water quality standards for both "waters of the state" and "navigable waters. Section 401 certification is the state's main tool for regulating activities affecting wetlands. Information on 401 certification is available at: Arizona Department of Environmental Quality.
- 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.
- The introduction of aquatic triploid grass carp, biological controls, aeration, and chemical controls (herbicide/algaecide) must be approved and monitored according to permit and licensing protocols and compliance.
- The disposal of sediments from surface water ponds (stormwater detention) may be subject to regulation.
- Golf course management may be affected by Total Maximum Daily Loading (TMDL), mitigation, and watershed basin management action plans (BMAP). Information about TMDL's in Arizona is available at:Arizona Department of Environmental Quality.
  https://legacy.azdeq.gov/environ/water/assessment/tmdl.html

- Wetlands are protected areas; consult with federal and state agencies before altering natural aquatic areas. Information about wetlands and riparian management in Arizona is available through the Bureau of Land Management.
- Constructed wetlands should have an impervious bottom to prevent groundwater contamination.
- Studies of water supplies are 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.

Stormwater Capture

Although golf courses are typically large properties ranging in size from 60 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, a typical golf course drainage system may be designed to detain a two- or five-year rain event. In other words, when a significant rain event happens every 2-5 years, 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.

BMP's 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.

Controlling stormwater on a golf course is more than just preventing the flooding of the clubhouse, maintenance, and play areas. In addition to controlling the amount and rate

of water leaving the course, stormwater involves storing irrigation water, controlling erosion and sedimentation, enhancing wildlife habitat, removing waterborne pollutants, and addressing aesthetic and playability concerns. Not all stormwater on a golf course originates there; most may be from adjoining lands, including residential or commercial developments.

Principles

- 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.
- Most stormwater discharges in Arizona are permitted under various general permits. However, an Arizona Pollutant Discharge Elimination System (AZPDES) is required for any point source discharge of pollutants to a water of the United States (WOTUS). More information about stormwater regulations is available at Arizona Department of Environmental Quality.

- **Best Management Practices**

- Install berms and swells to capture pollutants and sediments from runoff before it enters the irrigation storage pond. Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms.
- Maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass.
- Special high-permeability concrete is available for cart paths or parking lots.
- Design stormwater control structures to hold stormwater for appropriate residence times in order to remove total suspended solids.
- Use a stormwater treatment train to convey water from one treatment structure to another.
- Eliminate or minimize directly connected impervious areas as much as possible.
- Disconnect runoff from gutters and roof drains from impervious areas, so that it flows onto permeable areas that allow the water to infiltrate near the point of generation.
- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, instead of letting it run off. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediments, while allowing the overflow to drain away.
- Ensure that no discharges from pipes go directly to water.
- Monitor pond water level for water loss (seepage) to underground systems. If seepage is occurring, it may be necessary to line or seal the pond or install pumps to relocate water.
- Install water-intake systems that use horizontal wells placed in the subsoil below the storage basin; use a post pump to filter particulate matter.

- A backup source of water should be incorporated into the management plan.
- Inspect irrigation pumps, filtration systems, conveyances and control devices to prevent/correct system issues. A regular preventive maintenance schedule should be established.

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, the presence of invasive or weedy species, aesthetics, watershed and groundwater assessments, and other environmental considerations.
- Algal growth and invasive mollusks should not invade and establish in waterbodies.
- 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.
- Irrigation should not directly strike or run off to waterbodies, and no-fertilization buffers should be maintained along water edges. A 5-10-foot buffer is recommended.
- Outline goals and priorities to guide the development of the BMP necessary to support the lake/aquatic management plan.
- Superintendents should monitor designated waters in their area for the persistence of toxic herbicides and algaecides in the environment.
- Secondary environmental effects on surface water and groundwater from the chemical control of vegetation should be monitored and recorded.
- Apply fertilizer and reclaimed (reuse) irrigation/fertigation appropriately to avoid surface water and groundwater contamination.
- Apply copper products per label instructions to reduce the risk of impairing water quality and causing negative biological impacts.
- Identify position of property in relation to its watershed. Watersheds in Arizona.

- Identify overall goals and validate concerns of the local watershed.
- Identify surface water and flow patterns.
- Indicate stormwater flow as well as existing and potential holding capacity.
- Indicate impervious surfaces, such as buildings, parking lots, or pathways.
- Indicate major drainages and catch basins that connect to local surface water bodies.
- Identify and understand depth to water tables and soil types.
- Locate and protect wellheads. 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. Well Protection

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. See section Water Quality Sampling Program for a sample water-quality monitoring plan.
- Sampling parameters are determined based on golf course operation and basin-specific parameters of concern (these may be identified by local/state Total Maximum Daily Load (TMDL) Programs). Typically, samples should be analyzed for nutrients, pH and alkalinity, sediments, and suspended solids, dissolved oxygen (DO), heavy metals, and any pesticides expected to be used on the golf course.
- Ongoing, routine water sampling provides meaningful trends over time. A single sample is rarely meaningful in isolation.
- Post-construction sampling of surface-water quality should begin with the installation and maintenance of golf course turf and landscaping. Samples should be collected a minimum of three times per year.
- If there is no discharge on the scheduled sample date, samples should be taken during the next discharge event.
- Post-construction surface-water quality sampling should continue through the first three years of operation and during the wet and dry seasons every third year thereafter, provided that all required water-quality monitoring has been completed and the development continues to implement all current management

plans. It may also be wise to sample if a significant change has been made in course operation or design that could affect nearby water quality.
- Sampling parameters should be determined based on golf course operation and any basin-specific parameters of concern (identified by the TMDL program or local regulators).
- The purpose of quality assurance/quality control (QA/QC) is to ensure that chemical, physical, biological, microbiological, and toxicological data are appropriate and reliable. Data should be collected and analyzed using scientifically sound procedures.
- However, even if the data are only for proprietary use and are not reported to any regulatory agency, it is strongly recommended that a certified laboratory be used and all QA/QC procedures followed.
- Golf course management must have good data to make good decisions. If a golf course should ever want to produce data for an agency or go to court to defend the facility from unwarranted charges, those data must meet QA/QC standards to be defensible as evidence.

Best Management Practices

- Establish DO thresholds to prevent fish kills (commonly occur at 2 ppm), keep DO levels above 3 ppm.
- Use artificial aeration (diffusers).
- Reduce stress on fish.
- Select algaecides containing hydrogen peroxide instead of copper or endothall to treat high populations of phytoplankton. Apply algaecides to small areas to prevent fish mortality; do not treat the entire pond at once.
- 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.
- Coordinate construction/renovation activities to minimize the amount of disturbed area and possible risk of contamination via runoff.
- Plan construction/renovation activities in phases to limit soil disruption and movement.
- Sod, sprig, or reseed bare or thinning turf areas, mulch areas under tree canopies to cover bare soil.
- Collect or direct clippings away from the water to areas were runoff will not deposit the clippings into the lake or pond. Avoid the use of trimmers along the edge of the water body.
- Mow lake and pond collars at a higher height to slow and filter overland flow to waterbodies.
- Remove excess sediments to reduce irrigation system failures.
- Treat dredged materials as a toxic substance. Avoid contact with turf.
- Locate littoral shelves at the pond’s inlets and outlets to reduce problems with the playability and maintainability of a water hazard.

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

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 (immersed plants), rooted to the bottom with their leaves floating on the water surface (floating-leaved plants), or free-floating on the water surface (floating plants). Different types of aquatic macrophytes have different functions in ponds.
- Plant life growing on littoral shelves may help to protect receiving waters from the pollutants present in surface water runoff, and a littoral shelf is often required in permitted surface water-retention ponds. Floating plants suppress phytoplankton because they absorb nutrients from the pond water and create shade.
- The use of aquatic plants to improve the appearance of a pond (aquascaping) can be included as part of the overall landscape design. Assure the plants don't displace storage capacity.
- Aquatic management of plants may be regulated under construction permitting and regulatory licensing requirements.
- 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

- Properly designed ponds with a narrow fringe of vegetation along the edge are more resistant to problems than those with highly maintained turf.
- In ponds with littoral plantings, problem plants should be selectively controlled without damaging littoral shelves.
- Encourage clumps of native emergent vegetation at the shoreline.
- A comprehensive lake management plan should include strategies to control the growth of nuisance vegetation that can negatively affect a pond’s water quality and treatment capacity.

- Frequently remove filamentous algae by hand and/or frequently apply algaecide to small areas of algae (spot treatment).
- To reduce the risk of oxygen depletion, use an algaecide containing hydrogen peroxide instead of one with copper or endothall.

Human Health Concerns

Principles

- Address areas where standing water may provide habitat for nuisance and disease-vectoring organisms such as mosquitoes.

Best Management Practices

- Use IPM principles and strategies to address pest insects that may pose a hazard to human health.
- Drain areas of standing water during wet seasons to reduce insect pest populations.
- Use *Bacillus thuringiensis* (Bt) products and insect growth regulators (IGR's) in appropriate areas according to label directions to manage waterborne insect larvae such as mosquitoes.

Floodplain Restoration

Principles

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

Best Management Practices

- Install stream buffers to restore natural water flows and flooding controls.
- Install buffers in play areas to stabilize and restore natural areas that will attract wildlife species.
- Install detention basins to store water and reduce flooding at peak flows.

Stormwater, Ponds, and Lakes

Stormwater is the conveying force behind what is called nonpoint source pollution. Nonpoint source 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. Nonpoint source pollution

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.
- Prior to the alteration of existing ponds or the construction of new ponds, facilities should consult the U.S. Army Corp of Engineers and the Arizona Department of Environmental Quality for information on necessary permits. Permitting Information

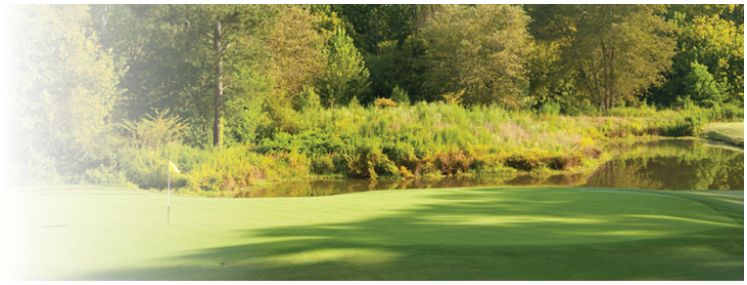
- Stormwater treatment is best accomplished by a treatment train approach, in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment.
- Source controls are the first car on the BMP treatment train. They help to prevent the generation of stormwater 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.
- Design stormwater treatment trains to direct stormwater across vegetated filter strips (such as turfgrass), through a swale into a wet detention pond, and then out through another swale to a constructed wetland system.
- Ensure that no discharges from pipes go directly to water.
- Eliminate or minimize directly connected impervious areas.
- Use vegetated swales to slow and infiltrate water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms.
- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, instead of letting it run off. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediments, while allowing the overflow to drain away.
- Maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass. Special high-permeability concrete is available for cart paths or parking lots.
- Disconnect runoff from gutters and roof drains from impervious areas, so that it flows onto permeable areas that allow the water to infiltrate near the point of generation.
- Golf course stormwater management should include "natural systems engineering" or "soft engineering" approaches that maximize the use of natural systems to treat water.
- Ensure that no discharges from pipes go directly to water.
- Use a treatment train approach.
- Institute buffers and special management zones.

Water Quality Monitoring and Management

Regulatory Considerations



Principle

As mentioned for all BMP sections regarding water, it is a precious commodity in the desert and golf courses judiciously manage this important resource. Surface waters from snowmelt in the region's mountains, protected groundwater, and reclaimed waters are delivered to golf courses seasonally at varied levels of quality.

Golf course owners and superintendents should seek, investigate, and know the regulatory requirements that exist in their location and to have knowledge of how to protect surface and groundwater quality.

Best Management Practices

- Consult with federal, state, tribal, and local water source agencies before managing golf course lakes and wetland areas. More information is available through the Arizona Department of Environmental Quality Water Division.
- Consult with federal, state, tribal, and local water source agencies, and/or consult an approved active management area plan before performing renovation or landscaping such as: fertilization; installation or removal of plants, major earthmoving, or waste disposal.
- The introduction of aquatic triploid grass carp, biological control agents, water treatments and aeration, and chemical controls (herbicide/algaecide) must be approved and monitored according to permit and licensing protocols and compliance.
- The disposal of sediments from surface-water ponds (stormwater detention) may be subject to regulation.
- Golf course owners are responsible for Total Maximum Daily Loading (TMDL's), mitigation, and watershed basin management action plans (BMAP). Information on TMDL's in Arizona.https://legacy.azdeq.gov/environ/water/assessment/tmdl.html

- Wetlands are protected areas; consult with federal, state, or tribal agencies before altering natural aquatic areas. Information about wetlands and riparian management in Arizona is available through the U.S. Department of Interior, Bureau of Land Management.
- Constructed wetlands should have an impervious bottom to prevent groundwater contamination.
- Studies of water supplies are needed for irrigation systems, including studies of waterbodies or flows on, near, and under the property are needed to properly design a course's stormwater system and water features to protect water resources.

Site Analysis

Principle

Identify the site's physical attributes and location, the invasive or weedy species present, aesthetics, watershed, streams, and groundwater assessments, and other environmental considerations. Know the sources of the waters being utilized. Design an aquatic plant management strategy that addresses the intended uses of the waterbody to maintain water quality. Also see related BMP sections regarding Planning, Design, and Construction; Irrigation; and Surface Water Management.

Best Management Practices

- Accommodate natural lake processes in the construction of lakes and ponds; include herbaceous and woody vegetation and emergent and submerged shoreline plants to reduce operational costs.
- Use Integrated Pest Management (IPM) strategies to limit pesticide use near waters and use 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 and follow label instructions to use pond waters for golf course irrigation to avoid turfgrass injury.
- Superintendents should monitor designated waters in their area for the persistence of highly toxic herbicides and algaecides in the environment.
- Irrigation should not directly strike or runoff to waterbodies and no-fertilization buffers should be maintained along edges.
- Outline goals and priorities to guide the development of the BMP necessary to support the lake/aquatic management plan.
- Secondary environmental effects on surface water and groundwater from the chemical control of vegetation should be monitored and recorded.
- Apply fertilizer and reclaimed (reuse) irrigation/fertigation appropriately to avoid surface and groundwater contamination.
- Apply copper products per label instructions to reduce the risk of negative biological impacts and impairing water quality.

- Identify position of property in relation to its watershed.
- 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. Information on wetlands and riparian management in Arizona is available through the Bureau of Land Management at https://www.blm.gov/programs/natural-resources/wetlands-and-riparian/riparian-health/arizona

Water Quality Sampling Program

Principles

Every golf course environment is unique with respect to location, geography, water source(s), climate, and construction. All these factors should be considered when developing a monitoring plan. A comprehensive geo-technical report will determine how surface and ground water will move across and through the course. Climate conditions will influence concentration levels of soil constituents, course drainage, vegetative cover and fertilizer rates.

- 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 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.
- A water quality monitoring plan should be prepared to ensure the ongoing protection of groundwater and surface-water quality after construction is completed. The same sites should be monitored during the preconstruction phase, although the monitoring plan can be modified based on site-specific conditions. An example of a water quality monitoring plan, Environmental Best Management Practices for Virginia's Golf Courses.
- Sampling parameters are determined based on golf course operation and basin-specific parameters of concern (these may be identified by local/state Total Maximum Daily Load [TMDL] Programs). The entry and exit points of golf course water sources are logical sampling points.
- 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.
- Post-construction surface-water quality sampling should begin with the installation and maintenance of golf course turf and landscaping. Samples should be collected a minimum of three times per year.
- 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.
- Sampling parameters should be determined based on golf course operation and any basin-specific parameters of concern (identified by the TMDL program or local regulators).
- Golf courses should also sample for macroinvertebrates as determined useful by water quality specialists.

Best Management Practices

- Establish dissolved oxygen (DO) thresholds to prevent fish kills (occur at levels of 2 ppm), for example, use artificial aeration (diffusers).
- Reduce stress on fish; keep DO levels above 3 ppm.
- Select algaecides containing hydrogen peroxide instead of one containing copper or endothall to treat high populations of phytoplankton.
- Use IPM principles to limit excess use of pesticides.
- Spot-treat filamentous algae or frequently remove algae by hand to prevent lowering oxygen concentrations in water.

- Use dyes and aeration to maintain appropriate light and DO levels.
- Apply algaecides to small areas to prevent fish mortality; do not treat the entire pond at once.
- Coordinate construction/renovation activities to minimize the amount of disturbed area and possible risk of contamination via runoff.
- Plan construction/renovation activities in phases to limit soil disruption and movement.
- Sod, sprig, or reseed bare or thinning turf areas.
- Mulch areas under tree canopies to cover bare soil.
- Avoid the use of trimmers along the edge of the water body.
- Mow lake and pond collars at 2 inches or higher to slow and filter overland flow to water bodies.
- Remove excess sediments to reduce irrigation system failures.
- Treat dredged materials as a toxic substance. Avoid contact with turf.
- Locate littoral shelves at the pond's inlets and outlets to reduce problems with the playability and maintainability of a water hazard.

Sampling Parameters, Collection, and Analysis

Principles

- A water quality monitoring program must include monitoring of surface water, groundwater, and pond sediments. It should be implemented in three phases: background, construction, and long-term management.
- Sampling of all watershed ingress and egress points is important to know what is coming into the property to identify potential impacts and baseline of water quality data.
- The purpose of 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 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. As discussed above, it is important to continue these plantings into the water to provide emergent vegetation for aquatic life, even if the pond is not used for stormwater treatment.
- Effective 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.
- Golf course stormwater management should include “natural systems engineering” or “soft engineering” approaches that maximize the use of natural systems to treat water.

Best Management Practices

- Riparian buffer areas are above the high-water mark and should be unfertilized and left in a natural state.
- Reduce the frequency of mowing at the lake edge and collect or direct clippings to upland areas.
- Institute buffers and special management zones.
- The placement of bunkers and the shaping of contours surrounding a green should allow proper drainage and provide for the treatment and absorption of runoff from the green.
- Use turf and native plantings to enhance buffer areas. Increase height of cut in the riparian zone to filter and buffer nutrient movement to the water.
- Use a deflector shield to prevent fertilizer and pesticide prills from contacting surface waters.
- Apply fertilizer and pesticides based on the effective swath; keep application on target and away from buffers or channel swales.
- Use a swale and berm system to allow for resident time (ponding) for water to infiltrate through the root zone to reduce lateral water movement to the surface water body.
- Maintain a riparian buffer to filter the nutrients in stormwater runoff.
- An appropriate-sized buffer (steeper slope requires great buffer width) of turf mowed at a higher height of cut and minimally fertilized with enhanced-efficiency fertilizers can provide an effective buffer.
- Use plant buffers with native species to provide pleasing aesthetics, habitat, and food sources for wildlife.

- Ideally, littoral zones should have a slope of about 1 foot vertical to 6-10 foot horizontal.
- Encourage clumps of native emergent vegetation at the shoreline.
- Establish special management zones around pond edges.
- Reverse-grade around the perimeter to control surface water runoff into ponds and reduce nutrient loads.
- Planting on slopes with less than a 6-foot horizontal to a 1-foot vertical may not be as successful over the long term.
- Construct random small dips and ridges of a few inches to a foot to promote diversity within the plant community and provide a healthier and more productive littoral zone.
- All or most of the out-of-play water bodies should have shoreline buffers planted with native or well-adapted noninvasive vegetation to provide food and shelter for wildlife.
- Practice good fertilizer management to reduce the nutrient runoff into ponds that causes algae blooms and ultimately reduces DO levels.
- Manipulate water levels to prevent low levels that result in warmer temperatures and lowered DO levels.
- Aerate shallow lakes less than 6 feet in depth to maintain acceptable DO levels.
- Where applicable, aerate at night to control oxygen depletion in any pond.
- Install desirable plants to naturally buffer DO loss and fluctuation.
- Dispose of grass clippings where runoff and wind will not carry them back to the lake.
- Nutrient rich runoff encourages alga blooms and other phytoplankton; apply appropriate fertilizer rates and application setbacks.
- Dredge or remove sediment to protect beneficial organisms that contribute to the lake's food web and overall lake health.

Wetland Protection

Principles

- Arizona does not have a wetlands regulatory program separate from the federal §404 permitting program under the Clean Water Act, but state law does outline water quality standards for both "waters of the state" and "navigable waters. Section 401 certification is the state's main tool for regulating activities affecting wetlands. Information about_401 certification.
- The biological activity of plants, fish, animals, insects, and especially bacteria and fungi in a healthy, diverse wetland is the recycling factory of our ecosystem. While wetlands do pose a special concern, their mere presence is not incompatible with the game of golf. With care, many golf holes have been threaded through sensitive areas, and with proper design and management golf can be an acceptable neighbor.

- When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turf areas with native vegetation or structural buffers.
- Constructed or disturbed wetlands may be permitted to be an integral part of the stormwater management system.

Best Management Practices

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

Stormwater Management

- **See Surface Water Management – section 3**

Sediment

Principle

During construction and/or renovation, temporary barriers and traps must be used to prevent sediments from being washed off-site into waterbodies. In the low desert region, severe monsoon windstorms will blow soil similarly. 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.

Best Management Practices

- Plant shoreline grasses or other ground cover plant materials to prevent bank erosion. Alternatively, decomposed granite (DG) or rocks will prevent erosion.
- Use dry detention basins/catchments to buffer flooding and excessive runoff that may contain sediment.
- When constructing drainage systems, pay close attention to engineering details such as subsoil preparation, the placement of gravel, slopes, and backfilling.
- Internal golf course drains should not drain directly into an open water body but should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- Maintain a vegetative cover on construction sites until it is actually ready for construction.

Sodic/Saline Conditions

Principles

- All natural waters contain soluble salts; however, the amount and type of salts they contain vary greatly.
- Reclaimed water typically contains high levels of salts, especially sodium.
- 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.
- Saltwater intrusion from groundwater pumping can create a problem with some irrigation wells.

Best Management Practices

- Regularly monitor water quality to ensure that salt concentrations are at the acceptable levels for turf irrigation.
- Conduct routine soil tests to determine sodium adsorption ration (SAR), exchangeable sodium percentage (ESP), electrical conductivity saturated paste method/unit (EC), and free calcium carbonate content.
- Mix surface water with groundwater to lower the total salt concentration. TDS levels may vary seasonally with different water sources.
- Consider using soluble fertilizers with a relatively low concentration of salts. Consider a controlled-release fertilizer that may reduce salt injury.
- Identify salt additions and saline sources that contribute to the total salt concentration.
- Select alternative turfgrass and landscape plants that are more salt-tolerant.
- Reduce salt accumulations in the soil by flushing soils as needed with a higher-quality water source. Excess irrigation to germinate and establish overseeded winter turfgrasses assists with leaching of accumulated salts.
- Design irrigation systems to account for flushing of salt accumulation from soil.
- Amend soil and water to remove salt ions from affected areas. Gypsum applications are the most typical and economical means of alleviating sodium concentrations in desert soils. Sulfur and sulfuric acid use are beneficial to slowly amend sodic soils.
- Using sulfur burners treats irrigation water in lakes and ponds to benefit soil conditions.
- Evaluate BMP to determine effectiveness toward managing sodic/saline conditions.

Nutrient Management

Regulatory Considerations

Golf course turfgrasses require varied nutrient management practices to achieve desired aesthetic and functional levels. Proper nutrient management plays a key role in the reduction of environmental risk and increases course profitability, while at the same time allowing for the generation of good turf conditions. Among other benefits, applied nutrients increase the available pool of nutrients and allow turfgrass to recover from damage, increase its resistance to stress, and increase its playability. However, the increase in available nutrients also increases the potential risk of environmental impact. Excess nutrients may move beyond the turfgrass via leaching or runoff. Other organisms also respond to increases in nutrients and, in some cases, these organisms may deleteriously alter our ecosystem. The goal of a proper nutrient management plan should be to apply the minimum necessary nutrients to achieve an acceptable playing surface and apply these nutrients in a manner that maximizes their plant uptake.

Principles

- Design a nutrient management plan that optimizes turfgrass growth and performance while minimizing risk within the golf course's unique ecosystem.
- Be aware that regulatory agencies (state, local, or tribal) may govern turf nutrient management depending on location.
- Turfgrass nutrient BMP's may be designed according to regulatory agency policies and requirements.

Best Management Practices

- Contact state, tribal, and/or local state agencies to stay abreast of any regulatory policies.

Soil Testing

Principles

- Soil testing provides the foundational information for nutrient management required for proper turfgrass maintenance.

- After proper sampling and laboratory analysis, the interpretation of results and appropriate recommendations provide for optimal turfgrass management.
- Record keeping and regular soil testing will provide managing nutrient applications more efficiently.
- Consult local land-grant university Cooperative Extension specialist for the most current turfgrass/soil recommendations. Consult the Extension specialist to understand which laboratory soil test methods and values are appropriate for your location.

Best Management Practices

- Accurate and consistent sampling is essential to providing useful soil test information over time.
- Schedule soil testing regularly and seasonally to understand plant use of nutrients.
- Divide the course into logical components such as greens, fairways, tees, roughs, etc., for each hole.
- A minimum of 10 to 15 soil sample cores should be randomly collected from each section and blended together to provide a representative, uniform soil sample.
- Each soil sample should be taken from the same depth, which is usually representative of the effective rooting depth.
- Use a laboratory extractant which is appropriate for your soils.
- For high pH soils, the “Olsen Test” for phosphorus would be most appropriate.
- The same extractant must be used for each test in order to compare soil test results over time.
- The purpose of a soil test is to provide the grower with a prediction of a plant’s response to an applied nutrient.
- Use recommended application amounts for important tested elements if the laboratory has correlation data between given levels of plant available soil nutrient and a response to that nutrient by turfgrass.
- Keeping soil tests results from prior years will allow you to observe changes over time. This record-keeping practice will provide good evidence of the impact of your nutrient management plan.
- Soil tests results provide information beyond nutrient concentrations that are important for managing turfgrass systems in arid soils including soil salinity (which affects water availability), soil sodium level (which effects soil structure) and pH (which often leads to iron, zinc, and manganese deficiencies in alkaline, high pH soils).
- Tissue testing for nutrients is essentially a ‘snap shot in time’ of the plant’s uptake status, which can be highly influenced by environmental factors and may not necessarily reflect the soil nutrient supplying capacity.
- Tissue and soil tests may not accurately reflect the status of iron in the turfgrass system, or the likelihood of a response to applied iron. If an iron deficiency is suspected, apply iron and observe the response.
- 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.

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Plant Tissue Analysis

Principles

- Tissue testing provides a precise measurement of nutrients within the plant at a given time. Tissue test sufficiency ranges are as good as the correlation data of a given element to an acceptable quality level for a given turfgrass.
- Proper sampling techniques at regular and consistent intervals for tissue testing, and record keeping, provide a good measure for maintaining turf health.

Best Management Practices

- Tissue samples may be collected during regular mowing.
- Do not collect tissue samples after any event that may alter the nutrient analysis. Such events may include fertilization, topdressing, pesticide applications, etc.
- Turfgrass areas of concern should be sampled separately from normal and typically acceptable turfgrass areas. Collect samples from both areas to provide a comparison of the results.
- Place tissue samples in properly marked paper bags. Do not use plastic bags. Allow tissue samples to air-dry at your facility before mailing them to a laboratory.
- When turfgrass begins to show signs of a possible suspected nutrient stress, a sample should be collected immediately.
- More frequent tissue testing provides a more accurate assessment of turfgrass nutrient status over time. Two to four tests per year are common on greens and one to two tests per year are common on tees and fairways. Overseeding and transition times are critical times to determine plant nutrient status.
- Keep records of soil and tissue test results from prior years to observe changes over time.

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. Knowledge of the turfgrass growth in relation to temperature and climate will help in determining the amounts, frequency of application and types of nutrient elements needed to produce good quality turf without over-fertilization.

- 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 product.
- A complete fertilizer contains N, P_2O_5, and K_2O.

- The laws governing the labeling of fertilizer vary among states. Consult your land-grant university or the appropriate state or tribal agency regarding the laws in your location. Arizona currently does not have any limits or restrictions on fertilizer types or amounts applied.

Label

- The label informs the user about the contents of the fertilizer product and the proper use should result in little to no environmental risk.
- The fertilizer label should include:
    - brand name
    - grade or fertilizer analysis
    - manufacturer's name and address
    - guaranteed analysis
    - "Derived from" statement
    - net weight
- **Cost per unit of fertilizer element:**

    - When purchasing fertilizer products, the actual cost of the nutrient on a weight basis is more important than the price of the weight of the formulated product itself.

    - To determine the amount of nutrient element in a known weight of product, use the equation as follows: % analysis of the individual element multiplied by the weight of the product in the container = weight in pounds of the individual element in the product.

    - The cost per pound of the individual element equals the cost of the total product container divided by the pounds of nutrients in the weighed product.

Macronutrients

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

- Understanding the role of each macronutrient within the plant should provide you with a greater understanding of why these nutrients play such a key role in proper turfgrass management.
- The goal of all applied nutrients is to maximize plant uptake while minimizing nutrient losses. Understanding each process will increase your ability to make sound management decisions and ultimately leads to an increase in profitability and a reduction in environmental risk.

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). N plays a role in numerous plant functions including being an essential component of amino acids, proteins and nucleic acids.

Fate and transformation of N

- *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

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, turfgrass species, and soil pH all should be included in your nutrient application decision. In high pH desert soils, as much as 50% of the nitrogen from straight urea may be lost the atmosphere. A slow-release N source is any N-containing fertilizer where the release of N into the soil is delayed either by: 1) requiring microbial degradation of the N source; 2) coating the N substrate which delays the dissolution of N; 3) using a chemical inhibitor in the product formulation; 4) reducing the water solubility of the N source; or physically cracking the coating.

- *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*
  - Sulfur-coated urea
  - UMAXX and UFLEX urea
  - Polymer/resin-coated

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

- *Urease and nitrification inhibitors*

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

The role of phosphorous (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
    - Superphosphate
    - Triple superphosphate
    - 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 ½ that of nitrogen.

Potassium is not a component of any organic compound and moves readily within the plant. Potassium is key component of osmoregulation (ion storage) 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
    - Potassium thiosulfate
    - Potassium phosphate

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

A soil pH of 6.3 is ideal because it provides the greatest probability of micronutrient availability. Soil pH adjustments occur very slowly and are temporary. The low desert soil pH is generally 8. The native soils have very low organic matter of less than 2%.

Best Management Practices

- To lower soil pH, products containing elemental sulfur can be applied.
- To increase soil pH, apply a liming material (calcium carbonate, calcium oxide, dolomitic limestone) that contains Ca^{2+} and neutralizes acidity.
- In some cases, utilizing injection pumps into irrigation water to address pH can be beneficial. A sulfur burner may be used to help adjust pH and remove bicarbonates in turf irrigation water.
- Only on high sand content root zones, will soil pH changes be nominally affected by the addition of acids or bases in the irrigation water itself.

Nutrient Management

Principles

- Understand the importance of application timing for effective use of applied nutrients.
- In Arizona, higher elevation cool-season turfgrasses have different nutrient requirements versus the low desert bermudagrass that is commonly overseeded in the winter with a cool-season grass. These differences require that a nutrient management plan be flexible enough to allow turfgrass managers to address their unique needs.
- The objective of all nutrient applications is plant uptake and the corresponding desirable response.
- Soil amendments applied to the desert turfgrasses are intended to remediate excess sodium conditions in soils. Gypsum and sulfur applications are encouraged to assist in the process.

Best Management Practices

- Apply nutrients when turfgrass is actively growing.
- Apply N fertilizers at the appropriate time of year to maximize bermudagrass spring transition and establishment of fall overseeded cool-season grasses. Generally, ammonium sulfate or urea are inexpensive sources with high N content.

- Follow N application rate recommendations based on soil test results and historic records that demonstrate turf response and performance or from your land-grant university research results.
- N application from slow-release materials should take into consideration the release rate of the chosen material. Undesirable consequences may result if insufficient material is applied or rapid release occurs.
- Use of a high P source fertilizer during overseeding, sprigging, or sodding aides in the root establishment of the turfgrass.
- Most desert soils naturally have adequate levels of K.
- During the winter, applications of chelated iron usually provides rapid greening of the cool-season grasses.
- Sand-based greens and tees should be monitored regularly to maintain macro- and micronutrient sufficiency.
- The reduced height of cut and excessive traffic damage on putting greens results in an increased need for growth leading to an increase in nutrition.
- Tees and landing areas often have higher fertility requirements than fairways and roughs because they suffer constant divot damage.
- Fairways and roughs often require fewer nutrient inputs than other locations because of their increased height of cut, less damage, and clipping return.
- Exercise caution when applying nutrient applications during turfgrass establishment as these applications are particularly susceptible to loss via leaching and runoff.
- Soil amendments such as the application of gypsum and sulfur aide in sodic soil remediation.
- Select and use the most appropriate spreader for a given fertilizer material.
    - Walk-behind rotary
    - Drop spreader
    - Bulk rotary
    - Spray
- Calibrate each piece of application equipment prior to use.
- Properly store fertilizers in a dry location.
- Optimally follow fertilizer applications with adequate irrigation or rainfall to avoid foliar burning. Avoid applying fertilizer to soils that are approaching or at field capacity or following rain events that leave the soils wet.
- Do not apply fertilizers when the weather forecasts include heavy rains especially with potential flooding and/or runoff.

Cultural Practices

Mowing

Cultural practices are an important part of golf course turf management. Cultural practices such as mowing, grooming, verticutting, aerifying, and rolling are necessary to provide a high-quality playing surface while enhancing plant health.

Heavily used and highly trafficked areas such as putting greens, pathways, and cart access areas often deteriorate because of compacted soil, thatch accumulation, and excessive use (traffic wear). 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 agricultural 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.
- Mowing management includes selection of the mowing height and the time between mowing events (mowing frequency).
- 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 or irregularly scheduled mowing can result in alternating cycles of excessive vegetative growth followed by scalping, which depletes food reserves of the plants and often results in the loss of turfgrass density.
- 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 that is mowed below its low height tolerance base will have decreased shoot growth. The plant adjusts to this stress condition by: 1) attempting to grow new shoots and leaves that are required for photosynthesis; 2) balancing its food production for both shoots and roots in the attempt to maintain a sustainable root/shoot ratio. This occurs at the expense of root food reserves, resulting in a loss of root function.
    - Scalping (removal of 50% or more of the turf in a single mow) halts shoot growth for a few days, followed by the sudden emergence of new shoots with wide leaves as the turfgrass attempts to recover new green tissue. The energy for these new shoots comes at the expense of root food reserves. Repeated scalping results in a thin and often weedy turf
- Root growth is least affected when no more than 30 - 40% of the 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

- Mowing frequency should increase during periods of rapid growth and decrease during dry or cold stressful periods.
- If turf becomes too tall, it should not be mowed down 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.
- Shade affects turfgrass growth by filtering out photosynthetically active solar radiation. As a result, turfgrass plants respond by growing upright in an effort to capture more light to meet their photosynthetic needs. Mowing height should be increased by at least 30% to improve the health of turf grown in a shaded environment.
- The use of the plant growth regulators has been shown to improve overall turf health when used as a regular management tool for grasses growing in shaded environments.
- Climate induced stresses such as prolonged cloudy weather, drought, or extended freezes can have a significant impact on turf health. Increasing mowing heights as much as practical will offer increased photosynthetic capacity and rooting depth of plants.
- On greens, selective rolling can help improve ball roll distance along with lower mowing heights. Rolling can help maintain grass quality when greens are mowed at several successive mowing heights to reach the final “low mowing” height.
- Multiple cutting and rolling events can adjust green speeds.
- Use proper mowing equipment that is sharpened regularly.
- Reel mowers are ideally suited for maintaining turfgrass stands that require a height of cut below 1.5 inches. They produce the best quality cut when compared to other types of mowers.
- A prism gauge can provide for achieving precision height of cut and viewing the quality of cut.

- The USGA stimpmeter can be used to measure ball-roll distance on greens.
- Rotary mowers, 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, decreased shoot density, and the potential for disease development.
- Flail mowers can be used to maintain utility turf on secondary roughs and other non-play areas that are mowed infrequently and do not have a high management requirement.
- Mowing patterns influence both the aesthetic and functional characteristics of a turf surface.
- Use of groomers or brush attachments can improve the quality of cut and physical characteristics of the plant on greens.
- 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. If removed, clippings should be properly disposed so they do not become a pollution or nuisance problem.
- Collecting and removing clippings can physically remove undesirable weed seeds and foliar pests and diseases.
- Clippings should be returned to the site during the mowing process unless the presence of grass clippings will have a detrimental impact on play. Cases when clippings should be removed include times when the amount of clippings is so large that it could smother the underlying grass or on golf greens where clippings might affect ball roll.
- Collected clippings should be disposed of properly to prevent undesirable odors and nuisance pests near play areas and to prevent fire hazards that can occur when clippings accumulate. Consider composting clippings or dispersing them evenly in natural areas where they can decompose naturally without accumulating in piles.
- Leaf blowers and mechanical brushes can disperse clumped clippings.
- Power vacuums can collect excessive clippings from large areas.

Cultivation

Principles

- Cultivation involves disturbing the matt, thatch and/or soil through the use of various mechanical implements to achieve important agronomic goals that include benefits of the 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, especially if performed when turfgrass growth is slow.
- Frequency of cultivation should be based on traffic intensity and level of soil compaction.
- Core aerification is effective for managing soil compaction and aiding in improvement of soil drainage – water and air.
- Accumulation of excessive thatch and organic matter will reduce root growth, encourage disease, and help create undesirable turfgrass surface playing conditions.
- Light and frequent applications of sand topdressing, especially on greens, will smooth the playing surface, control thatch, and potentially change the physical characteristics of the underlying soil when done in conjunction with core aerification.
    - Use caution if topdressing or “sand-capping” fairways as a layered soil can result in a perched layer that is impenetrable for water and creating new a soil/rootzone problem.

Best Management Practices

- Core aerification involves removal of cores or plugs from the soil profile. Cores are usually 0.25 to 0.75 inch in diameter at 4 to 8 inches depth. Annual core aerification programs should be designed to remove 15%-20% of the surface area. High-traffic areas may require a minimum of two to four core aerifications annually.
- Core aerification should be conducted only when grasses are actively growing to aid in quick recovery of surface density.
- Vary depth of aerification events by incorporating varying length tines to prevent development of compacted layers in the soil profile as a result of cultivation.
- Solid tines cause less disturbance to the turf surface and can be used to temporarily reduce compaction, soften surface hardness, increase water and air infiltration, and promote beneficial gas exchange. Solid tines can be used when turf recovery is slow during low temperatures or stress conditions.
- Solid tines used on fairways and higher cut turfs cause minimal visible disturbance and have the same benefits that are achieved on greens. Solid tines are more “time efficient” than core aerification on large turf areas.
- Use of venting knife tines on greens will aid in air and water movement to roots, usually affecting more turf surface and soil volume than when using solid needle tines.
- Deep-drill aerification creates deep holes in the soil profile through use of drill bits. Soil is brought to the surface and distributed into the canopy. Holes can be backfilled with new root-zone materials if a drill-and-fill machine is used. These machines allow replacement of heavier soils with sand or other materials in an effort to improve water infiltration into the soil profile.
- Deep drill aerification followed by filling the holes with sand is an option for push-up soil-based greens which have multiple soils textures.
- Vibratory slicer or vibratory disk implements can used on fairways and roughs to shatter subsurface compaction layers and to improve water and air infiltration on soils which have blocky soil structure.
- Slicing and spiking reduce surface compaction and promote water infiltration with minimal surface damage.
- Deep slicing may or may not be faster than core aerification and may be less effective. Slicing is best accomplished on moist soils.
- A spiker can break up crusts on the soil surface, disrupt algae layers, and improve water infiltration.
- Vertical mowing (verticutting) can be incorporated into a cultural management program to achieve a number of different goals. The grain of a putting green can be reduced by setting a verticutter to a depth that just nicks the surface of the turf. Deeper penetration of knives will stimulate new growth by cutting through stolons and rhizomes while removing accumulated thatch.
- Verticutting depth for thatch removal should reach the bottom of the thatch layer and extend into the surface of the soil beneath the thatch.

- Dethatching with a verticutter is an aggressive practice that is not recommended on golf putting greens because of the damage that occurs and the extensive recovery time required.
- Initiate vertical mowing when thatch level reaches 0.25 to 0.5 inch in depth. Shallow vertical mowing should be completed at least monthly on putting greens to prevent excessive thatch accumulation.
- Shallow verticutting during spring transition can aid in the gradual removal of overseeded winter turf.
- Grooming is essentially a light vertical mowing of the very top of the greens canopy using thin, closely spaced, small diameter knife blades on an additional rotating shaft on a greens mower.
- Groomers are effective for improving management of grain and improving plant density.
- Topdress the playing surface with sand following core aerification and heavy vertical mowing to aid in recovery of turf. Rates will vary from 0.125 to 0.25 inch in depth and will depend on the capacity of the turf canopy to absorb the material without burying the plants.
- Light, frequent applications of topdressing sand on putting greens can smooth out minor surface irregularities, and aid in the management of thatch accumulation.
- Light topdressings are often done after grooming and/or shallow vertical mowing events.
- Mechanical and/or hand brushing helps incorporate sand topdressing and minimizes sand contact with the reel and bedknife.
- Use only weed-free topdressing materials with a particle size similar to that of the underlying root zone.
- Cores may not need to be removed if they can be broken down and dragged to fill aerification holes to supplement topdressing sand.
- Use of finer materials can result in layering and can have a negative impact on water infiltration, rootzone drainage, and natural salt leaching.
- Rolling of putting surfaces 3 - 5 times per week following mowing can increase putting speeds by roughly 10%, allowing for improved ball roll without lowering height of cut.
- To minimize potential for compaction caused by rolling, use light-weight rollers.

Overseeding Warm-Season Turfgrass

Principles

- The fundamental purpose of overseeding is to establish a temporary cool-season grass into the warm-season base for improved color and playability during the fall and winter when the warm-season grass enters dormancy.
- Overseeding increases the need for irrigation, fertilization, and routine mowing.
- Overseeding may result in significant thinning of the base grass during spring transition. Base bermudagrass turf should grow throughout the summer for 100 days to optimally establish roots and rhizomes for the winter and the next spring transition.
- Successful overseeding programs require year-long planning and incorporate all aspects of root-zone cultivation and weed control in an effort to maintain health of the warm-season turfgrass while allowing successful establishment of the overseeded cool-season grass species.

Best Management Practices

- Excessive thatch (> 0.5 inch) in the warm-season turfgrass base will prevent good seed-to-soil contact and will result in sporadic germination and establishment. Remove and reduce thatch as part of an active cultivation program during the warm-season grass growing season that is not a part of overseeding preparation.

- Reduce or eliminate fertilization of the base grass 3 to 4 weeks before the planned seeding date to minimize growth and competition. If needed, application of iron may help maintain turfgrass color.
- Perform the last aerifying event five to six weeks before the planned overseeding date.
- Severe aerifying and verticutting should not be performed as part of the overseeding preparation as it can damage carbohydrate-filling rhizomes and crowns of the bermudagrass by reducing growing points for spring emergence.
- Light verticutting as part of overseeding preparation can help open the canopy when the turfgrass is very dense.
- Using appropriate plant growth regulators (PGR's) such as trinexapac-ethyl or triclopyr herbicide will aid in reducing bermudagrass growth to minimize competition with the overseeded winter grasses. After emergence of winter grasses, PGR's aid in their tillering and continue to suppress bermudagrass competition.
- Bermudagrass cultivars are best adapted for overseeding and spring transition. Generally, seashore paspalum and zoysiagrasses are not aggressive competitors against overseeded grasses, nor do they tolerate mechanical disturbances used for overseeding preparation.
- Perennial ryegrass cultivars with improved heat tolerance can delay spring transition and create increased competition for water, nutrients, and light with the warm-season turfgrass base.
- Irrigate newly planted overseeded grasses to maintain constant moisture levels, not allowing the soil surface to dry out. Gradually reduce irrigation once the seedlings have been mowed.
- During overseeding, high air temperatures together with frequent irrigation causing high humidity conditions may be conducive for *Pythium* disease infections while establishing winter grasses.
- The first mowing of the overseeded grass should be done with lightweight mowing equipment after the water has sufficiently drained off from the surface. Use a sharp bladed machine at slow ground speeds. Avoid making sharp turns with the mower.
- Apply an N and P containing quick-release fertilizer after the first mowing event at the rate of 0.5 lbs. N/1000 ft^2.
- Before freezing nighttime temperatures occur, apply foliar iron for green color retention.
- Move hole locations on putting greens daily during the establishment period to minimize damage to seedlings from foot traffic.
- After the initial stand establishment of the overseed grass and the first few mowings, restrict golf carts to "paths only" to help the new grass fully establish.
- During spring transition, excessive fertilizer applications may extend the growth and competitiveness of the overseeded grass. It is a fine line to observe when the warm-season turfgrass regrowth is apparent and fertilizer applications can stimulate its growth.
- Transition-aide herbicides may be used to facilitate winter grass removal. Rapid removal early in the spring can identify weak areas of foundation bermudagrass

that require re-sodding or renovation. Slower acting herbicides can provide a more gentle and gradual transition to remove winter grasses and allow emergence of the summer grass.
- Colorants (dyes and pigments) can be used to provide winter color to dormant grasses as an alternative to overseeding.
- Colorants can enhance the soil temperatures as the darker surface absorbs solar radiation and bermudagrass transition can be accelerated.
- Overseeding practices may generate significant dust that may require dust control measures. Be aware of local, state, county, or tribal regulations for air quality standards.
- Optimal timing and implementing proper practices are critical for maximizing bermudagrass health and vigor as it stores food reserves in preparation for winter dormancy and then spring emergence during the following spring transition. If overseeding in early fall when temperatures are still conducive for bermudagrass growth, severe aerifying and/or verticutting preparation will allow bermudagrass to regrow aggressively against the overseed grass and expend food reserves that are needed for the spring transition.

Shade and Tree Management

Principles

- In general, most turfgrasses perform best in full sun. The warm-season grasses, especially bermudgrass cultivars, require more than a half-day of solar radiation for optimal growth.
- Excessive shade reduces photosynthesis and air circulation, thus increasing the susceptibility of the turf to pest and disease problems.

Best Management Practices

- Place and plant young and smaller trees anticipating their full mature growth size in an area.
- Prune tree limbs and roots as needed to reduce competition for sunlight, water, and nutrients.
- When possible, trees located near closely mowed areas such as tees and greens should be removed or their canopy should be thinned to allow adequate light to promote good turf growth.
- Understand the variability in sun angles at different times of the year and how this affects turf health. Mobile phone “Apps” are available on smartphones to track daily sunlight angles for turf areas.
- 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.
- Ensure that trees are properly irrigated for deep roots. Shallow turfgrass irrigation forces tree roots to compete for nutrients and water at the soil surface.

Integrated Pest Management

Regulatory Considerations

The philosophy of integrated pest management (IPM) was developed in the 1950's 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, product, 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, vertebrate pests,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.

Principles

- Some federal, state, local and tribal regulations cover practically anyone who manufactures, formulates, markets, and uses pesticides.
- Record keeping of pesticide use may be required by law. Laws may require submission of all information (i.e. specific location, date, time, dosage, weather conditions, etc.) for each pesticide application. 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

- Proper records of all pesticide applications should be kept according to local, state, tribal, or federal requirements.
- Submit to Arizona Department of Agriculture, Form 1080 following pesticide applications, especially for pesticides required by the Arizona Department of Environmental Quality to protect groundwater quality.

- 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 formulated product, amount of water)
    - Adjuvant/surfactant and amount applied, if used
    - Area treated (acres or square feet) and location
    - Application equipment (nozzle description and configuration, pressure, speed)
    - Additional remarks, such as the severity of the infestation or life stage of the pest
    - Follow-up to check the effectiveness of the application

IPM Overview

Principles

- The fundamental basis of a safe and environmentally sound pest control program is a process called IPM.
- IPM strategies include cultural, biological, and chemical techniques alone and /or in combination.
- IPM focuses on the basics of identifying the pest(s), selecting and using 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 or using the least toxic and effective chemical pesticides whenever possible.
- Selective chemical controls should have minimal effect on beneficial organisms, the environment, and humans and minimize the development of pesticide resistance.

Best Management Practices

- Selective chemical pesticides should be carefully chosen to provide effective control of specific target pests with minimal environmental and human effects.
- Identify key pests that affect turfgrasses and desirable landscape 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 (e.g. prepare the site, select resistant cultivars, properly manage irrigation), reduce pest habitat (e.g. practice good sanitation, proper landscape pruning and turf dethatching), or to help promote biological control (e.g. provide habitat and food sources).

- Decide which pest management practices or tactics are appropriate and carry out corrective actions. Direct the control tactic to where the pest infestation and/or damage is occurring.
- Use preventive chemical applications only when your professional judgment and historical records indicate that properly timed preventive applications will control the anticipated target pest, disease, or weed effectively while minimizing the economic and environmental costs.
- Follow-up to determine whether the pest management strategy actually reduced or prevented pest populations to achieve economical control while minimizing risks to the environment and to humans.
- 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, such as pest monitoring, other applicable practices, and the use of chemicals is a last measure when threshold levels are exceeded.
- The goal of an IPM strategy is to optimize the growing conditions to maintain an aesthetic and a playable grass surface for greens, fairways, tees, and surrounding areas.
- The tolerance or level of acceptance should be determined for turfgrass injury or damage (e.g. zero tolerance on greens to acceptable injury in the rough).
- Records should be maintained for turf management practices such as mowing, fertilization, aerifying and verticutting, irrigation for all turf areas seasonally.
- Weather records should be maintained as it influences turf growth and pest, disease, and weed incidence.
- Criteria for a pesticide application should be based on effectiveness against the target, selectivity and toxicity to non-target species, cost, and site characteristics, as well as its solubility and persistence.

Best Management Practices

- Keep specific individual records for maintenance of greens, fairways, tees, roughs.
- Determine tolerance levels for turf injury or damage on greens, fairways, tees, and roughs.
- Monitor / scout regularly to observe occurrences of pests, disease, or weeds. Use appropriate light trapping techniques, pitfall traps, or soap flushes to monitor for insect pests.
- Maintain accurate records for mowing height of cut, frequency, fertilization amounts of products and frequency, use of plant growth regulators, aerifying and verticutting, irrigation amounts, quality of water, and frequency.
- Maintain weather records, especially to help correlate extreme temperatures and rainfalls to pest, disease, and weed infestations.

- Decide which pest management practice(s) are appropriate, carry out corrective actions, and then record the activities, relative conditions, and results.
- Use the GCSAA IPM Planning Guide to set goals and build an IPM planner.

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 crop's economic and damage threshold levels may warrant treatment.
- Injury and damage threshold levels are quantitative and qualitative for the golfer and superintendent as obvious visual turfgrass impairments. The economic injury or damage levels are sufficient to warrant course(s) of action to limit the pest so not to cause further damage from occurring to incur greater costs.
- Setting economic and/or damage threshold levels for insect pests, diseases, or weeds is challenging for golf courses. Golfers are sensitive and often intolerant of any injury or damage to turf that could affect the appearance and/or playability of turfgrass and ornamental plants.
- When and where possible, create and develop quantitative and/or qualitative injury or damage threshold levels for key pests, diseases, and weeds in turf for greens, fairways, tees, and roughs.
- Visual observations during regular monitoring and scouting will afford qualitative changes in appearance of turfgrass conditions with respect to color, density, or vigor due to pests or diseases.
- A single weed, earthworm castings, or ant mounds can disrupt playability on a green and not be tolerated whereas they can be tolerated on a fairway or rough area and no action may be necessary.
- A heavy infestation of birds pecking and damaging greens may indicate presence of soil insects and skunks, javelinas, racoons, or bears damaging fairways and roughs may indicate presence of grubs.

Best Management Practices

- Monitor and scout to observe qualitatively the turfgrass conditions of greens, fairways, tees, and roughs.
- Create and develop a quantitative evaluation method to determine and compare turf color, density, or vigor over time that could indicate insect or disease infestation or infection.
- Monitor weed populations by species and amount of infestation in locations on the course.
- Use available pest's economic threshold levels to guide pesticide application decisions (see IPM Guide).

- Use preventive chemical applications only when professional judgment and quantitative data records indicate a need for properly timed pesticide application for an anticipated target pest.
- Record and use this information when making similar decisions in the future.
- Improve and increase education for golfers and maintenance personnel to raise their tolerance of minor aesthetic damage without compromising plant health, play, and aesthetics.

Monitoring

Principles

- Monitoring, or scouting, is the most important element of a successful IPM program. Monitoring helps to document the presence, development, and extent of pests, diseases, or weeds along with the conditions that are conducive for their 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 all personnel to observe and document turf conditions regularly each day while conducting their tasks, noting which pests or weeds are present.
- Utilize insect trapping techniques such as blacklight traps, pitfall traps, and soap flushes to quantify insect pest occurrences.
- Train personnel (e.g. assistant and spray technician) to understand the pest's life cycle, and to know which life stage to target.
- Train personnel (e.g. assistant and spray technician) to determine whether the corrective actions actually reduced or prevented pest populations.
- Record and use this information when making similar decisions in the future.
- Train all personnel to observe and document pest infestations regularly each day while conducting their tasks, noting which pests or weeds are present on or around key landscape plants.
- Train all personnel to observe and look for signs of pests, weeds, and diseases. These may include mushrooms, animal damage, insect frass, or webbing.
- Train all personnel to observe and identify the symptoms of pests or diseases. Look for symptoms such as chlorosis, dieback, growth reduction, defoliation, mounds, or tunnels.
- Train all personnel to observe and determine the damage to turf and landscape plants. Problem areas might include the edges of fairways, shady areas, or poorly drained areas.
- Train all personnel to observe and document when and where any damage occurred. Note the time of day, date, weather conditions, and flowering stages of nearby plants.

- Map pest outbreak locations to identify patterns and susceptible areas for future targeted spot applications and eventually reduce broadcast pesticide applications.

Record Keeping

Principles

- It is essential to record the results of scouting in order to develop historical information, document patterns of pest activity and develop threshold levels, 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 (RUP's). 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.
- Arizona Department of Agriculture requires that Form 1080 be submitted for RUP's and certain products determined by the Department of Environmental Quality to protect the groundwater.

Best Management Practices

- Identify and record key pest occurrences on turf and key plants and their locations (e.g. greens, tees, fairways, non-play areas, etc.).
- Monitor and keep accurate records for the key turf pest grubs, masked chafer grubs and black turfgrass ataenius grubs. Blacklight traps are effective to monitor beetles from spring through fall seasons.
- Determine the pest's life cycle and know which susceptible life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).
- Secondary pests including cutworms, armyworms, and webworms, the adults can be monitored by the blacklight traps. Billbugs may be monitored using pitfall traps. Incidences of secondary pests should be noted and recorded as they may not always occur.
- Monitor and record incidences of ants, rove beetles, mole crickets, mosquitoes, bee swarms, false chinchbugs, earthworms, snakes, rodents (gophers and ground squirrels), ducks, geese, and coots.
- Secondary turf damage may result from vertebrate pests such javelinas, skunks, racoons, and bears rutting turf for soil grubs, worms, and billbugs so record-keeping is critical to future localized pest management techniques
- 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. Alter and manipulate the areas, if possible, to provide optimum light conditions for the turfgrass to flourish.
- 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.
- Raise the mowing height of cut to provide more leaf surface for photosynthetic activity.
- Reduce traffic in shaded areas to protect turfgrasses and trees from injury and soil compaction, if practical.

Biological Controls

Principles

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

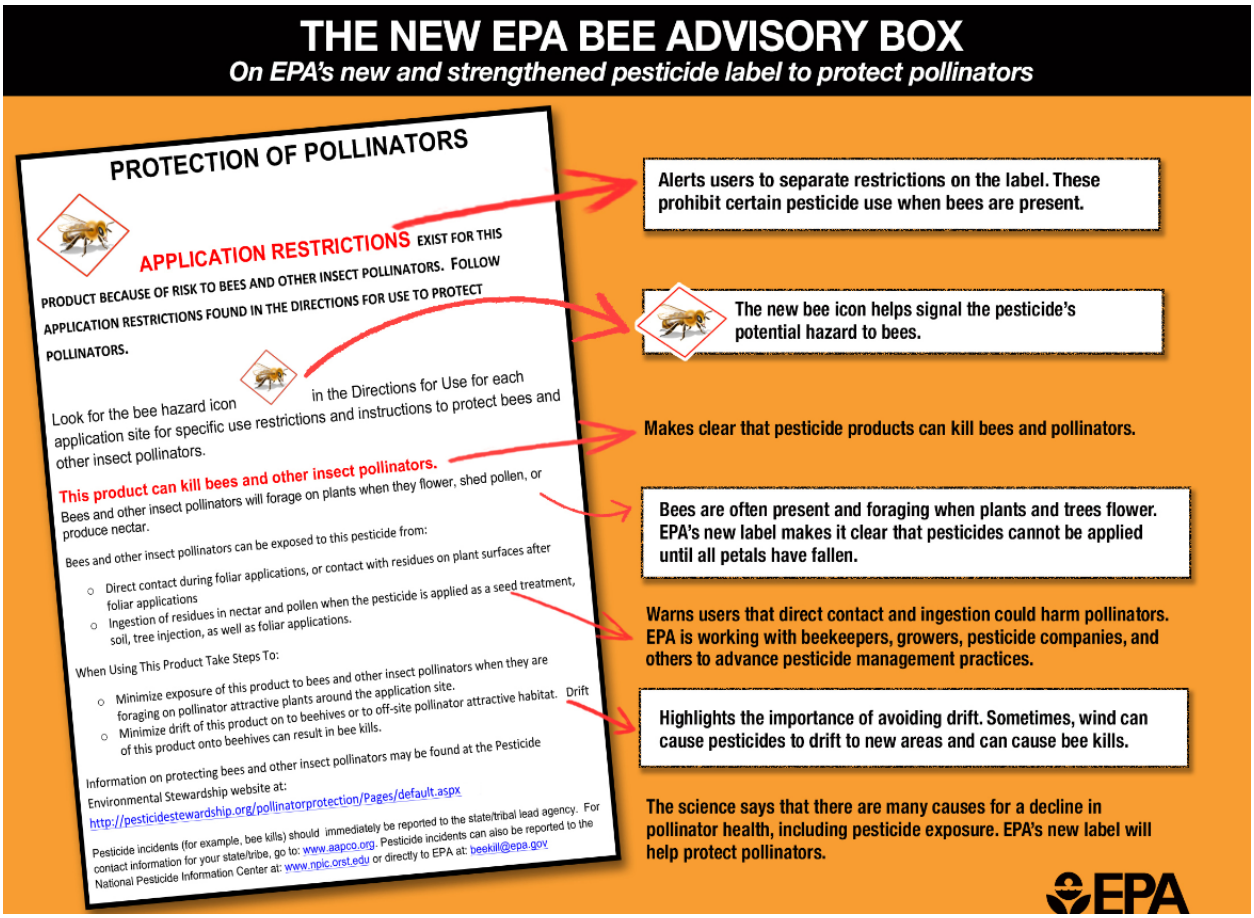
Best Management Practices

- Identify areas on the golf course that can be modified to be attractive for natural enemies, provide a habitat for them, and protect them from pesticide applications.
- Install flowering plants that can provide parasitoids with nectar or provide alternate hosts as a honeydew source for sucking insect pests (aphids, mealybugs, or soft scales).
- Avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide a refuge for beneficial organisms.
- Release insect-parasitic nematodes to naturally suppress mole crickets and white grubs in locations where conditions are conducive for their survival.

Pollinators

Principles

- It is important to minimize the impacts on bees and beneficial arthropods as pollinators. Bats and birds are also important pollinators. Pesticide applicators must use appropriate tools, follow label instructions, and laws and regulations to safeguard pollinators, the environment, and humans.
- Pollinator-protection language (“bee box”) 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

- When using pesticides, follow label directions to minimize impacts on bees and other pollinators.
- Do not apply pesticides when pollinators are active.
- Avoid applying pesticides during bloom season. Follow label directions concerning the application of pesticides when plants are in bloom (carefully read and follow instructions in the "bee box" on labels).
- Use insecticides that have a lower impact on pollinators.
- Use granular formulations of pesticides that are known to be less hazardous to bees.
- Before applying a pesticide for a pest insect, scout/inspect the area for beneficial insect populations, and apply only when the economic threshold level for injury/damage has been reached.
- To reduce pesticide spray drift, use nozzle sizes that spray coarse droplets as directed by label instructions. Monitor wind speed and direction and be aware of temperature inversions that may affect offsite movement of volatile pesticides.
- Avoid applications during low temperatures or when dew is forecasted.
- If necessary, apply pesticides during the part of the day when bees are not active.

- Prevent and eliminate flowering weeds (i.e. mow or use herbicides) that may be attractive for bees.
- Consider using lures, baits, and pheromones or other cultural techniques 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.
- A properly trained, knowledgeable, and licensed person should be responsible for making the ultimate decision to select and use the appropriate pesticide(s).
- 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.
- Make note of any environmental hazards and groundwater advisories included on the label.
- Rotate pesticide modes-of-action to reduce the likelihood of developing resistance.
- Follow guidelines and advice provided by the Fungicide Resistance Action Committee (FRAC), Herbicide Resistance Action Committee (HRAC),and Insecticide Resistance Action Committee (IRAC).

Insect Pests

Principles

- Insects and other arthropods can injure and/or damage turfgrasses aesthetically or physically to affect playability of the turf.
- Insect pests can occur seasonally as a key pest or occur intermittently as secondary or nuisance pests.
- Key pests in the low desert have been identified as the grubs of masked chafers and/or black turfgrass ataenius that feed on the roots of warm-season bermudagrasses.
- Secondary occasional pests include billbugs, armyworms, cutworms, webworms, ants, rove beetles, bee swarms, and earthworms. Pests that occur on golf courses are mosquitoes that are a human health concern that vector human diseases.
- Scouting and monitoring are critical to know when pests occur on turfgrasses and to what extent they cause injury or damage.
- Threshold levels are determined by individual tolerance levels of injury that occur on turf and where they occur on greens, fairways, tees, or rough areas.

- Preventive and cultural tactics can be integrated with biological and chemical control methods to reduce and manage the insect infestations.

Best Management Practices

- Proper insect identification is essential for effective management and control.
- Determine the extent of the infestation if it is widespread or localized to specific areas of turf.
- Scout and monitor populations and correlate it to turf management activities (i.e. irrigation, mowing, or surrounding vegetation greening up or drying up)
- Use trapping techniques such as blacklight traps, pitfall traps, and soap flushes to evaluate populations of pests.
- Determine economic threshold levels and select appropriate control options.
- Utilize cultural practices that result in altering pest habitats such as reducing excess wet areas conducive for certain insects or mow and remove clippings to eliminate mites in turf.
- If insecticides are to be applied, use selective products that are effective against the target pest without affecting non-target beneficials or the environment or humans.
- Utilize preventive insecticides in a timely manner to anticipate regularly occurring pests in tandem with monitoring techniques.
- Compare and select appropriate plant systemic insecticides versus fast-acting contact insecticides.

Disease

Principles

- In the presence of a susceptible host and a conducive environment, plant pathogens can damage and destroy intensely managed turf to disrupt play.
- No measure can completely eliminate the threat of turfgrass disease on a golf course. However, superintendents have multiple tactics and tools that can minimize/reduce the impact of disease.
- Cultural techniques can improve turfgrass health and minimize disease problems by implementing good organic layer management, fertility programs, water management, and properly adjusting mowing height of cut. 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

- Correctly identify the disease pathogen. Diagnostic clinics can usually confirm the causal agent.
- Employ proper cultural practices that minimize/reduce turfgrass stress.

- Correct and manage the conditions that produce stressful environments for the turf (e.g. improve airflow and drainage, reduce or eliminate shade.)
- Fungicide use should be integrated into an overall management strategy for a golf course.
- The appropriate (most effective) preventive fungicide should be applied to susceptible turfgrasses when unacceptable levels of disease are likely to occur.
- Preventively apply appropriate 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

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 a desirable, healthy, and vigorous turfgrass surface, and where herbicides are appropriately selected and judiciously used. A successful weed management program consists of:
    - preventing weeds from being introduced into an area
    - using proper turfgrass management and cultural practices to promote vigorous, competitive turf
    - properly identifying weeds and knowing their seasonal growth habits
    - properly selecting and using an appropriate herbicide when necessary
- Weeds may be alternate hosts for plant pathogens, nematodes, and insect pests; certain weeds can cause allergic reactions to humans; and regulatory agencies can categorize noxious weeds.
- 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 live for more than two years (perennials). Annuals that complete their life cycles from spring to fall are referred to as summer annuals and winter annuals in the low desert emerge in the fall and seed in the spring.

Best Management Practices

- Proper weed identification is essential for effective management and control.

- Select appropriate turf species or cultivars that are adapted to the prevalent environmental conditions to reduce weed competition and encroachment.
- To prevent weed encroachment, adopt or maintain cultural practices that protect turfgrass from environmental stresses such as shade, drought, and extreme temperatures.
- To reduce weed infestations, address improper turf management practices, such as the misuse of fertilizers and chemicals, improper mowing height or mowing frequency, and improper soil aeration, and physical damage and compaction from excessive traffic, and improper irrigation management.
- Proper fertilization is essential for turfgrasses to sustain desirable color, growth density, and vigor and to better resist diseases, weeds, and insects.
- Avoid scalping; it reduces turf density, increasing weed establishment.
- Weed-free materials should be used for topdressing.
- Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to broadleaf weeds.
- Record and map weed infestations to help identify site specific issues for preventative actions.
- Use appropriate preemergence and postemergence herbicides at the proper timings when weeds are most susceptible.
- Follow label instructions and use proper adjuvants to obtain the greatest efficacy and safety when applying herbicides.
- Follow label instructions to ensure safety to the desirable turf and to the surrounding environment and humans.
- Do not misuse or overuse similar chemistries to preserve longevity of products and to avert the development of herbicide resistance.

Nematodes

Principles

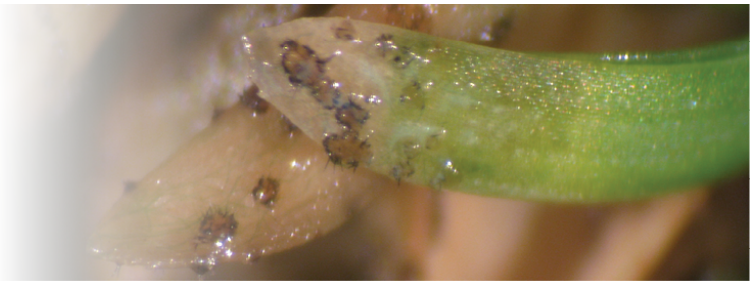
- Plant-parasitic nematodes adversely affect turfgrass health.
- Plant-parasitic nematodes are microscopic unsegmented roundworms, usually between 0.015 and 0.125 inch (0.25 and 3 mm) in length and are difficult to control.
- Plant parasitic nematodes debilitate the root system of susceptible turfgrasses and causes turf to be less efficient for water and nutrient uptake from the soil and make it much more susceptible to environmental stresses.
- Over time, turf in the infected areas becomes less dense and with severe infestations death may occur. The roots of turfgrasses infected by nematodes may be shortened and have very few, if any, root hairs, or they may appear dark and rotten.
- Turfgrasses usually begin showing symptoms of nematode injury as they experience additional stresses, including drought, extreme high or low temperatures, and wear.

Best Management Practices

- If nematode activity is suspected, an assay of soil and turfgrass roots is recommended to identify and determine the extent of the problem.
- The application of a nematicide on golf course turf should always be based on assay results.
- Reduce turfgrass stress by diverting traffic away from areas infected by nematodes.
- Increase mowing height to reduce plant stress associated with nematodes and minimize other stresses caused by insect pests, disease infections and weed infestations or abiotic stresses.

Pesticide Management

Regulatory Considerations



Pesticides are part of an overall pest management strategy that includes biological controls, cultural methods, pest monitoring, and other practices to maintain healthy and vigorously growing turf, 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 impacts on the environment and human health.

Principle

Pesticides contain active ingredients (the component of the product that targets the pest) and inert ingredients such as solvents, surfactants, and carriers. Pesticides are regulated by federal, state, and tribal laws because of environmental and human health concerns.

Best Management Practices

- Only apply pesticides that are registered for use in Arizona. This can be verified on the Arizona Department of Agriculture's webpage.
-
- Only apply pesticides that are legally registered for use on the site (i.e. do not apply pesticides labeled for agricultural crop uses or vegetation management even though they may contain the same active ingredient).
- Read the label and labeling and apply according to those directions.

Human Health Risks

Principle

Pesticides' toxicities vary greatly. 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 while the risk of a low toxicity pesticide may be high if there is a great amount of exposure.

Best Management Practices

- Select the least toxic pesticide with the lowest exposure potential.
- Know the emergency response procedure in case excessive exposure occurs (see emergency preparedness).
- Follow label instructions for Worker Protection Standards (WPS) when suing pesticides on nursery greens.
- Follow label instructions for protecting workers and animals during pesticide applications.
- Follow label instructions for re-entry to treated areas after applications when sprays have dried.

Environmental Fate and Transport

Principle

Environmental characteristics of a pesticide are normall found in 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 and use pesticides that have a low runoff and leaching potential. Arizona has established a groundwater protection list of active ingredients that may be prone to leaching into the groundwater.

  Groundwater Protection List

- Before applying a pesticide, evaluate the impact of site-specific characteristics (e.g. proximity to surface water; water table and well-heads; soil type; prevailing wind) and pesticide-specific characteristics (e.g. half-lives and partition coefficients, etc.).
- Select pesticides with minimal or reduced impact on pollinators.
- Select pesticides that, when applied according to the label, have no known effect on endangered species 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 located, designed, constructed, and operated.

Best Management Practices

- Store, mix, and load pesticides away from surface water or sites that directly link to surface water or groundwater.
- Store pesticides in a lockable concrete or metal building that is away from other buildings which allows fire department access and helps protect the other structures and the storage structure from other fires.
- Take into account local emergency planning requirements to help ensure the safety of emergency response personnel.
- Storage facility floors should be impervious and sealed with a chemical-resistant paint.
- Floors should have a continuous sill to retain spilled materials and no drains, although a sump may be included.
- Sloped ramps should be provided at the entrance to allow the use of wheeled handcarts for moving material in and out of the storage area safely.
- Shelving should be impervious and strong and made of sturdy reinforced metal.
- Metal shelving should be kept painted to avoid corrosion. Stainless steel shelving is preferred. Wood shelving should never be used, because it may absorb spilled pesticides.
- Automatic exhaust fans and an emergency wash area should be provided. Explosion-proof lighting may be required. Light and fan switches should be located outside the building, so that both can be turned on before staff enter the building and turned off after they leave the building.
- Avoid temperature extremes inside the pesticide storage facility. Heating and cooling will alleviate concerns for temperature extremes.
- Personal protective equipment (PPE) should be easily accessible and stored immediately outside the pesticide storage area.
- Do not transport pesticides in the passenger section of a vehicle.
- Never leave pesticides unattended during transport.
- Store and transport pesticides only in original containers.
- 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.
- Prominently post “Important Telephone Numbers” including CHEMTREC, for emergency information on hazards or actions to take in the event of a spill.
- Ensure an adequately sized spill containment kit is readily available.
- Designate a spokesperson who will speak on behalf of the facility should an emergency occur.
- Host a tour for local emergency response teams (for example, fire fighters, etc.) to show them the facilities and to discuss the emergency response plan. Seek advice on ways to improve the plan.

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.
- Accurate records provide and establish proof of use and follow-up investigation of standard protocols regarding:
    - Date and time of application (start and end times).
    - 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
- Submit pesticide application Form 1080 to the AZ Dept of Agriculture following all pesticides applications.

Sprayer Calibration

Principle

Properly calibrated application equipment for liquid or dry products is paramount to mitigating environmental and human health concerns. It assures proper coverage and applying the proper amount to save on expensive pesticide costs.

Best Management Practices

- Ensure that spray technician(s) is/are licensed, properly trained, and experienced.
- Minimize off-target applications and drift by using properly configured application equipment.
- Properly calibrate all application equipment at the beginning of each season (at a minimum) or after equipment modifications (nozzle changes, pressure adjustments, etc.).
- Check equipment daily for drips and leaks, pressures, spray patterns, etc. when in use.
- Use recommended spray volumes for the targeted pest to maximize efficacy.
- Calibration of walk-behind applicators should be conducted for each person making the application to take into consideration their walking speed, etc.

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 application equipment for the size of area being treated.

Inventory

Principle

Store as small of quantity of pesticides for as short of time period as possible. Adopt the “first in–first out” principle, using the oldest products first to ensure that the product efficacy remains at it highest.

Best Management Practices

An inventory of the pesticides kept in the storage building and the Safety Data Sheets (SDS) for the chemicals used in the operation should be accessible on the premises in case of fire or other emergency, but not kept in the pesticide storage room itself.

Shelf Life

Principle

- Pesticides can degrade over time. Do not store any 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. Mark the date of receipt on the product container. A simple spreadsheet can be a record of purchase date and each use date.
- Many states offer "amnesty" days to dispose of cancelled, suspended, and/or unusable pesticides that are being stored. Should products become no longer usable or unidentifiable, contact the Arizona Department of Agriculture about its annual unused pesticide disposal program.
- Ensure labels are properly affixed on every product container and products are in their original containers.
- Consult inventory when planning applications and before making purchases.

Leaching Potentials

Principle

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

The Arizona Departmental of Environmental Quality reviews and maintains a list of pesticides to protect groundwater.

Best Management Practices

- Understand pesticide sorption principles so that appropriate decisions can be made. Refer to the Arizona Groundwater Protection list for the active ingredients that are identified as having a greater leaching potential. Groundwater Protection List

- Understand site characteristics that may be causes for potential leaching losses (e.g. sand-based putting greens, coarse-textured soils, shallow water tables, bare ground).
- Read and follow label restrictions that may pertain to your facility that helps protect the environment.
- Avoid using highly water-soluble pesticides.
- Exercise caution when using spray adjuvants that may facilitate off-target or leaching into groundwater.

Mixing/Washing Station

Principle

Pesticide leaks or spills, if contained, should 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 pesticide mixing center.

Best Management Practices

- Loading pesticides and mixing them with water or oil diluents should be done over an impermeable surface (such as lined or sealed concrete), so that spills can be collected and managed.
- Mixing station surface should be smooth to provide for easier cleaning and the recovery of spilled materials. It should not be so smooth to cause a slipping hazard. A slightly sloped surface would help to recover spilled materials.
- The sump must be cleaned and dry at the end of each day. Liquids and sediments should also be removed from the sump and the pad. When a different pesticide or an incompatible product (i.e. one that cannot be legally applied to the same site) is to be used, clean the mixing/loading area thoroughly.
- Dispose of liquid rinsate and sediment materials by spraying on the site that was treated as you would a pesticide, strictly following label instructions.
- Absorbents such as cat litter or sand may be used to clean up small spills and then applied as a topdressing in accordance with the label rates or disposed of as a hazardous waste.
- Sweep up solid materials and use as intended.

Disposal

Principle

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

Best Management Practices

- Collect wash water (from both inside and outside the application equipment) and use it as a pesticide "make up" water in accordance with the label instructions. Usually the wash water should be applied on the site that was treated.
- The pesticide container rinsate should used as "make up" 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 (e.g. closed-loading systems) 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 at a minimum, the label required PPE for employees who work with pesticides including those who service pesticide application equipment.
- Most pesticides require wearing long pants, long-sleeved shirt, socks and shoes.
- Eye protection and dermal exposure are minimized by wearing goggles and proper impermeable gloves.
- Ensure that PPE is sized appropriately for each person using it.
- Make certain that PPE is appropriate for the pesticides being used.
- Ensure that PPE meets the needs of the job and is not just the least expensive. The label will provide guidance on the type of gloves required.
- Wash and store PPE where it is easily accessible but not in the pesticide storage area. Disposable PPE should not be reused.
- Employees who apply pesticides and wear facility uniforms or other PPE home should not contact children. Immediately wash separately any PPE or clothes exposed to pesticides.
- Provide laundering facilities or uniform service for employee uniforms.
- The federal Occupational Safety and Health Administration (OSHA) requires employers to do a health screening and a fit test for workers who must wear properly fitted respirators.
- Meet requirements for OSHA 1910.134 Respiratory Protection Program.
- Follow the Worker Protection Safety (WPS) requirements if a golf course has a nursery - a location from where plants are moved to be planted in another.

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 Arizona 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 upon emptying 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. Or offer the pesticide containers at recycling events or to a recycling facility.

Pollinator Protection

Regulatory Considerations

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 honey bees (*Apis mellifera*) are among 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, birds, and bats is important to the sustainability of agriculture.

Pesticides are products designed to control pests (e.g. insects, diseases, weeds, nematodes, etc.). Pesticides and other plant growth regulators, surfactants, and biostimulants are used in golf course turfgrass management. The non-target effect of pesticides 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.

Principles

- Pollinator-protection language is a label requirement found on pesticide labels; follow the label, it is the law.
- Many insecticide labels have “bee box” that describes specific instructions for use around bees and other pollinators.
- Pesticide applicators must be aware of honey bee toxicity groups and able to understand and know precautionary statements to follow specific instructions.
- Recordkeeping is required by law in order to use 1) restricted use pesticides, 2) products with active ingredients on the Arizona DEQ groundwater protection list (see Pesticide Managment Chapter), and 3) soil applied products, and 4) for the WPS rules that apply to nurseries on golf courses.

- IPM principles recommend that you keep records of all pest control activity so that you may refer to information about past pest problems or other situations to select the best course of action in the future.

Best Management Practices

- Proper records of all pesticide applications should be kept according to local, state, or federal requirements.
- Accurate records provide and establish proof of use and follow-up investigation of standard protocols regarding:
    - Date and time of application (start and end times).
    - 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
- Those applying pesticides, and who make decisions regarding their applications should know and follow pollinator protection label statements.
- Those applying pesticides should be aware of honey bee biology.
- Those applying pesticides should understand the various routes of exposure (outside the hive and inside the hive).
- Those applying pesticides should understand the effects of pesticides on bees.

Pollinator Habitat Protection

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 directions related to the application of pesticides during the plant's stage of growth (avoid spraying during bloom periods). Avoid applying pesticides during bloom season.
- Do not apply pesticides when pollinators are active. Spray when bees are not active in early morning or in the evening.
- Use coarse-droplet nozzles that provide adequate coverage and directs the sprays on to the target.
- Monitor the wind speed and direction to reduce and minimize off-target drift.
- Before applying a pesticide, scout/inspect the area for both harmful and beneficial insect populations and use pesticides only when a threshold of damage has been indicated.
- Mow flowering plants, including weeds before insecticide application. If flowering weeds are prevalent, control them before applying insecticides.
- Use insecticides that have a lower impact on pollinators.
- Use the latest spray technologies, such as drift-reduction nozzles to prevent off-site (target) movement of pesticide.
- Avoid applications during weather when dew is forecast.
- Use alternative cultural practices instead of spraying when possible.
- 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 habitats and/or enhance existing habitats.

Maintenance Operations

Regulatory Considerations

Equipment maintenance, fuels and lubricants, and turf protection chemicals and their storage can have an impact on water quality, the environment, and human health, on-site and off-site both during construction and during the maintenance of existing golf courses.

Local, state, and tribal regulations may be applicable for your site. Engagement among developers, designers, local community groups and permitting agencies is essential to designing, constructing, and sustaining a golf maintenance and storage facility that minimizes environmental impact and meets the needs for laws and regulations.

Storage and Handling of Chemicals

Principles

- Proper handling and storage of pesticides, fertilizers, and petroleum-based products are critical and important to reduce and limit risks of injury or death of an operator, employee, 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, tribal, and local regulations for specific requirements related to storage of chemicals.
- **Also see Pesticide Management Section.**

Best Management Practices

- Storage buildings should have appropriate warning signs and placards per applicable laws and regulations.
- Personal protective equipment (PPE) should be available to all personnel handling, mixing, loading, and applying chemicals.
- Follow all PPE statements on pesticide labels and other chemicals.

- Store PPE away from pesticide storage areas in a safe, protected area that is easily accessible.
- Develop an emergency response plan and educate all golf course personnel regarding emergency procedures on a regular basis.
- Individuals conducting emergency chemical cleanups should be properly trained under requirements of federal Occupational Safety and Health Administration (OSHA).
- Store pesticides in a lockable concrete or metal building that is well ventilated.
- Locate pesticide storage away from other buildings, especially fertilizer storage facilities.
- Floors of chemical storage buildings should be impervious and sealed with chemical-resistant paint.
- Floors of chemical storage buildings should have a continuous sill to contain spills and should not have a drain. A sump is acceptable.
- Shelving should be fabricated from plastic or reinforced metal. Metal shelving should be painted to avoid corrosion. Wood shelving should never be used because of its ability to absorb spilled pesticides.
- Automatic exhaust fans and an emergency wash area should be provided
- Explosion-proof lighting may be 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 separate from the storage room, but readily accessible on-site.
- Do not store large quantities of pesticides or chemicals for long periods of time. Follow a “first in, first out” principle to rotate products into use to ensure products do not expire. Purchase and use products as use as needed.
- Store chemicals in original containers. Never store them in containers that might be mistaken as packaging for food or drink.
- Arrange containers so the labels are clearly visible. Securely fasten loose labels to ensure containers and associated labels are kept together.
- Damaged labels should be replaced immediately.
- Store flammable pesticides separate from those that are nonflammable.
- Store liquid materials below dry materials to prevent leaks from contaminating dry products.
- Ensure that oil containers and small fuel containers (service containers) are properly labeled and stored within the facility.

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).
- When possible, replace solvent baths with recirculating aqueous washing units. Soap and water or other aqueous cleaners are often as effective as solvent-based products and present a lower risk to the environment.
- Always use appropriate PPE when working with solvents.
- Never allow solvents or degreasers to drain onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.
- Collect used solvents and degreasers in containers clearly marked with contents and date
- Schedule collections for disposal by a commercial service.
- Blow off all equipment with compressed air to reduce damage to hydraulic seals.

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

- Pesticides that have been mixed for application must be disposed of as waste and may be classified as hazardous waste depending on the materials involved.

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

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

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

Fueling Facilities

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

- Locate fueling facilities on roofed areas with a concrete (not asphalt) pavement. Areas should be equipped with spill-containment and recovery facilities.
- Use of above ground fuel tanks is preferred.

Pollution Prevention

Principles

- Plan appropriately to minimize the possibility of an elicit 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.
- Also see any other sections with respect to Planning, Design, and Construction; Irrigation; Surface Water Management; Water Quality Monitoring and Management; and Pesticide Management.

Best Management Practices

- Pesticides should be stored in a lockable concrete or metal building.
- Pesticide storage and mixing facility floors should be impervious and sealed with a chemical-resistant paint. Floors should have a continuous sill to retain spilled materials and no drains, although a sump may be included.
- For valuable information about constructing chemical mixing facilities, reference the Midwest Plan Service book, Designing Facilities for Pesticide and Fertilizer Containment (revised 1995); the Tennessee Valley Authority (TVA) publication, Coating Concrete Secondary Containment Structures Exposed to Agrichemicals (Broder and Nguyen, 1995); and USDA–NRCS Code 703.
- 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.
- FIFRA, Section 2(ee), allows the applicator to apply a pesticide at less than the labeled rate.
- The sump should then be cleaned of any sediment before another type of pesticide is handled.
- Discharge to a treatment system that is permitted under industrial wastewater rules.
- Never discharge to a sanitary sewer system without written permission from the utility.
- Never discharge to a septic tank.
- Use a closed-loop wash-water recycling system and follow appropriate BMP.
- Use non-containment wash water for field irrigation.
- Do not discharge non-contaminated wastewater during or immediately after a rainstorm, since the added flow may cause the permitted storage volume of the stormwater system to be exceeded.
- Whenever practical, replace 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.
- Blowing off equipment with compressed air instead of washing with water is often easier on hydraulic seals and can lead to fewer oil leaks.
- Grass-covered equipment should be brushed or blown with compressed air before being washed. Dry material is much easier to handle and store or dispose of than wet clippings.
- It is best to wash equipment with a bucket of water and a rag, using only a minimal amount of water to rinse the machine.
- Clean up spills as soon as possible.
- Keep spill cleanup equipment available when handling pesticides or their containers.
- If a spill occurs of a pesticide covered by certain state and federal laws, you may need to report any accidental release if the spill quantity exceeds the “reportable quantity” of active ingredient specified in the law.
- Large spills or uncontained spills involving hazardous materials may best be remediated by hazardous material cleanup professionals.
- For emergency (only) information on hazards or actions to take in the event of a spill, call CHEMTREC, at (800)424–9300. CHEMTREC is a service of the Chemical Manufacturers Association. For information on whether a spilled chemical requires reporting, call the CERCLA/RCRA help line at (800) 424–9346.
- Do not allow any wash water to flow directly into surface waters or storm drains.
- 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.
- Do not discharge wash water to surface water or groundwater either directly or indirectly through ditches, storm drains, or canals.
- Do not conduct equipment wash operations on a pesticide mixing and loading pad. (This keeps grass clippings and other debris from becoming contaminated with pesticide).
- Solvents and degreasers should be used over a collection basin or pad that collects all used material.

- Oil/water separators can be used but must be managed properly to avoid problems. Do not wash equipment used to apply pesticides on pads with oil/water separators
- 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 tha 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.
- Do not mix used oil with used antifreeze or sludge from used solvents. Antifreeze must be recycled or disposed of as a hazardous waste.
- 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.
- Lead-acid storage batteries are classified as hazardous wastes unless they are recycled. All lead-acid battery retailers in Florida are required by law to accept returned batteries for recycling.
- Spent lead-acid batteries must be recycled if they are to be exempt from strict hazardous waste regulations.
- Equipment used to apply pesticides and fertilizers should be stored in areas protected from rainfall.
- Pesticide application equipment can be stored 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.
- After cleaning them, puncture the pesticide containers to prevent reuse (except glass and refillable mini-bulk containers).
- Keep the rinsed containers in a clean area, out of the weather, for disposal or recycling.
- Storing the containers in large plastic bags/tubs to protect the containers from collecting rainwater.
- Recycle rinsed containers in counties where an applicable program is available, or take them to a landfill for disposal. Check with your local landfill before taking containers for disposal, as not all landfills will accept them.

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.

Planning

Start with assembling a team of qualified consultants. The team should have experience in working with golf course environments, maintenance practices and native landscape materials.

- Landscape Architect
- Golf Course Architect
- Golf Course Irrigation Consultant
- Agronomist
- Arborist
- Golf course superintendent

Species Selection and Size Considerations

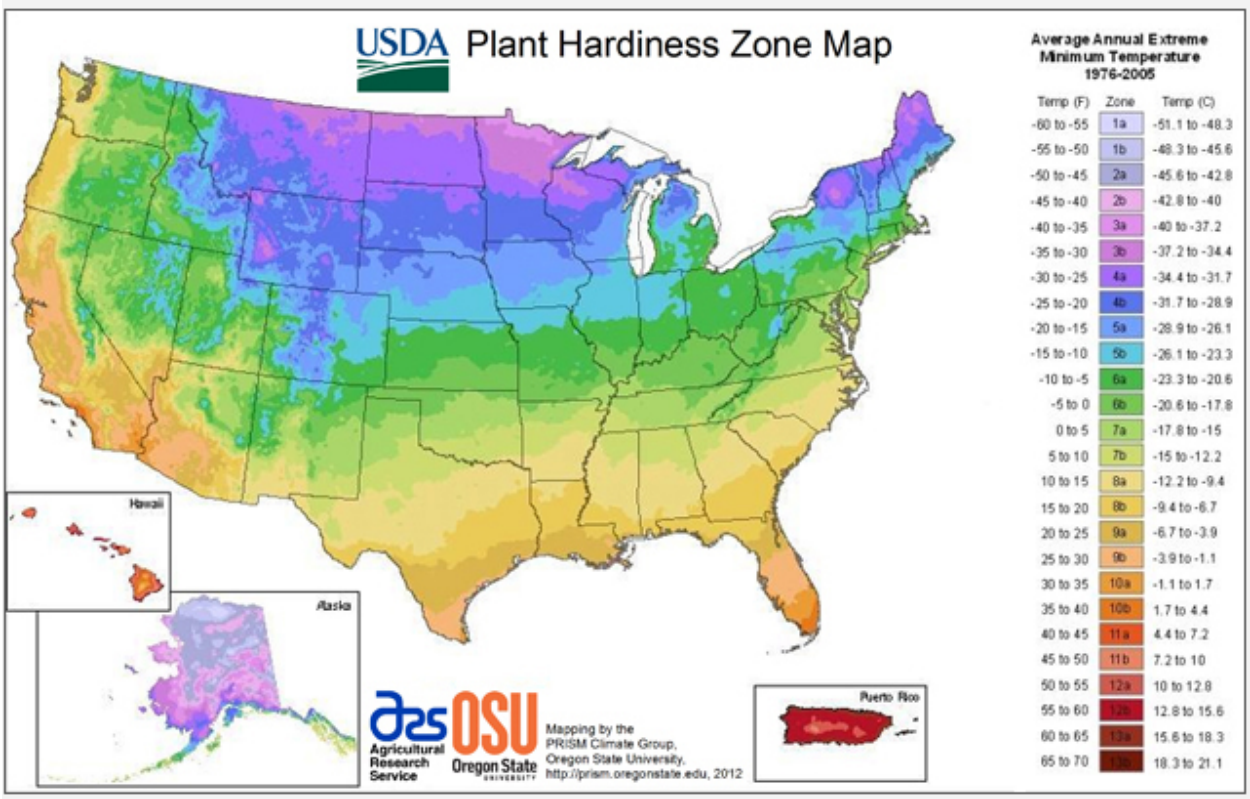
Principles

- The fundamental principle for the environmentally sound management of landscapes is “right plant, right place.” The ideal plant from an environmental standpoint is the one that nature and evolution placed there. It has adapted specifically to the soil, microclimate, rainfall, 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.
- Know and incorporate the associated blooming periods of plant material, as proper incorporation and layering can also enhance the aesthetic value/impact.
- 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. Most central Arizona soils in the deserts have less than 2% organic matter content.
- Plant species selection goal 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 (in terms of species, massing and density). 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.
- Observe and follow state, local, tribal laws and regulations for plant digging and relocation on properties.

Best Management Practices

- A plant selection process should match the surrounding natural ecosystem as practical, while meeting the needs of the golf course.
- Select trees, plants, and grass species to attract birds and wildlife 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.
- Place plants appropriately to utilize separately installed irrigation systems separate from the turf.
- Direct sprinkler heads away from trees that may interfere with irrigation coverage efficiency.
- Do not place valuable saguaro cactus or trees directly in the line of flight off tees.



Design and Function

Principles

- 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 detrimental effect that tree canopy and shade or other design features may have on the health and function of the turf.
- Garden plants, shrubs, ground covers, or native plants may provide a pleasing a view and also provide useful food, cover. color, or other aesthetic environmental benefits to wildlife; they may also require reduced maintenance.
- Trees and shrubs along streams provide temperature moderation with shade, which lowers water temperature in summer and increases it in winter. It also provides for better soil stabilization and erosion control along water courses.

Best Management Practices

- Well-designed forested or desert buffers should contain a mixture of fast- and slow-growing native trees, shrubs, and grasses to provide a diverse habitat for wildlife.

- Use forested or desert buffers to trap and remove upland sources of sediments, nutrients, and chemicals.
- Use forested or desert buffers to protect fish and wildlife by supplying food, cover, and shade.
- Use forested or desert 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 native grasses as a landscape element when and where appropriate.
- ReferenceADWR Low Water Use Drought Tolerant Plant List – Phoenix Active Management Area
- Other sources to consider: “Native Plants for Southwestern Landscapes” - Judy Mielke, 1993, “Landscaping with Native Plants in the Southwest” - George Oxford Miller, 2007, “Plants for Dry Climates” - Mary Rose Duffield and Warren Jones, 2001. There are certainly many others, but these (3) are very reliable resources for plant information used by professionals (specific to Arizona/Southwest).

Planting Methods

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 many years. Where these environmental factors have been modified, the challenge is finding other suitable plants. A 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 landscape 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 and organic matter content.
- Keep mulch materials away from plants and tree root flares to prevent excess dampness and potential disease development.
- Planting depth of should be not be excessively deep and sufficient to expose the root flares. The hole should be sufficiently deep to cover roots and backfilled with the same soil. Organic mulch materials are not recommended because decomposition will cause the plant to sink deeper.

Best Management Practices

- The plant palette and irrigation system should be appropriate for site conditions, taking into account that, in some cases, soil improvement can enhance water-use efficiency.

- Plants should be grouped together based on irrigation demand in addition to status relating to the permanent or temporary need for establishment (i.e. turning off perimeter or native revegetation zones after establishment at 1-2 years).
- The percentage of landscaped area in irrigated high-water-use hydrozones should be minimized. Local government ordinances should address the percentage of irrigated landscaped area that may be included in high-water-use hydrozones. These high water-use limits should not apply to landscaped areas requiring large amounts of turf for their primary functions (for example, ball fields and playgrounds).
- In most instances, established, drought-tolerant landscape plants have a root system substantial enough to keep them alive with little or no supplemental irrigation.
- Proper pruning and fertilizing will also benefit landscape plants while they are becoming established. Once established, shrubs and trees should be allowed to grow naturally and not be artificially shaped into “gum balls”.
- 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.

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, course superintendents and 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 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's personnel, including the services the facility provides to its customers and community.

- Incorporate quality management elements for continual improvement (plan, implement, check and monitor, and act and adopt) to reduce environmental and economic impacts.
- Understand that the irrigation pump is the largest user of energy. A well-engineered pump station is critical to reducing energy consumption. A pump station can account for up to 50 percent of a golf facilities energy use.

Best Management Practices

- Conduct an energy audit. A professional audit can reduce energy costs by 5% to 30%.
- Conduct a lighting audit.
- Conduct a carbon footprint analysis. Explore ways to decrease output and increase sequestration.
- Add insulation where needed.
- Use non-demand electrical hour rates by charging golf carts, pumping to acquire water, charging maintenance equipment, and high electricity users later in the day or early in the morning.
- Limit high-consumption activities during periods when demand is high.
- Use alternative energy from natural sources, such as solar, 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. Work with a golf course architect to determine out of play areas where turf can be removed and replaced with drought tolerant landscapes.
- Install LED lighting and/or retrofit devices.
- Install motion sensors for lights where appropriate.
- Install a programmable thermostat.
- Install solar/geothermal pumps for pools and spa.

Evaluation

Principles

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

Best Management Practices

- Monitor energy use by tracking data, evaluating billing meters, etc. ("You can't manage what you don't measure.")
- Install appropriate and 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 and cost-effectiveness.
- 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 and review the facilities last 12 months of energy bills.
- 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.

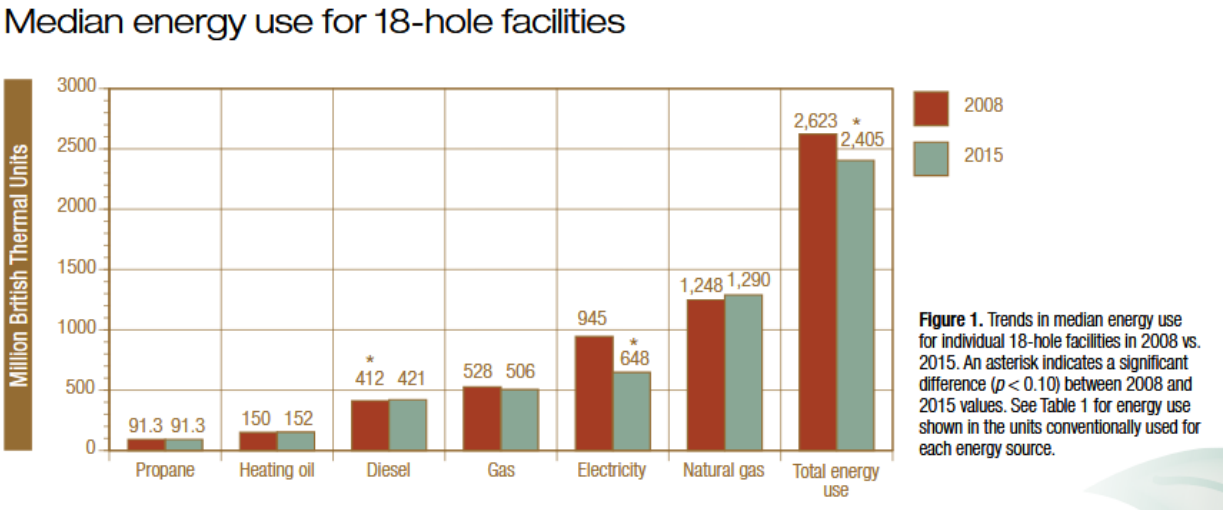


Figure 1. Trends in median energy use for individual 18-hole facilities in 2008 vs. 2015. An asterisk indicates a significant difference ($p < 0.10$) between 2008 and 2015 values. See Table 1 for energy use shown in the units conventionally used for each energy source.

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.
- Consider certification for facilities such as Green Building Council (Leadership in Energy and Environmental Design – LEED)

Implementation Plan

Principles

- Set goals for buildings/amenities and the golf course operation; develop an implementation plan. Communicate the plan with management, employees, members and guests.
- Set energy-use goals according to efficiency/conservation of the building, infrastructure and equipment efficiency. Goals could adjust or change, but they always should be at the forefront during decision-making processes.

Best Management Practices

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

Infrastructure

Principles

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

Best Management Practices

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

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. A list of energy incentive programs in Arizona is available at Department of Energy.
- Identify state/local programs and certification.
- Consider U.S. Green Building Council's LEED program. U.S. Green Building Council
- Consider EPA's EnergyStar, Portfolio Manager, etc. Energy Star
- 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. Buying local is less energy intensive.
- Evaluate energy acquisition and energy coming into the facility.
- Evaluate golf car equipment/operations and ensure proper selection, operation, charging, and maintenance.
- Incorporate training for employees.
- Incorporate the use of incentives.

Course Management Plan

Principles

- Set energy-use goals for efficiency/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. These include geothermal heating and cooling systems and small scale wind, solar and photovoltaic installations.
- 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.
- 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. These include geothermal heating and cooling systems and small scale wind, solar and photovoltaic installations.
- 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 (propane/electric), 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.

- Evaluate technology and upgrades; implement when feasible.

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(Note: URLs are as of September 2016)

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