TEXAS GOLF INDUSTRY

Best Management Practices Guide

Lone Star Chapter GCSAA

GCSAA
Golf Course Superintendents Association of America

INTRODUCTION

Texas, the largest state in the continental United States, is recognized for its rich history, agriculture, tourism, and a strong sense of American pride. There are more than 900 golf courses in the state, contributing over 98,000 jobs and $7.4 billion to the economy. Notable Texas golf courses include Whispering Pines, Dallas National, and Bluejack National. There are outstanding public courses such as the TPC San Antonio and unique municipal courses like Lions Municipal Golf Course, which is listed on the Registration of National Historical Places by the National Park Service. With nearly 1000 courses in the state, there are a myriad of options to choose from. The Lone Star Golf Course Superintendents Association (LSGCSA) is comprised of dedicated agronomists, golf maintenance professionals, industry partners, and educators who are responsible for the maintenance and sustainability of these golf courses throughout the state.

The LSGCSA encompasses five Texas GCSA chapters statewide, serving as a single, unified voice for providing education, resources, advocacy, and promoting best management practices. Texas superintendents are dedicated to providing high quality golf course facilities and healthy greenspaces for recreation, exercise, and environmental stewardship – with a goal to leave the land better than we found it. We take pride in the work we do and are committed within each of our communities.

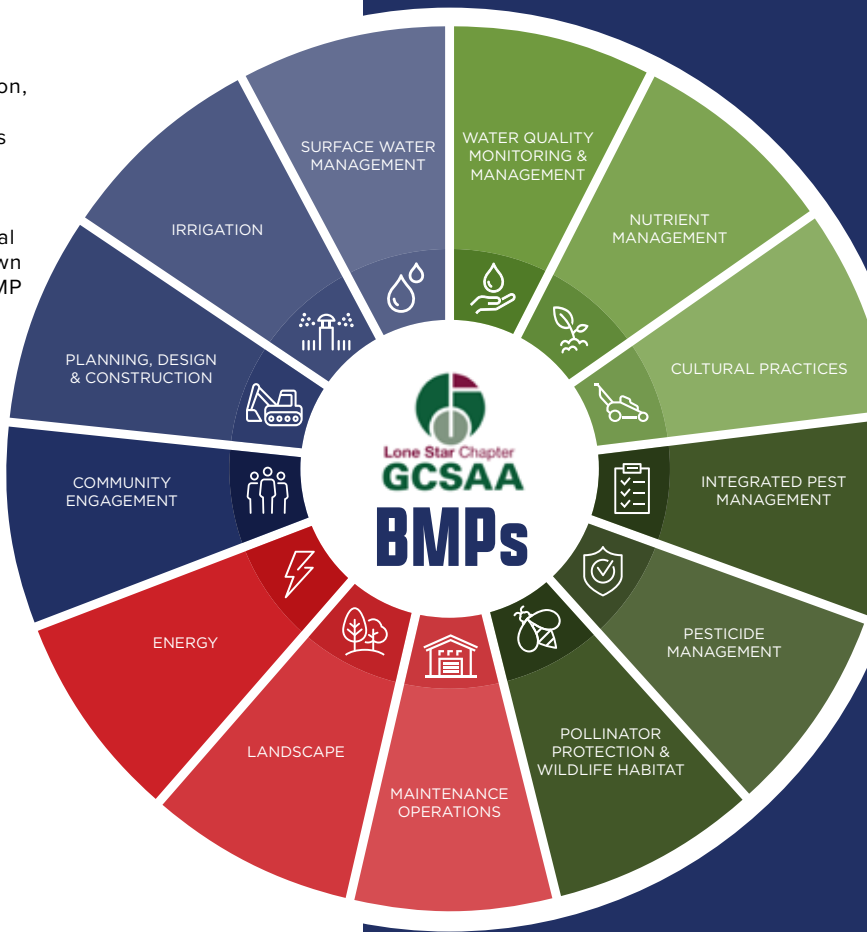
We developed this guide of best management practices (BMPs) to serve as operating standards for superintendents to strive toward and an educational resource for all stakeholders. The document details 13 sections ranging from community engagement to irrigation to water quality protection, pollinator protection, and wildlife habitat, in addition to others. Each section contains BMPs and regulatory considerations, as well as local resources for additional information.

This science-based educational tool will be integrated within the GCSAA online BMP tool, with the ultimate goal for each facility in the state lto develop and adopt its own site-specific BMP guide. Visit the Texas Golf Industry BMP Guide dedicated website at www.texasgolfbmp.org for future updates.

The guide was developed in collaboration with Radius Sports Group, a sustainability consulting firm, and has been reviewed by leaders in golf course management, construction, regulatory, and academic fields.

On behalf of the LGCSA, Texas superintendents statewide, our educators, and allied partners, we hope that this BMP guide will help demonstrate the Texas golf industry's leadership and commitment toward providing valuable ecosystem services, quality playing conditions, jobs, and economic impact for our State.

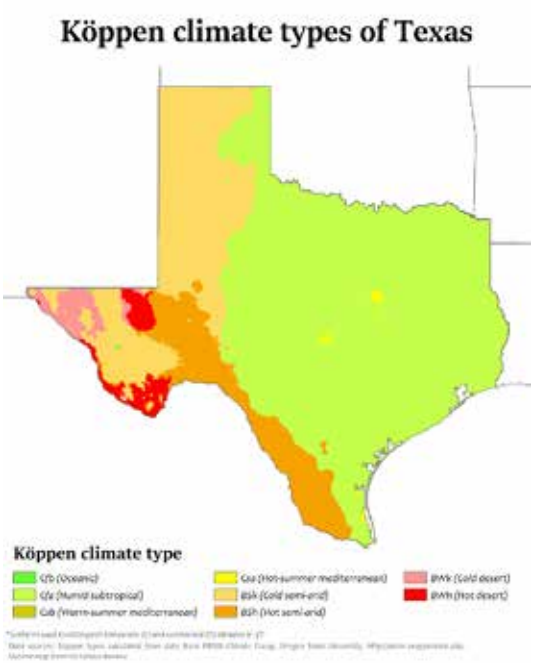
Sustainability is integrated throughout our BMPs in order to help guide golf courses in balancing performance and economic impact with environmental stewardship and community. Cities, regions, and communities have varying levels of sustainability planning; courses are encouraged to collaborate within their communities for continuous environmental improvement to make a positive impact today and in the future.



We share a strong sense of fellowship and are always striving for continuous improvement, helping each other out whenever we can. Sharing knowledge and resources are critical factors for contributing to sustainable golf course operations and environmental stewardship.

Texas Geography, Climate, and Soils

Texas is one of the most geographically diverse states in the United States, with forests, deserts, mountains, hills, prairies, canyons, and coastal plains. There are seven distinct geographical regions separated by different terrain. In the far west, Big Bend Country is known for being the only region in Texas with mountains. It displays typical characteristics of the American Southwest, with its rocky landscapes, vast deserts, and high elevations. Panhandle Plains is located in the northwest of the state and is filled with canyons carved out by rivers. The Prairies and Lakes region in central Texas has many lakes, forests, and gentle hills. The Easternmost region is Pineywoods, which has swamps and dense forests, and directly south of it is the Gulf Coast, known for its barrier islands, grasslands, and marshes. In the southwest, South Texas Plains is a blend of dry desert and countryside. Finally, right in the center of Texas is Hill Country, named after all of its hills, a distinct feature, along with natural springs and caves located there.



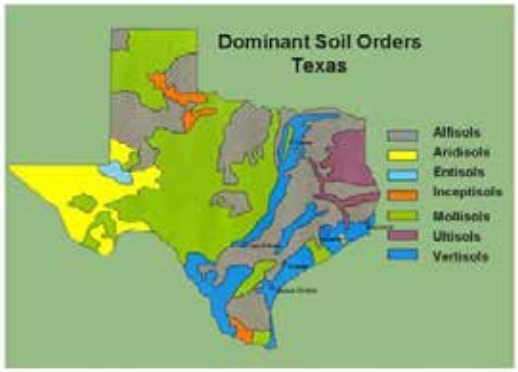
Texas Koppen Climate Zones

The state encompasses eight Köppen Climate Zones. Much of eastern Texas has a humid subtropical climate, characterized by hot summers, cool winters, and consistent precipitation year-round. Northwestern Texas is considered cold semi-arid, whereas southwestern Texas is hot semi-arid, with hot and dry summers. In the western part of the state, there are pockets of cold and hot deserts, with cold deserts being colder and receiving some snowfall in the winter.

Soil Orders of Texas

Throughout the world there are a total of 12 recognized soil orders. There are nine of these found within the state of Texas. Most Texas soils are classified into seven major soil orders: Alfisols, Aridisols, Entisols, Inceptisols, Mollisols, Ultisols, and Vertisols. There are also small areas of two other orders: Histosols and Spodosols. Texas has more than 1,300 soil series, with each classified into one of these nine orders. Understanding the unique topography and soils for a golf course is essential to healthy turfgrass and conservation practices.

Geography, climate, and soils create unique identities, benefits, and challenges for Texas golf courses. Golf course maintenance BMPs help promote stewardship of these lands, plant species and wildlife, and preservation of the state's natural resources.



Source: https://www.nrcs.usda.gov/

FOREWORD

GIB LEWIS
1504 SAN ANTONIO
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(512) 478-1881 • FAX (512) 478-1890

Texas is a state which boasts the biggest and the best and golfing is no exception. With over 900 courses in the state ranging from several top-ranked nationally to those listed on National Historical Places by the National Park Service, the Lone Star Golf Course Superintendents Association takes great pride and responsibility for the highest standard of maintenance of these state treasures.

I know you will be impressed with this Texas guide of best management practices as the gold standard for superintendents. It is an educational resource based on input from stakeholders detailing 13 topics that will allow golf course facilities to tailor their best management practices to fit their unique golf course. These topics range from design, to water quality and energy protection. This guide was produced with input from relevant stakeholders using science-based practices and agricultural advancements in the industry.

I commend the Texas superintendents statewide for their efforts of providing our golfers the best game possible while continuing to preserve and protect the beauty of our state and serving as environmental stewards for future generations of Texans.

Sincerely,

Gib Lewis

Gib Lewis
Texas House of Representatives 1977-1983
Texas Speaker of the House 1983-1993
Legislative Consultant, Texas Alliance of Recreational Organizations 1993-Present

BEN D. CRENSHAW

Some time ago, and I cannot remember where, I read that in ancient times, people used to judge a nation's wealth upon how healthy their grasslands were. This makes eminent sense to me, as it gives one a sense of sustainability and viability in order to provide food and water to feed its people.

I am a proud native Texan who realizes the importance of the study of sustaining the health of our turf, which of course, is near and dear to my heart both as a golfer and a golf course architect, but there is so much more to study in the ways of preserving our natural resources. Texas is a wide ranging combination of land, soil conditions, water, abundant wildlife and plant species. Texans know how to battle the elements! We have such fluctuations in our weather extremes.

Through the years, I have enjoyed talking with golf course superintendents, who are such hard working and dedicated professionals who ***never*** receive enough credit! I applaud the extensive efforts of the Lone Star Golf Course Superintendents Association to bring forward this 13 point *Texas Golf Industry Best Management Practices Guide*, which will serve our state well. The integration and study of the many aspects of these necessary tenants provides important goals which we must all strive for.

Let's take care of our golf courses, and our great state of Texas as well!

Sincerely,

Ben Crenshaw

ACKNOWLEDGMENTS

National Best Management Practices Planning Guide & Template developed by the GCSAA and USGA in partnership with the PGA TOUR. Funded through the EIFG.

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.

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

Special 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 BMPs 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”.

The LSGCSA would like to extend its gratitude to Radius Sports Group for its expertise in developing the BMP guide and to everyone who contributed time, knowledge, and resources. Thank you to superintendents and contributors across the state who provided photo contributions.

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Southern Texas Professional Golfers’ Association

Texas A&M AgriLife Extension Service

Texas Alliance of Recreational Organizations

Texas Commission on Environmental Quality

Texas Department of Agriculture

Texas Golf Association

Texas Lone Star Chapter, Club Management Association of America

Texas Parks and Wildlife

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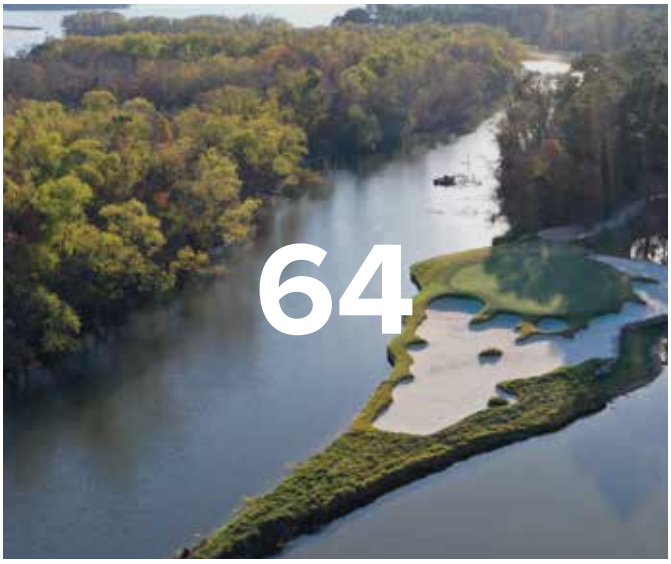
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01

COMMUNITY ENGAGEMENT

First Green Program

The golf industry is noteworthy for its commitments to philanthropy and charitable giving. The We Are Golf coalition estimates that courses contribute $3.9 billion nationwide in charitable giving. Golf courses also provide venues for charity events and golf tournaments. The Texas GCSA chapters are known for important contributions of service and volunteerism to communities throughout the state.

Texas GCSA chapters have helped numerous charitable organizations including:

- The Wounded Warrior Project
- Sticks for Kids
- Toys for Tots
- Various children's hospitals
- Rounds for Research
- First Tee Organizations

Each year, Texas superintendents participate in Patriot Golf Day which generally raises millions for Folds of Honor and funds more than 1,400 scholarships. Folds of Honor raises scholarship money for children of disabled and fallen American soldiers to honor their service to the country. PGA HOPE has also been added as a partner to help serve the needs of veterans and their families through the game of golf.

★ Thousands of small and local charities and fundraisers are supported each year by local golf facilities either donating either their golf facility to host or sponsor a fundraising event or by donating rounds of golf or golf merchandise to be auctioned or raffled to raise funds for the charity.

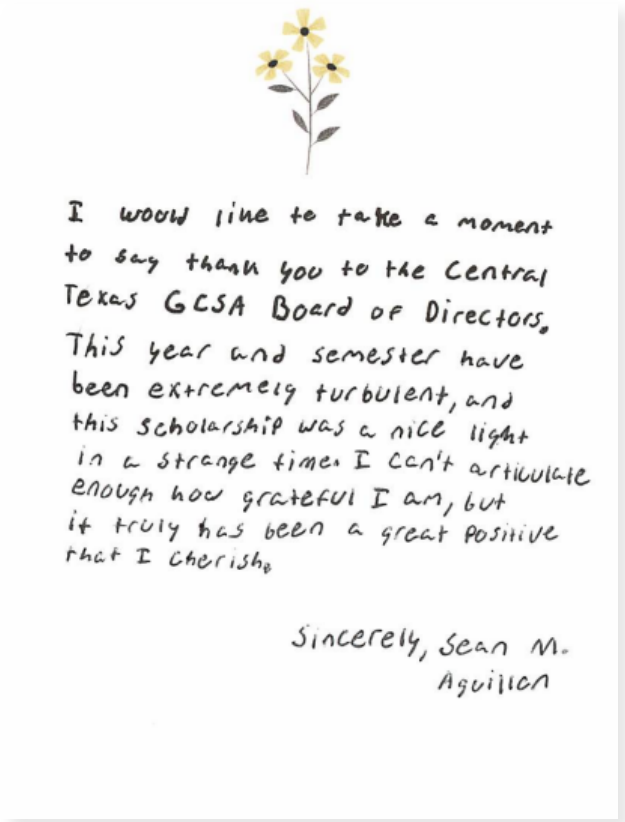
Effective community engagement brings together neighbors, local stakeholders, and nearby golf courses, building trust through mitigating conflicts, encouraging participation, and optimizing resources. To foster community well-being and environmental health, superintendents should aim to create relationships that allow for communication between golf courses and community members, customers, legislators, regulators, and civic leaders. Superintendents should meet with legislators regularly to discuss environmental, economic, and health-related legislation through participation in events like National Golf Day.

Best Management Practices

- Conduct stakeholder mapping to understand who to best engage in outreach efforts
- Identify what is important to each stakeholder
- Identify community values and principles
- Establish engagement targets, goals, and desired outcomes
- Understand the importance of building trust
- Plan engagement efforts, strategies, and methods of communication

Additional information on community engagement: https://extension.psu.edu/understanding-community-engagement

First Green Program



I woow like to take a moment to say thank you to the Central Texas GCSA Board of Directors. This year and semester have been extremely turbulent, and this scholarship was a nice light in a strange time. I can't articulate enough how grateful I am, but it truly has been a great positive that I cherish.

Sincerely, Sean M. Aguilar

Community Safety and Coronavirus

Sometimes golf course play has to be adapted to ensure public safety during times of crisis, like during a natural disaster and pandemics. Creating recreational opportunities is still important to health and community morale, so BMPs were developed to reduce certain risks for the safety of the community.

It is important to adhere to local, state, and federal guidelines from the Center for Disease Control and Prevention (CDC):

https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html

https://www.dshs.state.tx.us/coronavirus/

Best Management Practices

- Removal of ball washers, bunker rakes, and most trash cans
- Use pool noodles or PVC or EZ Lift devices to limit golf ball settling in cup
- Single rider golf carts
- Sanitation programs to kill virus
- Manual clocking in of staff
- Staggering start times to limit exposure
- Maintain minimum of six feet of social distancing
- Wash hands frequently with soap and water for a minimum of 20 seconds
- Wear masks as required

Additional resources related to golf club operations:

https://www.txga.org/covid-19-resource-hub/

https://wearegolf.org/back2golf/

02

PLANNING, DESIGN & CONSTRUCTION

Environmental, economic, and site suitability factors must be carefully considered in the development or renovation of a golf course. There are opportunities to maximize sustainability and energy efficiencies through proper design, planning, and building. Care should be taken to preserve and protect the natural environment, including natural resources, native plants, and wildlife.

Each project is different, this document is not intended to create a blanket standardization of golf course development. BMP guidelines provide a framework for strong, well informed decision-making. The needs and vision for every course location and site will be different; this document provides general guidance; all parts may not be applicable to all situations.

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.

Regulatory Considerations

Before initiating any construction, it is important to seek expert advice to understand permitting and regulatory requirements at the federal, state, and local levels. The scope or limits of the project can be adjusted in order to reduce the permitting process, as these will vary depending on both scope and location.

The first consideration in developing a new golf course should be whether or not the property is zoned for a golf course development, as the lack of appropriate zoning can significantly stretch the permitting timeline or even block the project altogether. A new course project must comply with all environmental regulation permits for the locality, such as a general environmental review, water withdrawal, and wetland impacts. For renovation projects, meeting with an environmental consultant can help identify permitting requirements early on in the project.

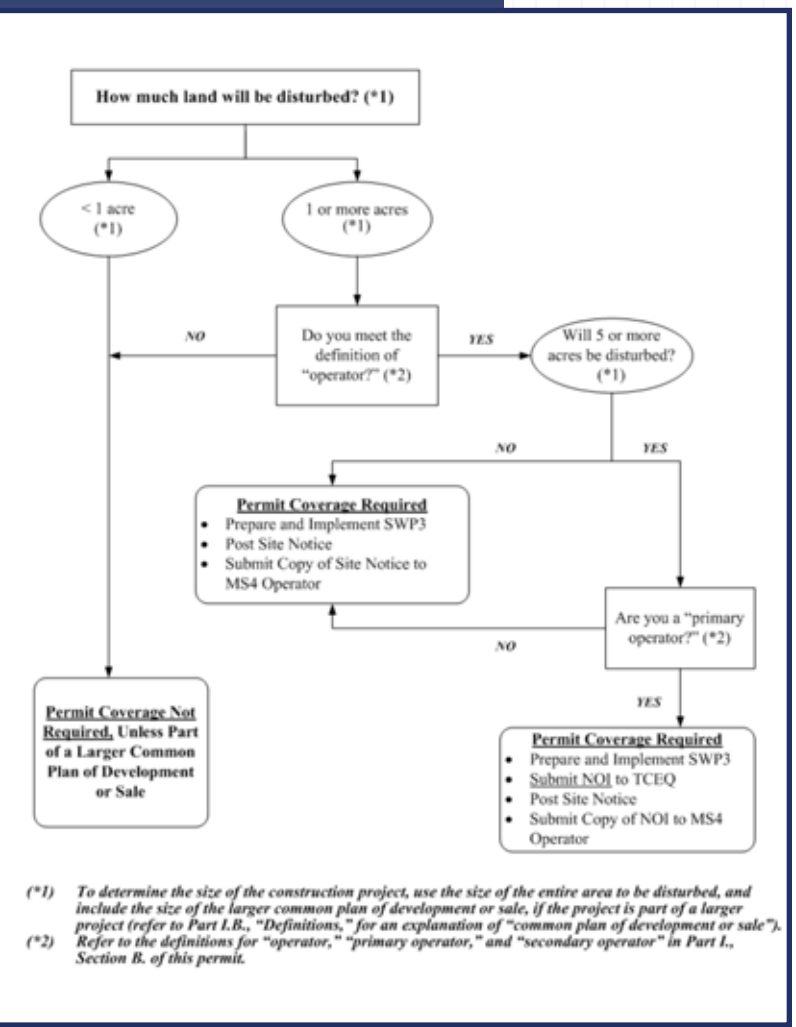
Permits from local, state, and federal agencies typically include general and project-specific conditions that must be followed. Approved permit plans and conditions should be provided to all contractors prior to bidding. Compliance throughout the project is generally monitored by the golf course superintendent or permitting consultants.

Flow Chart to Determine TCEQ Permit Requirements, Based on Disturbed Acreage

The TCEQ has developed a flow chart to determine what permits are required for construction activities related to the Texas Pollutant Discharge Elimination System (TPDES) and discharges of stormwater runoff.

Additional information:

https://www.tceq.texas.gov/assets/public/permitting/stormwater/txr150000-cgp.pdf



General Construction and Stormwater Permits

Stormwater management planning is necessary to ensure sediment controls are in place during construction and ensure that runoff from the course doesn't impact adjacent properties and waters.

Any discharge of stormwater associated with construction must be permitted unless in a waivered context. Determination of permit requirements, applications, and requests for further information on the Stormwater General Permit for Construction Activities should be directed to Texas Commission on Environmental Quality (TCEQ).

https://www.tceq.texas.gov/agency/water_main.html

Floodplains

Most man-made changes to land in the floodplain require a permit, including but not limited to development of buildings or other structures, mining, dredging, filling, grading, paving, excavation or drilling operations or storage of equipment or materials. Regulators will seek to insure there is no net loss in floodplain area on the site. Be sure to check with local municipalities for permitting requirements.

https://www.tsswcb.texas.gov/programs/flood-control-program

Wetlands

It is illegal to drain or fill any Texas wetland without a permit from the U.S. Army Corps of Engineers, which is reviewed and administered by the TCEQ; the Texas coast is under the jurisdiction of the Corps' Galveston District Office. At the federal level, wetlands are protected under the Clean Water Act (CWA) and activities are overseen by the U.S. Army Corps of Engineers (USACOE), Environmental Protection Agency (EPA), in addition to potential involvement from the U.S Fish and Wildlife Service (FWS), National Oceanic and Atmospheric Administration (NOAA), and maritime agencies. Wetlands may also be protected by local regulations or ordinances. It is critical to identify any wetlands, vernal pools, coastal zones, water bodies, intermittent streams and rivers prior to commencing planning for a new site or site extension.

https://www.tceq.texas.gov/permitting/401certification

https://texaswetlands.org/about/wetlands-protection/

https://tpwd.texas.gov/landwater/water/habitats/wetland/

Surface Waters

Surface water in Texas is owned by the state and held in trust for the citizens of the state. The right to the use of state water may be acquired by appropriation. The Water Rights Permitting Application must be submitted through the Texas Commission on Environmental Quality (TCEQ). Before diverting Texas state water, a declaration of intent must be made and approved by the watermaster of the designated Water Division.

https://www.tceq.texas.gov/permitting/water_rights/wr-permitting/wr_applications.html#process

https://www.tceq.texas.gov/assets/public/permitting/forms/10214a.pdf

https://statutes.capitol.texas.gov/Docs/WA/htm/WA.11.htm#11.325

Watershed Protection Plans

The TCEQ assesses Texas waters and prepares a water quality report including identification of impaired waters via the Texas Integrated Report for Clean Water Act 305(b) and 303(d). The Texas Soil & Water Conservation Board (TSSWCB) initiates implementation of associated Watershed Protection Plans (WPPs) to address water quality protection of Texas waterbodies and to restore impaired waters. There are 216 local Soil and Water Conservation Districts (SWCDs) which work with local stakeholders to promote stewardship and conservation efforts in support of WPPs. These plans and implementation efforts are aligned to EPA Guidelines in support of the CWA.

https://www.tceq.texas.gov/waterquality/assessment

https://www.tsswcb.texas.gov/programs/texas-non-point-source-management-program/watershed-protection-plan-program

Coastal Permits

Any construction or renovation work within coastal, tidal, or navigable waters must consider issues of coastal resilience. In Texas coastal management is the responsibility of the Texas General Land Office (GLO). Works which are likely to impact any of the following coastal areas must be conducted in line with the Coastal Management Plan and will be subject to permitting.

- Coastal Barriers
- Coastal Historic Areas
- Critical Erosion Areas
- Gulf Beaches
- Submerged Lands
- Submerged Aquatic Vegetation
- Coastal Preserves
- Coastal Shore Areas
- Hard Substrate Reefs
- Oyster Reefs
- Tidal Sand or Mud Flats
- Waters of Gulf of Mexico
- Coastal Wetlands
- Critical Dune Areas
- Special Hazard Areas Waters Under Tidal Influence

https://www.glo.texas.gov/coast/coastal-management/permitting/index.html

Rare and Endangered Species

Texas Parks and Wildlife Department (TPWD) regulates the taking, possession, transportation, or sale of any of the animal species designated by state law as endangered or threatened without the issuance of a permit. State laws and regulations prohibit commerce in threatened and endangered plants and the collection of listed plant species from public land without a permit issued by TPWD. Some species listed as threatened or endangered under state law are also listed under federal regulations.

https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/listed-species/species-protection.phtml

Planning, Design & Construction:
Internal and External Stakeholders

- Owners and/or Capital Manager
- Golf course architect
- Golf course superintendent
- Agronomist
- Civil engineer
- Irrigation designer & engineer
- Landscape architect
- Clubhouse architect
- Ecologist
- Entomologist
- Biologist
- Geologist
- Soil scientist
- Environmental engineer
- Archaeologist
- Cultural advisory team
- Land planner
- Golf course builder
- Energy analyst
- Resource management team
- Turfgrass consultant
- Economic advisor
- SWCD representative
- Water management expert
- Legal team

Planning

Proper planning provides the opportunity to integrate environmental and aesthetic characteristics of a property and minimize costs from unforeseen construction requirements. As a first step, define SMART (specific-measurable-attainable-relevant-timebound) objectives before starting any planning process. A feasibility study should be completed to identify:

- Site needs, resources, obstacles, strengths, weaknesses
- Potential ecological and cultural impacts
- Any possible resistance to development
- Timeframes
- Forecast costs
- Accessibility to resources and water sources
- Energy demands and availability
- Local, state, and national regulations or restrictions
- Expected return on investment
- Labor requirements

Once all feasibility study data has been collected, assess whether needs are feasible given existing resources and select a site that can achieve the needs and objectives of stakeholders.

Professional, experienced judgement is crucial when applying BMPs in the planning, design, and construction phases of the project. The implementation of a golf course project will typically benefit from the use of professional consultants familiar with similar requirements. A strong project team should be assembled with qualified internal and external stakeholders. Most projects commence with engaging a qualified golf course architect, a civil engineer, an environmental consultant, other consultants, and owner's representatives. The golf course architect and civil engineer may be helpful in assembling the permitting team. An experienced golf course superintendent is also integral to the planning process for any golf project.

Golf course superintendents should be engaged in all phases. For renovation projects superintendents bring extensive knowledge of the site which is critical to determining the most appropriate design and informing the design team of issues that may impact maintenance of the course or player enjoyment of the facility. The superintendent's knowledge of the BMPs and direct participation in planning and construction greatly affect the success of the project.

Best Management Practices

- Comply with Federal, Texas, and municipal laws and regulations.
- Assemble a qualified team with expertise in golf course development and environmental permitting. Include qualified internal and external stakeholders, the golf course superintendent, and an experienced project manager.
- Involve a qualified golf course superintendent/project manager at the beginning of the process to integrate sustainable maintenance practices in the development, maintenance, and operation of the course.
- Determine SMART objectives and complete a feasibility study of the project to evaluate whether existing resources are sufficient for identified needs.
- Before any planning starts, identify wetland boundaries, vernal pools, coastal zones, waterbodies, intermittent streams and rivers. These should be flagged and mapped in accordance with local, Texas, and federal regulations due to potential permit requirements.
- Consider available water for irrigation; power supply access and energy demands; cost and availability of materials (such as root zone mix or bunker sand); maintenance needs; regulatory requirements and restrictions.
- Contact the water supplier seeking suggestions to comply with water quality standards and BMPs so watersheds and/or aquifers are protected.
- Consult with TCEQ on Stormwater Pollution Prevention Plan
- Identify rare, protected, endangered, or threatened plant or animal species on the site. For a Texas-specific species list by county, reference: https://tpwd.texas.gov/gis/rtest/
- Archaeological awareness of the site and surrounding area should be considered.
- All golf-courses, new or existing, should have a Master Plan, focused on the long term, which ties together phased projects over time with a single vision in mind.

Archeological and Native American Land Rights

It is essential to consider any archeological or Native American land access or use restrictions before, during, and after construction and renovation projects. It is important to understand and respect cultures and traditions, including preservation of existing archeological finds, historic sites, and areas of cultural significance.

Texas is home to three federally recognized American Indian tribes:

- Alabama-Coushatta Tribe (Livingston, TX)
- Kickapoo Traditional Tribe (Eagle Pass, TX)
- Ysleta del Sur Pueblo (El Paso, TX)

Additional information:

http://www.native-languages.org/texas.htm

Contractor references for cultural resource investigations:

https://counciloftexasarcheologists.org/Contractors-List

Greenspace provided by golf courses helps reduce the urban heat island effect, supports ecosystem function, and provides wildlife habitats.

Access to Resources

After defining project objectives, it is important to prepare an existing conditions plan, identifying property boundaries, topography, vegetation limits, roads, wetlands, and other jurisdictional areas. This plan is a critical tool in preparing a project to avoid environmental harm and to determine the feasibility of achieving project goals. The development of a constraints plan, along with identification of a suitable water source (for new courses) may determine that a site is unsuitable for the intended golf course project before expensive planning and permitting has begun.

Sensitivity to Plant and Animal Species

It is essential that protected, endangered, or threatened plant or animal species are identified on the site. The US Fish and Wildlife Service can be consulted to identify species federally protected under the Endangered Species Act, together with rare and endangered species identified per Texas statute. A long-term protection plan should be developed which preserves, promotes, or expands critical habitat.

Wildlife habitat requirements (food, water, cover, space) should be identified and assessed with operations implemented to preserve wildlife habitat and migration corridors. Cart paths and crossings should be located to minimize environmental impact and accommodate wildlife movement.

Birdhouses, bat houses, nesting sites, and beehives should be constructed in out-of-play areas together with butterfly gardens which can also be established around the clubhouse. Riparian buffers along waterways should be retained to protect water quality and provide food, nesting sites, and cover for wildlife. Nuisance and exotic/invasive plants which are identified as pests should be removed and replaced with native species adapted to the site, based on site needs and preference. Minimize stream or river crossings to protect water quality and preserve stream banks.

Reference Pollinator Protection and Wildlife Habitat, Landscape, and Surface Water Management sections for additional BMPs.

Texas Rare and Endangered Species

Threatened

- Horned Lizard
- Bald Eagle
- Texas Tortoise
- Louisiana Pine Snake
- Texas Kangaroo Rat
- Alligator Snapping Turtle
- Black Bear
- Indigo Snake

Endangered

- Golden Cheeked Warbler
- Kemps Ridley Sea Turtle
- Aplomado Falcon
- Ocelot
- Red Wolf
- Houston Toad
- Black Capped Vireo
- Grey Wolf
- Jaguarundi

Protected Birds

- Red-tailed Hawk
- Red-shouldered Hawk
- Turkey Vulture
- Grey Horned Owl
- Scissor-Tailed Flycatcher
- Cardinal
- Indigo Bunting
- Black-Necked Stilt
- Blue Jay
- House Finch
- Tufted Titmouse
- Painted Bunting
- Green Jay
- Whooping Crane
- Roadrunner
- American Kestrel
- Tri-coloured Heron
- Brown Pelican
- Roseate Spoonbill
- Black Skimmer
- Great Blue Heron

For fish, reference: https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/listed-species/fish.phtml

For additional information, reference:

https://tpwd.texas.gov/education/hunter-education/online-course/wildlife-conservation/threatened-endangered-and-protected-animals

https://www.fws.gov/endangered/

Design

Golf course design should minimize impacts to sensitive environmental issues that have been identified during the site review and initial planning. Proper design will meet the needs of stakeholders, protect the location's environmental resources, and be economically sustainable. If impacts are unavoidable, the design should identify the level of impact and address how future golf course use and maintenance will be managed to reduce adverse effects. For example, relocation of trees and/or planting of native plants.

Existing foliage should be enhanced wherever possible through supplemental planting of native materials and vegetation along fairways, out-of-play areas, and water sources supporting fish and other water-dependent species. Exotic plants, together with invasive or nuisance species should be replaced with native species which are adapted to the site.

Best Management Practices

- Design to minimize or eliminate alteration of existing native landscapes and retain natural site characteristics. The plans should review different design options and select the plan that best meets the objectives with the least disturbance.
- Plant only certified turfgrass; select a species that meets needs of stakeholders and the site.
- Design out-of-play areas to retain or restore existing native vegetation where possible.
- Invasive plants should be removed and replaced with native species adapted to the site.
- Consider implementing increased plant diversity into the site to improve habitats.
- When planning golf cart paths or other areas with potentially high vehicle traffic, try to predict the effect the trail's layout could have on vegetation (e.g., running over vegetation due to sharp turns) or the layout of the irrigation system.
- Ensure that proper permitting has been obtained before disturbing any tidal or non-tidal wetland or the regulated buffer zone.
- For any type of work that would involve wetlands, reference state and municipal information.
- Before commencing any work in or around wetlands make sure these have been properly delineated by a professional consultant and approved by the regulatory agency.
- Water conservation and quality should be an integral part of the design goals, incorporating low maintenance areas and native or drought tolerant vegetation and managing stormwater flows.
- Have engineering, architect, construction team and golf course superintendent focus a significant amount of time on properly sizing drainage on and around the golf course property.
- Design to maximize play and minimize negative environmental impact.
- Design irrigation systems to minimize water use, drift, or overspray.
- Understand the latest irrigation technology available to use and water most efficiently.
- Consider potential wear patterns in turfgrass areas and create adequate space for ingress/egress at greens, tees, fairways, and bunkers.
- Conduct a shade study on all green complex areas as well as tees, plan accordingly so highly maintained turfgrass areas get adequate sunlight.

Selecting Turfgrass

The principle of “right plant, right place” should be adhered to when selecting a turfgrass species that meets stakeholder needs. A research green or turfgrass research plots can be used to trial desired species and cultivars for density, color, and tolerances. The decision to use one cultivar or multiple versions should consider whether the maintenance team will be able to keep the greens pure and uncontaminated for the long-term. Usually, single species selection is more cost-effective. The approach surrounds, tees, fairway, and rough height-of-cut are usually determining factors. It is important to keep up to date with turfgrass propagation and cultivation restrictions and ensure only certified species are planted.

It is a good idea to seek advice from a USGA agronomist or a turfgrass consultant when deciding which varieties of grass to use. This decision should be based on an evaluation of soil conditions, watering capabilities and the expected level of maintenance. USGA research can aid with selecting drought and disease resistant cultivars. Another reference includes the National Turfgrass Evaluation Program for help with cultivar selection: https://ntep.org/

Common Texas Turfgrass Species

Warm-season species	Cold-season species
Bermudagrass	Annual ryegrass
Buffalograss	Creeping bentgrass
Centipedegrass	Fine fescue
Seashore paspalum	Kentucky blugrass
St. Augustinegrass	Perennial ryegrass
Zoysiagrass	Tall fescue

Additional information:

https://aggieturf.tamu.edu/texas-turfgrasses/

https://agrilifeextension.tamu.edu/library/landscaping/turfgrass-selection-for-texas/

Determining Factors in Selecting Best Turfgrass Species

- Climate
- Water usage
- Water quality
- Adaptation
- Drought tolerance
- Salinity tolerance
- Pest & disease susceptibility
- Fertility requirements
- Color
- Shade tolerance
- Seedhead production
- Cost to plant (seed vs. sprigs)
- Patented rights
- Cost to maintain

Texas Wetland Definition

An area (including a swamp, marsh, bog, prairie pothole, or similar area) having a predominance of hydric soils that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support and that under normal circumstances supports the growth and regeneration of hydrophytic vegetation.

Source: Texas Water Code, Sec. 11.502: https://texas.public.law/statutes/tex._water_code_section_11.502

Wetlands

Wetlands provide critical habitats for plants, fish, and wildlife. They also provide protection from flooding and improve water quality, while providing scenic beauty and recreation. Texas has lost more than half of this habitat in the past 200 years with areas being drained, filled, or used as dumping grounds. Wetlands can be difficult to recognize as they may only have water in them part of the time, but there are millions of acres of wetlands, of varying types, across the state.

When incorporated into a golf course design, wetlands should be maintained as preserves and separated from highly managed turfgrass areas with native vegetation or structural buffers. Constructed or disturbed wetlands may require a permit to be an integral part of the stormwater management system. Boundaries for wetlands are field located by qualified specialists who take soil borings and review the plants to make the determination. Proposed work adjacent to streams and rivers is also highly regulated. A professional consultant should be used for the design of the project and to ensure correct permitting.

Additional information on wetlands in Texas:

https://tpwd.texas.gov/publications/pwdpubs/media/pwd_bk_k0700_0908.pdf

https://tpwd.texas.gov/landwater/water/habitats/wetland/

https://texaswetlands.org/about/wetlands-protection/

Floodplains

Around 12 percent of Texas' state land area is mapped floodplain and there are flood-prone areas identified in most counties, towns, and cities across the state. Regulations have been enacted to reduce the potential for downstream or coastal flooding, to protect people and property, and to reduce future flood losses.

A golf course can be a compatible use of a floodplain zone, dependent on the frequency and severity of flooding. When persistent floods result in course closures, turfgrass loss, and significant sediment removal and bunker repair then use of the floodplain for golf may not be sustainable without improvements. Where elevating features is proposed to make them less susceptible to floods, the volume of fill installed must be balanced by lowering an equal volume of nearby ground at the same elevation to compensate for the loss in flood zone volume.

Additional information on floodplain management in Texas:

https://www.twdb.texas.gov/flood/resources/doc/Texas_Quick_Guide.pdf

Water Access and Management

Prudent water management considerations with golf course design and construction can help balance aesthetic and playability requirements with water conservation. Surface water in Texas is owned by the state; permitting must be submitted to the TCEQ for use of Texas water and annual usage reporting is required by March 1 each year. When the right to use state water is lawfully acquired, it may be taken or diverted from its natural channel. Requests must be formally made to designated Watermasters of the Water Division.

Reference the Irrigation, Surface Water Management, and Water Quality Monitoring and Management sections for additional BMPs

Greens, Fairways, Tees, and Bunkers

Certified turfgrass cultivars for all areas of the golf course should be selected based on site evaluations and climate conditions. Work with the architect to determine total greens size. Green size should be designed to allow for enough hole locations and space for traffic, while remaining sustainable using available resources. Install yardage reference points for consistency when selecting hole locations. Sand base for the greens and future topdressing sand should be from the same sand source. Select an appropriate root-zone material that meets USGA established material protocols.

Select locations for greens and fairways which have adequate sunlight to meet plant-specific needs and sufficient drainage. Greens should be irrigated separately from surrounding turfgrass. Consider landing areas when working with the architect to determine fairway size for each hole; also define play and non-play maintenance boundaries. For ingress-egress of the holes, include multiple spots of entry to get on fairway and ensure there is plenty of space for wear.

For tees and approaches, select a size large enough to accommodate traffic and divot recovery. Par-three tees typically need more square footage than par-four and par-five tees. Consider 250 square feet of teeing ground per 1,000 rounds of golf on par-three tees and 150 square feet per 1,000 rounds on par-four and par-five tees and fives. Understand the long-term objective of play levels to help determine the projected space requirements.

Bunker placement should be considered in relation to circulation patterns at greens so as not to concentrate turfgrass wear, while keeping with golf course design considerations. All bunkers require suitable entry and exit points. The size, number, and style of bunkers including angle of repose for selecting the proper sand should be considered during design as these factors relate to resources available for daily maintenance. Select the proper color, size, and shape of bunker sand that meets the site requirements, course maintenance level, budgetary considerations, and sustainability goals. Determine what type of drainage the bunkers will contain. The option of bunker reduction and incorporating additional native areas can save resources and water if these are deemed priorities for the site.

Bunker construction includes preparation, creating slopes and shapes, deciding whether to use sod or sprigs or a combination, and calculating cost to maintain, including what long-term maintenance will be required.

Reference the Cultural Practices section for additional BMPs.

More information from the USGA may be found here:

https://www.usga.org/content/usga/home-page/articles/2018/02/decades-of-research-fuel-new-specs-for-putting-greens.html

https://www.usga.org/course-care/digitalcollections/creating-usga-putting-green.html

Landscape & Garden Areas

Landscape (non-play) areas are an essential part of the overall course design, providing aesthetics, wildlife habitat, noise abatement, and natural cooling. An ecological landscape design approach addresses environmentally safe and energy-saving practices; and is economically important. A fundamental principle for environmentally-sound management of landscapes is planning for the right plant species, adapted for the particular location, incorporating native Texas species to help with water and energy conservation.

Reference the Landscape and Pollinator Protection and Wildlife Habitat sections for additional BMPs.

Construction

Guide contractors to ensure optimal safety and environmental preservation. Ensuring planning and specifications are thoughtfully developed can support overcoming unforeseen challenges and reduce the number of changes required during construction, minimizing costs. Contractors should be well-qualified with significant golf course renovation or construction experience and familiar with environmentally responsible construction methods.

Before any construction begins developing construction plans that clearly communicate scope of work to all parties involved. Construction Plans are typically created by the golf architect, engineer, and irrigation designer. All critical data from the environmental resource inventory as well as key notes regarding construction processes should be included in the construction documents, along with permitting conditions. Sediment and erosion control or stormwater management plans that were established in design should also be included in this documentation.

Conduct a pre-construction conference with relevant stakeholders. This meeting should define lines of communication, review the scope of work and schedule, review methods for reducing environmental impacts and for the allow contractor(s) to become familiar with any permit requirements. Any resource areas impacted by the project should be clearly marked out prior to the meeting, and the meeting should include a field review of these areas and discussion of permit conditions impacting construction in, or adjacent to, those areas. The golf course architect, engineer, irrigation designer and other key consultants should remain involved through the construction phase to ensure plans and specifications are being followed and permit conditions being met.

Schedule construction to maximize turfgrass establishment and site drainage, environmental conservation, and resource management. During construction the site should be kept as stable as possible to reduce erosion. With large projects this may require completing and stabilizing a portion of the site prior to starting on a new area, to limit the amount of disturbed area at any one time. Smaller projects, however, may better reduce impact with a narrow construction window as opposed to phasing. The emphasis during construction must be on performing the work with quality and care to minimize the potential for future problems.

To monitor and manage environmental impacts before, during and after construction establish ground water testing protocols and coastal water sites before commencing work. Where a site has varied elevations include testing sites above and throughout the gradient of the property to ensure impacts outside and onsite can be mitigated and properly recorded. Determine testing protocols ahead of time, with testing intervals determined for each site by sensitivities toward surrounding features, ground water flows, proximity to drinking wells, coastal impacts, and other related factors.

The contractor, owner's representative, or a hired consultant should be responsible for monitoring and reporting on the construction process, including permit reporting. The level of diligence invested in monitoring can significantly influence the environmental and financial sustainability and viability of the project.

Best Management Practices

- Use only qualified contractors who are experienced in the special requirements of golf course construction, such as a member of the Golf Course Builders Association of America (GCBAA), or one with significant local golf course construction experience.
- Hold a pre-construction meeting with all relevant stakeholders.
- Maintain a construction progress report throughout the project to monitor progress and issues. Ensure this report is communicated to the proper permitting agencies.
- Develop a working knowledge of erosion and sediment control management. Texas has specifications including types of acceptable structures, materials, and design features.
- Incorporate a stormwater “treatment train” approach; a stormwater pollution prevention plan (SWPPP) may be required for construction activities.
- Schedule construction and turfgrass establishment to allow for the most efficient progress of the work, while optimizing environmental conservation and resource management.
- Use environmentally sound construction techniques and soil stabilization techniques which minimize erosion and maximize sediment containment. Consider limiting the area of disturbance at one time. Finish and stabilize one area before starting another area.
- Schedule construction to maximize turfgrass establishment and site drainage.
- Temporary construction components and siltation barriers should be built in a way that minimizes environmental impacts. They should be reviewed before and after any rain event and repairs made where damage has occurred.
- Develop and implement strategies to effectively manage sediment, minimize topsoil loss, protect water resources, and reduce environmental disruption and impact on wildlife and plant diversity.
- Integrate hydro-mulching, erosion blankets or straw mulch into the seeding process to enhance soil stabilization. Avoid using hay as mulch which may introduce unwanted weed seeds that may become a future problem.
- Check and repair erosion control barriers after every rain event.

Reference for GCBAA contractors:

https://www.gcbaa.org/Resources/Find-a-Member/Individual Directory/pagesize/10?p=CertifiedBuilder&Name=A

Developing your Stormwater Pollution Prevention Plan

Begin by asking yourself the following questions:

Who? Construction site operators (generally the person who has operational control over construction plans and/or the person who has day-to-day supervision and control of activities occurring at the construction site)

Where? Construction sites required to comply with stormwater discharge requirements

What? A guide to help you prevent stormwater contamination, control sedimentation, comply with regulations

Why? Stormwater runoff from construction sites can cause significant harm to rivers, lakes, and coastal waters

Stormwater management methods

- Infiltration chambers: allow water to better enter the ground and recharge aquifers.
- Retention basins: slow water flow off the property during heavy rain events while trapping sediments.
- Swales with check dams: slow runoff.
- Erosion control barriers and using mulch on seeded areas: assist with germination without soil erosion.
- Planting native aquatic species within the stormwater treatment system: aids in nutrient uptake.

Stormwater Management

Stormwater runoff occurs when rain or snowmelt flows over surfaces like driveways, sidewalks and streets, which prevents it from naturally soaking into the ground. Stormwater is a key force behind nonpoint source pollution and care must be taken to ensure that a golf course doesn't contribute to this pollution, especially during construction.

Good drainage is the primary tenet of good golf design and projects should maintain or even reduce the volume of stormwater leaving a site. Techniques that manage and conserve water should be adopted into the design. Golf courses can help filter stormwater naturally to remove waterborne pollutants through planned "treatment trains" (i.e., vegetated swales, depressed landscape islands, and constructed wetlands). Through a treatment train, water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment. This is an important consideration during design and construction to protect water quality.

A stormwater pollution prevention plan may be required for projects. Sediment control requirements may include the mapping of slopes greater than 15 percent or the determination of locations of highly erodible soils. Methods used to reduce sediment runoff may include the establishment of vegetative buffer strips, construction of interceptor swales that empty into detention basins, use of riprap to slow runoff and settle out sediment, and the installation of erosion control barriers. Adhering to planning principles should result in development that better fits existing site conditions and reduces

For Texas stormwater permitting requirements reference:

https://www.tceq.texas.gov/permitting/stormwater/index

Best Management Practices

- A "treatment train" is the best approach to stormwater management. Through this method water is conveyed from one treatment to another with conveyances that themselves contribute to the treatment.
- Eliminate or minimize as much directly connected impervious area 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. 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.
- Wherever possible use absorbent 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.

Reference Surface Water Management and Water Quality Monitoring and Management for additional BMPs.

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.

Erosion & Sediment Control

Sediment is defined as loose particles of sand, silt, and clay carried and deposited by wind or water. It most often occurs when heavy rain or irrigation flows over an area of exposed soil causing particles to be picked up by the moving water and deposited off site.

Erosion and sediment control are critical for construction. Sediment and eroded soil can be transported by wind to surface waters and degrade water quality by increasing turbidity. The turbid waters can harm aquatic plants and impair the habitat for fish, shellfish, and reptiles. The sediment may settle out, thereby reducing the volume of the waterbody and further impacting aquatic life. Another risk is the potential for soil, carried by wind and water erosion, to transport contaminants which can dislodge upon entering waterbodies. Work with the contractor to ensure erosion and sediment control management and that proper steps are taken, adhering to state requirements.

Examples of Erosion and Sediment Control Strategies

- Hydro-seeding, hydro-mulching, and sodding offer soil stabilization and assist in water retention
- Establishment of vegetative buffer strips
- Construction of swales that empty into detention basins
- Use of riprap to slow runoff and settle out sediment
- Installation of erosion control barriers
- Consider limiting the area of disturbance at one time
- Check and repair erosion control barriers after every rain event
- Use of straw, hay bales or pine straw can greatly reduce erosion potential
- For ingress-egress of the hole, if carts are allowed, make sure there is plenty of space for wear

Drainage

Sufficient drainage systems are necessary to establish and maintain healthy turfgrass. Drainage should address runoff containment, buffer zones, and filtration techniques in the design and construction process to ensure acceptable water quality. Drainage systems should be properly installed, repaired, and maintained. Turfgrass relies on adequate drainage to remain healthy and disease free. Damaged, improperly installed, or poorly maintained drainage systems negatively impact play and increase risks to water quality.

Best Management Practices

- When designing and constructing drainage systems consider engineering details such as subsoil preparation, slopes, backfilling, and placement of drainage gravel.
- Internal golf course drains should not drain directly into an open body of water or protected wetland. They should discharge through pretreatment zones (such as grass swales or retention basins) and/or vegetative buffers to help remove nutrients and sediments.
- The drainage system should be routinely inspected to ensure proper function.
- Post development flow rates should be equal to or less than predevelopment conditions. Where extensive clearing occurs or impervious surface is added, this will require the installation of water retention components that slow the release of water from the site.

Grow-In

Soil preparation and turfgrass establishment are critical elements in the golf course development process. This process must be carefully planned to minimize environmental risk. Special management areas may require a different approach and should be determined.

Most projects use a combination of seed and newly imported sod. The selection of the most appropriate grass, identifying drought and disease resistant cultivars, and determining starter fertilizer is critical. Consult with a regional USGA agronomist or a turfgrass consultant regarding best varieties of grass based on soil conditions, watering capabilities, and anticipated maintenance.

A “grow-in” fertility program should create calculated rates of pre-plant and establishment nutrient guidelines. Soil testing should be conducted prior to planting to best determine the amount and types of nutrients required. Potential long-term issues such as weed encroachment, disease, and drought susceptibility can be reduced with proper seedbed fertility. Nutrients should be applied, in either foliar or granular formulations, to the turfgrass surface. Slow-release nitrogen or light, frequent soluble-nitrogen sources should be used during grow-in. As feasible, deliver nutrients through the irrigation system (fertigation) in small quantities at regular intervals to reduce potential for runoff. Erosion barriers should remain in place through the soil preparation and grassing phase until full establishment of the turfgrass.

During the establishment period, 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. Continue with frequent mowing at roughly twice the final height of cut. This will hasten establishment. Create a timeline when areas are planted to give consistent time for establishment.

Heights of cut will be determined by the timeline as turfgrass becomes established and will be managed depending on area. Light verticutting and topdressing will improve playing surface and assist when reducing height-of-cut in each area. Reducing the height-of-cut often reduces weed establishment. Consider spot application of herbicides versus broadcast applications.

Best Management Practices

- Soil testing should be conducted prior to planting.
- Prepare area properly and clear of pests (weeds, pathogens, etc.)
- Compacted soil should be loosened prior to planting, with soil loose enough to allow for good penetration of seed.
- Sprigs should be “knifed-in” and rolled to hasten root establishment
- Erosion and sediment control devices should be in place and properly maintained.
- Spread mulch to slow runoff over the finely graded and smoothed ground surface.
- Irrigation should be applied lightly and frequently to newly seeded areas, with the goal of keeping the soil damp, without runoff. Irrigation will become less frequent and heavier as the grass grows and thickens.
- Top-dress sod to fill in the gaps between sod pieces to speed up establishment.
- Use appropriate seeding methods for the golf course’s conditions.
- Pre-plant fertilization should only be applied to bare soil immediately prior to seeding to reduce the chance of nutrient movement should a rain event occur. When using sod, nutrient applications should be delayed until sod has sufficiently rooted.
- Slow-release nitrogen or light, frequent soluble-nitrogen sources should be used during grow-in.
- Nutrients should be applied, in either foliar or granular formulations, to the turfgrass surface. Incorporating nutrients into the root zone increases environmental risk and does not result in more rapid establishment.
- Reduce phosphorus applications when possible and only apply based on soil-tests.
- Maintain unfertilized buffer strips between fertilized turfgrass and waterbodies.
- Use vegetated containment areas for drain discharges.
- Mow as soon as the sod has rooted, or when seedlings have reached a height of one-third greater than intended height-of-cut.
- Remove erosion barriers only after the turfgrass is fully established in the area being protected.

Reference Maintenance Operations and Energy for BMPs and detail regarding maintenance facility design, construction, and operations.

Reference Pollinator Protection, Wildlife Habitat, Landscape for additional detail regarding wildlife and landscape considerations.

Reference Irrigation BMPs for additional information regarding irrigation systems.

Reference Surface Water Management and Water Quality Monitoring and Management for additional information about surface water management and protecting water quality.

03

IRRIGATION

Irrigation is essential to maintaining healthy turfgrass and landscape areas. A critical consideration for golf course superintendents is to minimize water use, especially excess use from potable sources. Annual rainfall ranges from 56 inches in southeast areas of the state to less than 8 inches in the far west, and frost-free days range from 320 near Brownsville to less than 185 in the Panhandle. With a serious history of droughts, the State of Texas has placed significant focus on water conservation. Finding an effective balance between conserving water and golf course maintenance is critical from a regulatory perspective and in consideration of meeting golfers' expectations for turfgrass conditions and protecting owner's investments while demonstrating good environmental stewardship.

Proper irrigation helps to maintain optimal course playability, aesthetics, marketability and turfgrass stress reduction. A good irrigation management plan can also drive efficiencies through extending equipment life, stabilizing labor costs, minimizing risks, and reducing repair needs.

Golfers generally prefer firm, dry playing conditions. A wet, soggy golf course is not desirable and should be avoided whenever possible. In general, drier conditions help minimize disease, algae and turfgrass pests, improve soil aeration, reduce the risk of compaction and ruts, and provide for overall healthier turfgrass and more desirable playing conditions.

There are several water-management approaches which may be utilized:

Conservation and Efficiency: Conservation and efficiency consider 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 a cohesive approach that includes irrigation practices as part of course design, pesticide and nutrient practices, regulatory compliance measures, and structural measures as they concern environmental stewardship and policy.

Embracing Irrigation BMPs

There are several benefits to adopting BMPs for irrigation, including environmental, performance, and employee impacts:

- Conserve and protect the water supply
- Increase water efficiency
- Protect existing water quality
- Maintain optimal ball roll and playing conditions
- Reduce energy costs and facility's carbon footprint through saving electricity
- Increase pump and equipment life longevity
- Demonstrate responsible environmental stewardship
- Retain knowledgeable and effective employees
- Align with state water conservation and preservation goals; comply with regulations

BMPs related to water use help conserve and protect water resources and provide guidance to support compliance with local and state regulations.

Regulatory Considerations

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 regulatory requirements.

The State of Texas prioritizes conserving, protecting, and maintaining the biological soundness of surface and groundwater for the public's economic health and general well-being. Numerous regulations and governing bodies are in place on a state, regional, and local level.

Surface Water

Surface water in Texas is owned by the state and held in trust for the citizens of the state. State water is defined by Texas Water Code (TWC) § 11.021 as: the water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and every bay or arm of the Gulf of Mexico, and the storm water, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state is property of the state. The right to the use of state water may be acquired by appropriation. When the right to use state water is lawfully acquired, it may be taken or diverted from its natural channel. The Water Rights Permitting Application must be submitted through the Texas Commission on Environmental Quality (TCEQ).

TWC § 11.235: https://statutes.capitol.texas.gov/Docs/WA/htm/WA.11.htm#11.325

https://www.tceq.texas.gov/permitting/water_rights/wr-permitting/wr_applications.html#process

https://www.tceq.texas.gov/assets/public/permitting/forms/10214a.pdf

Water Divisions are structured throughout the state, under TWC, a watermaster may be appointed to a Water Division to ensure compliance with water rights and coordinate diversions to prevent waste or excess use. In the Brazos, Concho, and Rio Grande River basins, watermasters allocate water between users and ensure compliance with water rights. Before diverting Texas state water, a declaration of intent must be made and approved by the watermaster of the Water Division. A water use report must be submitted to TCEQ for water rights by March 1 each year.

https://www.tceq.texas.gov/permitting/water_rights/wmaster/about-wm

https://www.tceq.texas.gov/assets/public/legal/rules/rules/pdflib/304b.pdf

https://www.tceq.texas.gov/permitting/water_rights/wr-permitting/water-right-permits-annual-water-use-report#submitreport

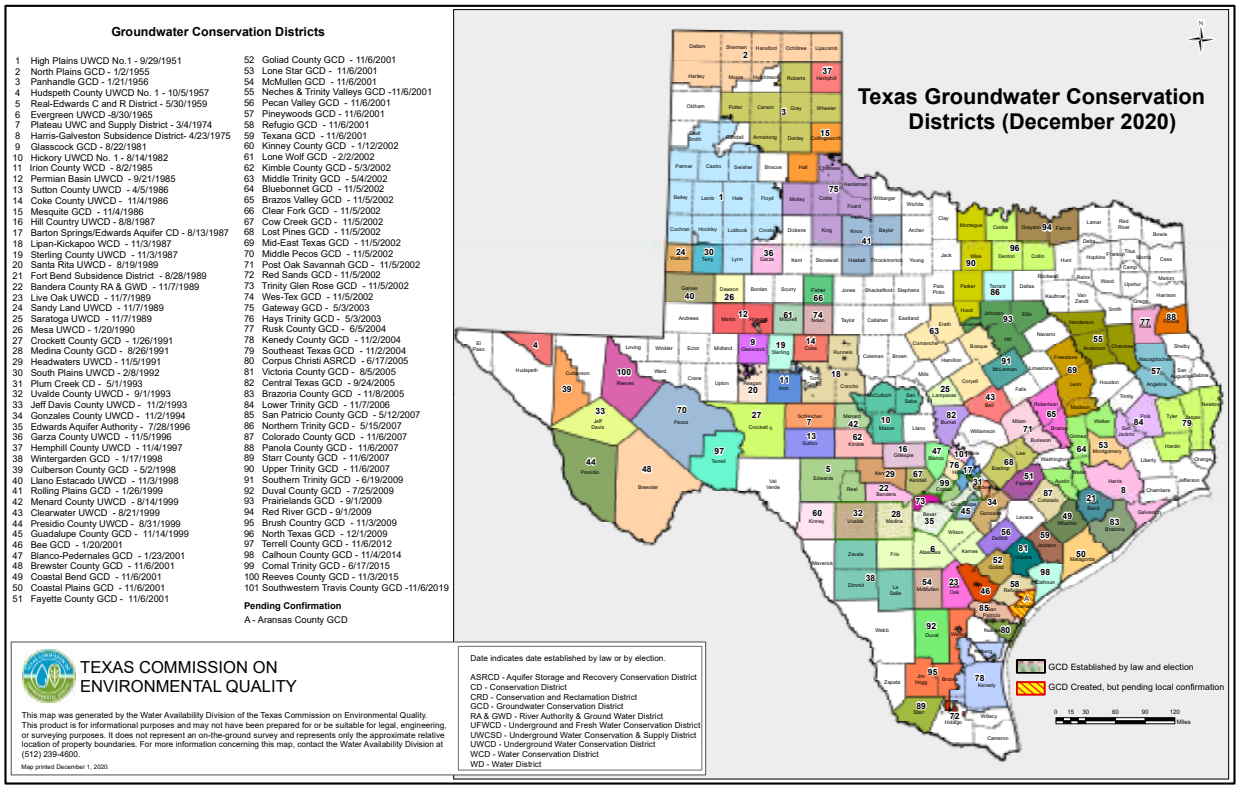
https://www.tceq.texas.gov/assets/public/permitting/forms/wur_instructions.pdf

Groundwater

Groundwater is owned by the landowner as real property. Groundwater Management Areas (GMAs) are delineated by the Texas Water Development Board (TWDB) which has designated 16 GMAs and recognizes 30 aquifers in the state. The GMAs are further divided into 102 Groundwater Conservation Districts (GCDs) for managing groundwater.

Priority Groundwater Management Areas (PGMAs) are regulated by regional GCDs evaluated by TCEQ, TWDB, and TPWD; and delineated by TCEQ. Reference additional information: https://www.tceq.texas.gov/groundwater/groundwater-planning-assessment/districts.html

Texas Groundwater Conservation Districts



Responsibilities of GCDs

GCDs are charged with managing groundwater by providing for the conservation, preservation, protection, recharge, and prevention of waste of groundwater resources within their jurisdictions

They are responsible for:

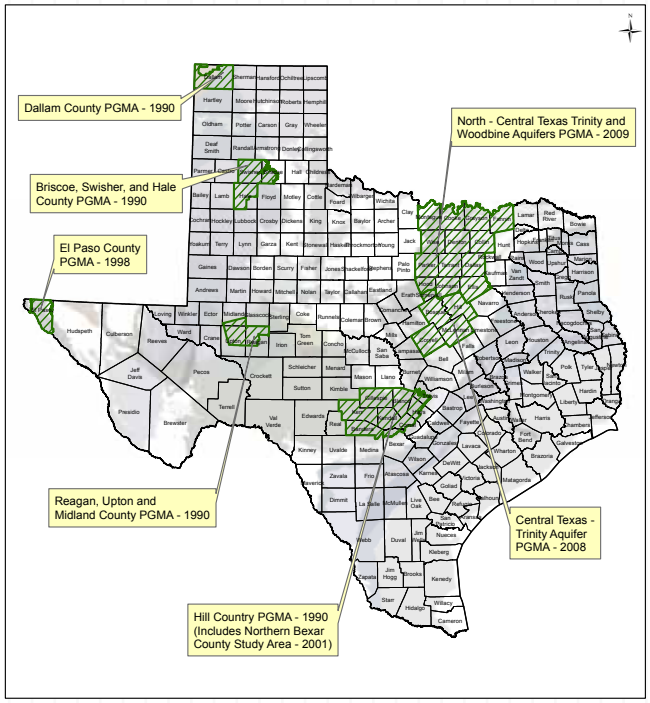
- Permitting water wells.
- Development of a comprehensive management plan.
- Adoption of the necessary rules to implement that management plan.

Water wells for which permits are required are subject to GCD rules governing spacing, production, drilling, equipping, and completion or alteration. This could impact withdrawal limits based on production and spacing. Exempt registered water wells are also subject to GCD rules governing spacing, tract size, and well construction standards to prevent the unnecessary discharge or pollution of groundwater.

Reference additional information regarding GCDs and TWC § 35.001: https://www.twdb.texas.gov/groundwater/management_areas/index.asp

https://tgpc.texas.gov/POE/FAQs/GCDs_FAQ.pdf

Texas Priority Groundwater Management Areas (PGMAs)



Reference additional information: https://www.tceq.texas.gov/groundwater/groundwater-planning-assessment/districts.html

Reclaimed Water Use Requirements for Landscape Irrigation: TAC § 344.6

1. There is no direct contact with edible crops, unless the crop is pasteurized before consumption.
2. The irrigation system does not spray water across property lines that do not belong to the irrigation system's owner.
3. The irrigation system is installed using purple components.
4. The domestic potable water line is connected using an air gap or a reduced pressure principle backflow prevention device, in accordance with §290.47(i) of Title 30.
5. A minimum of an 8 inch by 8 inch sign, in English and Spanish, is prominently posted on/in the area being irrigated and reads, "RECLAIMED WATER – DO NOT DRINK" and "AGUA DE RECUPERACIÓN – NO BEBER."
6. Backflow prevention on the reclaimed water supply line is in accordance with the regulations of the water purveyor.

Reference additional information: https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=30&pt=1&ch=344

Reclaimed Water

Texas Administrative Code (TAC) Title 30 § 210.32 and § 344.65 authorize Type 1 Reclaimed Water Use for golf courses with unrestricted public access.

Texas Landscape Irrigation Administrative Code

TAC Title 30 §344.1(45) requires that all landscape irrigation systems promote water conservation through the design, installation, service, and operation of an irrigation system in a manner that prevents the waste of water, promotes the most efficient use of water, and applies the least amount of water that is required to maintain healthy individual plant material or turfgrass, reduce dust, and control erosion.

Golf course 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. For irrigation system installation and irrigation work, only contract with a state licensed, registered company. TCEQ License Search database: https://www2.tceq.texas.gov/lic_dpa/index.cfm

Regulations cover irrigation licensing and backflow prevention TAC Title 30 § 344.50-344.52; and TAC Title 30 § 344.60-344.64:

- water conservation
- minimum standards for the design of the irrigation plan
- minimum design and installation requirements
- completion of irrigation system installation
- maintenance, alteration, repair, or service of irrigation systems
- use of a reduced pressure principle backflow device when injecting fertilizers or pesticides into an irrigation system

https://www.tceq.texas.gov/drinkingwater/irrigation/landscape.html

https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=5&ti=30&pt=1&ch=344&sch=F&rl=Y

https://www.tceq.texas.gov/assets/public/compliance/compliance_support/regulatory/irrigation/forms_li/irrigatorsquestionsanswers.pdf

Best Management Practices

- Comply with all Federal, Texas, and local laws and regulations.
- Conserve water and protect water systems by adhering to state and local water withdrawal allocations (gallons/day).
- Design and/or maintain a system to meet site's peak water requirements under normal conditions and be flexible enough to adapt to various water demands and local restrictions.
- Develop an annual water budget and maintain accurate records of actual annual water use as compared to the water budget and actual annual evapotranspiration data.
- Demonstrate good stewardship practices by supplementing irrigation 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).
- Consider reduction of manicured turfgrass and conversion to native areas to reduce water use.
- Separate the landscape into separate program for clubhouse and common areas.
- Use mulches in shrubs and flower beds to reduce water evaporation losses.
- Use drip irrigation in landscape areas to supply water only to plants that need it.
- Perform daily, weekly, quarterly, and annual inspections of the irrigation system; look for ways to increase efficiency and reduce energy use associated with irrigation systems and practices.
- Pump station should consist of Variable Frequency Drive (VFD) motors, pressure sensors (both high and low), water meters, and leak detection.
- Consider Gravity Feed to reduce energy consumption and costs.
- Utilize a Central Computer to allow for time adjustments, use weather stations for a baseline, and control costs by using efficiency to run the shortest water cycle with best pressure and distribution.
- Use the weather station to calculate evapotranspiration (ET) and determine amount of water that needs to be returned to the soil.

- Conserve water using tools like soil moisture meters, infrared pictures to detect hot spots quicker, hoses, and live feeds of the system via a computer or smart phone.
- Monitor soil moisture and set an acceptable threshold, when below threshold, hand water the specific site.
- Choose correct type of irrigation for area requiring water; ranging from full or part circle sprinkler heads to rotor or pop up to drip irrigation.
- Place meters at wells and pump stations; monitor daily.
- Conduct irrigation efficiency testing periodically utilizing a Texas Certified Irrigator to determine opportunities to increase efficiency.

Water sources include potable water, well water, surface water, and reclaimed water.

- Potable water: Water suitable for drinking.
- Well water: Underground water held in the soil and in pervious rocks.
- Surface water: Water from streams, ditches, or diversions.
- Reclaimed water: Water processed from converting wastewater to a form reused for other purposes such as irrigation.

Irrigation Water Suitability

Wherever possible, golf course designers and managers should try 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; municipal drinking water should be considered only when there is no alternative.

Studies of water supplies together with waterbodies or flows on, near, and under the property are recommended. These maybe helpful to properly design a course's stormwater systems, water features, and to protect water resources. If treatment options are required these should be included in the budget to address water quality and equipment maintenance.

Best Management Practices

- Identify optimal water source for accessibility, sustainability, water quality, and turfgrass selection; ensure ability to meet seasonal and bulk water allocations for grow-in and routine maintenance.
- Consult with an irrigation designer to evaluate site and water availability.
- Maintain accurate records, using a metered water supply, to document irrigation water used monthly and annually. Avoid relying on estimated flow data provided by the central irrigation control computers, instead install a totalizing flow meter for accurate record keeping.
- Monitor the quantity of water withdrawn to avoid aquatic life impairment.
- Use alternative water supplies/sources that are appropriate and sufficiently available to supplement water needs.
- Monitor reclaimed water tests regularly for dissolved salt content.
- Regularly perform soil testing to monitor the accumulation of salts and sodium delivered in the recycled (reclaimed, effluent, or non–potable) water supplies.
- Develop a strategic management plan to determine appropriate steps for cultivation/amendments to address water quality concerns. Amend sodic water systems appropriately (with gypsum or an appropriate ion) based on assessments to minimize sodium build-up in soil.
- Protect backup/emergency supplies of potable water used to replenish recycled water storage reservoirs. Use an approved backflow protection device such as a reduced pressure principle device or an air gap structure as specified by state and/or local regulations.
- Flush with freshwater or use appropriate amending materials regularly to move salts out of root zone and/or pump brackish water to keep salts moving out of the root zone.
- Monitor salinity levels in the soil using sensors.
- Irrigation pipeline systems directly connected to municipal water distribution mains must have an approved backflow device at the point of connection.
- Potable supply lines to buildings (for domestic uses) at recycled (reclaimed, effluent, non-potable) water use sites typically must be protected with backflow prevention device(s) in place, that are operating correctly and tested regularly.
- Account for the nutrients in effluent/reused/reclaimed water when making fertilizer calculations.
- Post signage (in English and Spanish) in accordance with local utility and state requirements when reclaimed water is in use.
- Plumbing pipes and fixtures used in transport and delivery of reclaimed water must be painted purple.
- Where practical, use reverse-osmosis (RO) filtration systems to reduce chlorides (salts) from saline groundwater; if using RO to improve water quality, be certain the reject concentrate (brine) is disposed of in a legal, proper, and environmentally responsible manner.
- Use salt-tolerant varieties of turfgrass and plants to mitigate saline conditions resulting from an alternative water supply or source, if necessary.
- Reclaimed water irrigation should not occur adjacent to waterways when avoidable to prevent potential unintended adverse water quality impacts, site specific characteristics (e.g., soils, geology, topography, vegetation) should be evaluated on a case-by-case basis to determine appropriate protective setbacks; if unavoidable, then measures should be implemented over time to minimize potential adverse impacts to surface water (mitigation measures may include revised riparian vegetation management practices, sprinkler head adjustments, and additional monitoring).
- Routinely monitor shallow groundwater table of freshwater for saltwater intrusion or contamination of heavy metals and nutrients.

Additional information on irrigation water suitability:

http://gsr.lib.msu.edu/2000s/2000/000914.pdf

http://plantscience.psu.edu/research/centers/turf/extension/fact-sheets/water-quality

https://anrcatalog.ucanr.edu/pdf/8009.pdf

http://www.fao.org/3/t0234e/t0234e00.htm

Beneficial Use of Treated Effluent Water as an Irrigation Source

Treated effluent water reduces the amount of groundwater, raw surface water, or potable water required for irrigation use.

- Many wastewater treatment plant permits are non-discharge permits and construct or designate an area golf course as the permitted discharge site.
- Use of reclaimed water supports water conservation efforts, provides water security, and serves as a drought-proof water source.
- Turfgrass helps filter nutrients and breaks down chemicals and biological contaminants in treated effluent water.
- Reclaimed water nutrients (i.e., nitrogen and phosphorus) can be efficiently used by turfgrass and economically beneficial, these nutrients should be accounted for when making fertilizer calculations.
- Reclaimed water sources can be an economical, reliable, and continuous source for irrigation.

Reclaimed water use is governed by the TCEQ Chapter 210 (Use of Reclaimed Water) of the TAC; authorized under the TWC.

Additional Information:

https://www.usga.org/course-care/water-conservation-on-golf-courses-fbe-1f5ee.html

http://www.stma.org/sites/stma/files/pdfs/gcsaa_recyledwater_leaflet-1.pdf

https://link.springer.com/chapter/10.1007/978-3-319-28112-4_17

Accounting for Nutrients in Effluent Water Supply When Making Fertilizer Calculations

Water reports from wastewater treatment plant's internal laboratories do not always report nitrate (NO3) and ammonium (NH4) as nitrogen (N). NO3-N means nitrogen in the form of nitrate (NO3) and NH4-N means nitrogen in the form of ammonium (NH4) in mg/l.

To convert nitrate (NO3) or ammonium (NH4) to nitrogen, 10 mg/l N = 45 mg/l NO3 = 13 mg/l NH4, each should be reported as 10 mg/l NO3-N or 10 mg/l NH4-N.

For further discussion visit Water Quality for Agriculture: Section 5.1 at: http://www.fao.org/3/t0234e/T0234E06.htm#ch5.1

To calculate the nitrogen contribution provided from a recycled water supply, multiply the mg/l (or ppm) of NO3-N and NH4-N combined by 2.72 to determine the pounds of actual nitrogen contained in an acre-foot (326,000 gallons) of water. One acre-foot (AF) is the equivalent of 12" of water applied over one acre.

Example:

10 mg/l of NO3-N and 20 mg/l NH4-N for a total of 30 mg/l total N are reported by laboratory analysis to be contained in a recycled water sample.

30 mg/l X 2.72 = 81.6 lbs. of N per AF

If 32,600,000 gallons per year are used to irrigate 50 irrigated acres of turf. 32,600,000 gal / 50 Acres = 652,000 gal/Acre

652,000 gallons per acre / 326,000 gallons per AF = 2 AF per Acre

2 AF per Acre X 81.6 lbs of N per AF = 163.2 lbs. of actual N per Acre or 3.74 lbs of N per 1000 sq ft.

If the nutrients are in their elemental form of N, P, or K, then multiply the ppm (or mg/l) value by 2.72 to get the pounds per acre foot (AF) of water (12 inches of water over 1 acre = 325,851 gal). If only applying 6 inches of ET in a month then adjust the number to reflect less than an AF of water applied to the turf.

In *Turfgrass Soil Fertility and Chemical Problems, Assessment and Management* by Carrow, Waddington, and Rieke, there are some common fertilizer calculations in Appendix A for P and K, if not already reported in elemental form.

- Lbs. P205 (0.437) = Lbs. P
- Lbs. K20 (0.830) = LBS. K

Regarding any other minor or secondary nutrients, they are generally reported on the water test in elemental form. Then they need to be multiplied by 2.72 to again get the pounds included in an acre foot (AF) of water.

Water Quality for Agriculture: Section 5.1: http://www.fao.org/3/t0234e/T0234E06.htm#ch5.1

Source: Huck, M. 2020. Accounting for Nutrients in Effluent Water Supply When Making Fertilizer Calculations. San Juan Capistrano, California.

Water Conservation and Efficient Use Planning

Water consumption and costs can be reduced through conservation strategies, use of alternative water sources, and identifying efficiencies. Watering practices should be documented and referenced to show savings in water use and to set weekly, monthly, or annual goals for improvement. Communicating these goals to maintenance staff and water managers can encourage engagement and continuous improvement. It can also be effective to share goals and results with course members and the wider general public to support local conservation initiatives. BMP usage on golf courses and related communications have been found to be particularly useful for educating the community and public around water use.

If practicable, converting turfgrass in out-of-play areas to native or adapted plants, grasses, or groundcovers can help reduce the amount of irrigation needed. The best and most effective method to reduce water use on any golf course is to reduce the irrigated acreage where possible.

The Texas Water Development Board (TWDB) has identified water conservation and efficiency improvement BMPs for utilities that service golf courses. Reference the TWBD Report 362, section 5.2, Golf Course Conservation: http://www.twdb.texas.gov/conservation/BMPs/Mun/doc/5.2.pdf

Best Management Practices

- Selecting drought-tolerant varieties of turfgrasses can help maintain an attractive and high-quality playing surface, while minimizing water use.
- Non-play areas may be planted with drought-resistant native or other well-adapted, non-invasive plants that provide an attractive and low-maintenance landscape.
- Native plant species are important in providing wildlife habitat with 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 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.
- Always closely monitor soil moisture levels, particularly during a drought. When practicable, irrigate when the least amount of evaporative loss will occur.
- Control invasive plants or plants that use excessive water.
- Some golf courses are designed with a “target golf” concept to minimize acreage of irrigated turfgrass. Existing golf courses can try to convert out-of-play areas to naturally adapted native plants, grasses, or ground covers when feasible to reduce water use and enhance aesthetics.

General information on water conservation on golf courses:

United States Golf Association (USGA) Research on Turfgrass Water Use

http://www.usga.org/course-care/water-resource-center/research-on-turfgrass-water-use.html

“Water Conservation” Golf Course Superintendents Association of America (GCSAA)

http://www.gcsaa.org/course/communication/golfcoursefacts/water-conservation

Reference the Landscape and Pollinator Protection and Wildlife Habitat sections for additional BMPs regarding native plants.

Drought Response

Be prepared for extended drought or restrictions by developing a written drought management plan in consultation with public water suppliers and in alignment with TWC, TCEQ, regional boards, and local agencies. Lack of availability to water resources due to drought can lead to unacceptable turfgrass quality and impact playability of the course. Managers of golf greens cannot afford to wait until drought symptoms occur. A soil moisture meter can be used to determine moisture needs of greens and tees in order to support proactive mitigation before drought impact becomes visible.

Additional information on the state water plan addressing drought, regional water plans, and local planning:

TWC § 16.051, 16.053, 16.054, 16.055: https://statutes.capitol.texas.gov/Docs/WA/htm/WA.16.htm

Best Management Practices

- Use soil moisture meters to determine moisture thresholds and plant needs.
- Irrigating established plant material too shallowly encourages shallow rooting, increases soil compaction, and favors pest outbreaks. For fairways and roughs, use infrequent, deep irrigation to supply enough water for plants and to encourage deep rooting.
- For golf greens and tees, most roots are in the top several inches of soil, use a soil sampling tube or soil profiler to regularly monitor and determine rooting depths.
- Proper cultural practices such as aeration, mowing height, irrigation frequency and amounts should be employed to promote healthy, deep root development.
- Create a drought management plan for the facility that identifies steps to be taken to reduce irrigation/water use and protects critical areas, etc.
- Use appropriate turfgrass species adapted to the location of the golf course being managed

Irrigation System Design

Irrigation managers should be fully trained, with a complete understanding of soil-water relationships, principles of crop coefficients, and evapotranspiration. Fundamental experience and knowledge provide the basis for irrigation management. For irrigation system installation and irrigation work, only contract with a landscape irrigator licensed by the TCEQ. A well-designed, efficient irrigation system should include precision scheduling for maintained turfgrass areas based on soil infiltration rates, soil water-holding capacity, plant water-use requirements, depth of the root zone, and desired level of turfgrass performance in order to maximize watering.

An irrigation designer and water quality specialist should evaluate the site, water quality mitigation requirements, and water availability. Utilize reclaimed water when possible. The owner should advise the designer of details regarding plant materials, soils, elevation, expectations, and budget. The designer should produce drawings for the pump station, hydraulics, configure pipe sizing, and determine sprinkler locations based on pre-planning meetings. The water quality specialist will assist in determining any required source balancing delivery system, material requirements, and flushing requirements. When in the design phase, pipe sizing and pump capacity should be budgeted for in order to have the shortest and most efficient water-time-window. Sprinkler selection, spacing, configuration (as triangular or rectangular arrangements) and nozzle selections should maximize distribution uniformity (DU).

The separation of landscape into a separate irrigation program can help with conservation. Clubhouse and common areas, with correct species selection, can require one to two cycles of irrigation per week compared to four or five cycles for turfgrass. Use drip irrigation as an option in landscape areas to supply water only to the plants that need it. Utilize reclaimed water when possible. Separate irrigation zones within landscapes, combine plants with similar water requirements (verses watering to the highest water requiring species in a planting) to minimize water usage and pruning requirements.

A well-designed system supported by a well-trained irrigation manager protects water resources, conserves supply, maximizes water use, and reduces operational cost.

Information on landscape irrigation certification programs and to find a state-licensed professional: https://www.tceq.texas.gov/drinkingwater/irrigation/landscape.html

Benefits & Placement of Part-Circle or Adjustable Heads

- Install along lakes, ponds, and wetlands margins.
- Use to avoid overspray of impervious areas such as roadways and sidewalks.
- Use to avoid overspray into natural water features and/or other environmentally sensitive areas particularly when using recycled/reclaimed/effluent water.
- Place along areas that will be considered non-irrigated, such as forest borders, native meadows, perennial rock gardens, etc.

Water Quality and Irrigation System Design

Water quality can have significant implications for turfgrass health and soil structure. There are four key water properties listed on water reports and four key soil properties listed on soil salinity and texture reports to help turfgrass managers assess irrigation water quality.

Four Key Irrigation Water Properties

1. Total salts
2. Sodium adsorption ratio (SAR)
3. Adjusted sodium adsorption ratio (Adj SAR)
4. Boron

Four Key Irrigation Water Properties

1. Total soluble salts (TSS)
2. Exchangeable sodium percent (ESP)
3. Boron
4. Soil texture

Reference properties, ratios, classifications, and management recommendations at:

https://extension.okstate.edu/fact-sheets/turf-irrigation-water-quality-a-concise-guide.html

Generally, when there is a water quality issue, a long-term management plan should be developed that considers routine assessment, appropriate amendments, leaching, and cultivation practices to monitor and reduce salt loading. Additionally, similar to drought concerns, a species or cultivar adapted to saline conditions should be selected.

Reference the Water Quality Monitoring and Management section, Nutrient Management, and IPM for additional BMPs regarding water quality.

Understanding Distribution Uniformity (DU) vs. Efficiency

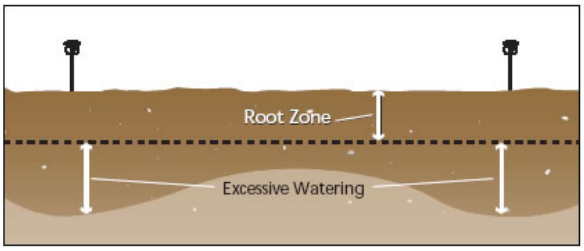


FIGURE 1: Depiction of irrigation resulting in poor DU and excessive watering

Poor DU combined with poor application efficiency wastes water applied beyond the root zone and perhaps wet playing conditions depending soil drainage

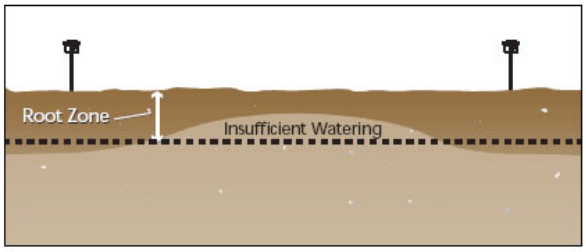


FIGURE 2: Depiction of irrigation resulting in poor DU and insufficient irrigation in parts of the field

Poor DU and good application efficiency does not waste water but in a turfgrass application would leave noticeable dry spots in turfgrass

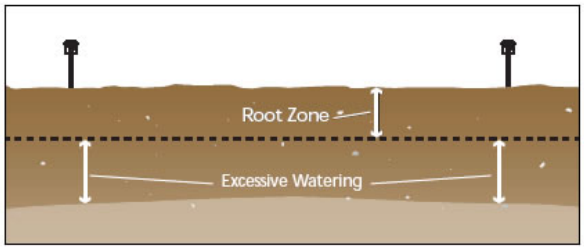


FIGURE 3: Depiction of irrigation resulting in good DU but poor irrigation efficiency

Good DU and poor application efficiency results in wasted water applied beyond the root zone and perhaps wet playing conditions depending soil drainage

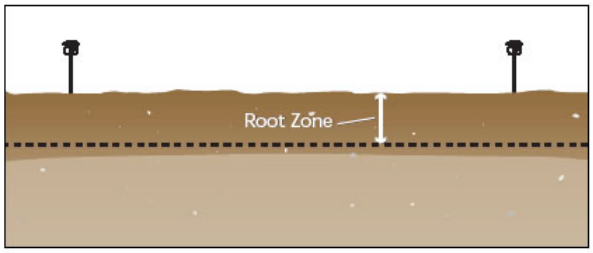


FIGURE 4: Depiction of irrigation sufficiently watering the entire field with good DU and irrigation efficiency

Good DU and good application efficiency does not waste water and optimizes playing conditions

Source: Connecticut Golf Industry BMP Guide, 2020

Best Management Practices

- Use a qualified irrigation designer/consultant; for irrigation system installation and irrigation work, only contract with a state-registered company and landscape irrigator licensed by the TCEQ; designer must approve any design changes before construction.
- Design should account for optimal water distribution efficiency and effective root-zone moisture coverage; target 80% or better distribution uniformity.
- Implement zoning. Putting surface, slopes, and surrounds should be watered independently. Turfgrass and landscape areas should be zoned separately; in addition to use areas: greens, tees, primary roughs, secondary roughs, fairways, native, trees, shrubs, etc.
- Design an irrigation system that delivers water with high DU and operate (schedule) the system for maximum application efficiency.
- Incorporate individual sprinkler control instead of "block systems" into design, particularly with fine turfgrass areas.
- Secure a general irrigation schedule with recommendations and instructions on modifying the schedule for local climatic, soil, and growing conditions as part of the design package. It should include base ET rate for the 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. Since golf rotors and many other sprinklers' precipitation rates may exceed soil infiltration rates, avoiding surface runoff is often accomplished by operating sprinklers in short durations with a "cycle and soak" programmed to occur between each application cycle.
- Ensure proper operating pressure – it must not be greater than the available source pressure or a booster pump will be needed.
- The design operating pressure must account for peak-use times, maximum flow rates, and supply line size and operating pressures at final buildout for the entire system.
- The system should be flexible enough to meet peak water requirements and allow for operating modifications to meet seasonal irrigation changes or local restrictions. Typically, a system should be designed with at least 15% additional capacity (i.e., flow rate at the specified operating pressure) to accommodate "catching up" over 7 days if an irrigation event is missed due to a power failure, etc.
- Design should account for the need to leach out salt build-up from poor-quality water sources by providing access to freshwater.
- Underground cables, pipes, and other obstacles must be identified, and their locations flagged prior to construction.
- Only qualified specialists should install the irrigation system; construction must be consistent with the design; construction and materials must meet existing standards and criteria.
- Space permanent irrigation sprinklers and other distribution devices according to manufacturer's recommendations.
- Space sprinklers in turfgrass areas for head-to-head coverage.
- Sprinkler spacing distance should be based on average wind conditions during irrigation.
- For variable wind directions, triangular spacing is more uniform than square spacing.
- Distribution devices and pipe sizes should be designed for optimal uniform coverage.
- The first and last distribution device should have no more than a 10% difference in flow rate. This usually corresponds to about a 20% difference in pressure.
- Distribution equipment (such as sprinklers, rotors, and micro-irrigation devices) in each zone must have the same precipitation rate.
- Water supply systems (for example, wells and pipelines) should be designed for varying control devices, rain shutoff devices, and backflow prevention.
- Water conveyance systems should be designed with thrust blocks (or joint restraints) and air-release valves and/or vacuum release valves as necessary.
- Sites with significant elevation change may require a design incorporating pressure reducing valve (PRV) station(s) and/or multiple points of connection (POCs), pump stations and/or mainline systems separately pressurized to minimize zones of excess and/or insufficient pressure due to elevation-related pressure loss and/or gain.
- 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 while making repairs to the system.
- Manual quick-coupler valves should be installed near greens, tees, and bunkers so these can be hand-watered during severe droughts; consider adding manual quick-coupler valves to areas known to be drier than others.
- Update multi-row sprinklers with single head control for conservation and efficiency.
- Ensure heads are set at level ground and not on slopes.

Non-Play and Landscape Areas

Map any environmentally sensitive areas such as sinkholes, wetlands, or flood-prone areas, and identify species classified as endangered or threatened by federal and Texas designation, and state species of special concern. Identify and eliminate invasive species. The most efficient and effective watering method for non-turf landscape is drip or micro-irrigation.

Wherever possible key stakeholders (golf course architect, superintendent, golf professional, etc.) should evaluate the amount of functional turfgrass and transition to non-play areas which require significantly less, if any, irrigation.

Rain gardens may be installed near roofs and other impervious surfaces to catch and temporarily hold water, helping to provide supplemental irrigation needs for landscape areas.

Best Management Practices

- Designate 50% to 70% of non-play area to remain as natural cover according to “right-plant, right-place,” a principle of plant selection that favors limited supplemental irrigation.
- Incorporate natural vegetation in non-play areas.
- Consider rain gardens for supplemental irrigation.
- Use micro-irrigation and low-pressure emitters in non-play areas to supplement irrigation.
- Routinely inspect non-play irrigation systems for problems related to emitter clogging, filter defects, and overall system functionality.

★ Native vegetation that does not require supplemental irrigation should be retained and enhanced for non-play areas to conserve water where possible.

Irrigation Pumping System

Pump stations, when properly sized and maintained, can deliver critical improvements in water and energy savings. The pump station should be equipped with control systems that protect distribution piping, provide for emergency shutdown necessitated by line breaks, and allow maximum system scheduling flexibility.

The pump station should consist of the following key elements:

- VFD motors: Regulate water pressure and deliver pump control based on pressure. Help reduce energy costs by alternating pump starts and running at lower RPMs based on flow and pressure needed for the system.
- Pressure Sensors: Provide adjustable sensor pressure to maintain optimal system pressure with current flow; can set high pressure and low-pressure levels for automatic shutdown.
- Water Meters: Current flow monitored by control unit to optimize energy consumption.
- Leak Detection: A combination of pressure and water output that can activate shutdown for low pressure.

Best Management Practices

- The design operating pressure must not be greater than the available pump's capabilities or source pressure.
- The design operating pressure must account for peak-use times, peak flow rates, and supply-line diameter and operating pressures at final buildout for the entire system.
- Maintain air-relief and vacuum-breaker valves by using hydraulic-pressure-sustaining values.
- Install VFD systems to lengthen life of older pipes and fittings until a new irrigation system can be installed.
- An irrigation system should 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, filters, and sprinklers should follow the manufacturer's recommendations.
- Keep records of filter service performed to identify potential system corrosion, well problems, or declining irrigation water quality. Even under routine conditions, keeping filters operating properly prolongs the life of an existing system and reduces pumping costs.
- Document pump motor/equipment run-time hours and 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 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.
- Application/distribution uniformity 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.
- Conduct pump efficiency tests every 1 to 5 years to monitor pump wear, ensure pumps are in good working order, operating efficiently, and not wasting energy.
- Test frequency should depend on water quality with 1 to 3-year intervals if water is contaminated with sand, silt, clay etc., and longer intervals of 3 to 5 years with clean or potable water.
- System checks and routine maintenance on pumps, valves, programs, fittings, and sprinklers should follow the manufacturer's recommendations. Ensure lubrication, overhauls, and other preventive maintenance are completed according to the manufacturer's schedule

Gravity Feed

Gravity feed systems are designed with a reservoir placed at a higher elevation than the highest area that requires water. The systems use pressure reducing valves to regulate pressure as it travels downhill and supply this pressure to the irrigation system. As the system does not require electrical motors to supply pressure, energy consumption levels are much lower than electrical systems. Quarterly upkeep requirements can increase maintenance costs; however, these systems provide a reduction to energy costs.

Irrigation System Scheduling

Responsible irrigation management conserves water and minimizes risk associated with nutrient and pesticide movement. Irrigation scheduling must take plant water requirements and soil intake capacity into account to prevent excess water use that could lead to leaching and runoff. Plant water needs are determined by ET rates, recent rainfall, recent temperature extremes, and soil moisture.

Irrigation should be based on ET rates and soil moisture replacement and not simply run on a calendar-based schedule. An irrigation system should be operated based only on the moisture needs of the turfgrass, or to water-in a fertilizer or chemical application, as directed by the label.

Older electric/mechanical time clocks cannot automatically adjust for changing ET rates. Frequent adjustment is needed with these systems to reflect the needs of individual turfgrass areas.

An onsite weather station will offer the best ET information. When unavailable, follow several local weather stations that can be found on Weather Underground: www.weatherunderground.com or the Texas ET Network: https://texaset.tamu.edu/. It is important to note when using a local weather station's data, that ET may not be calibrated for turfgrass and the weather station location may not be on turfgrass, so the numbers may not be exactly what is desired. It is possible, however, to draw conclusions over time in relation to what the turfgrass requirements are.

Best Management Practices

- The reliability of older clock-control station timing depends on calibration of the timing devices; this should be done periodically, at least seasonally.
- An irrigation system should have rain sensors to shut off the system after 0.25 to 0.5 inch of rain is received. Computerized systems allow a superintendent to access the control system 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 particles off the leaves while minimizing runoff.
- Irrigation quantities should not exceed the available water holding capacity of the soil based on texture and root zone depth.
- Irrigation schedule should coincide with other cultural practices (for example, the application of nutrients, herbicides, or other chemicals).
- Irrigation should occur in early morning hours before temperatures rise and relative humidity drops.
- Base plant water needs should be determined by ET rates, recent rainfall, recent temperature extremes, and soil moisture; driven by site surveying and scouting.
- Use mowing, verticutting, aeration, nutrition, and other cultural practices to control water loss, maintain infiltration rates, encourage conservation, and increase efficiency.
- Depending on physical soil characteristics and turfgrass type, using solid-tine aeration equipment in place of verticutting is an option.
- Slicing and spiking relieve surface compaction and promote water penetration and aeration.
- Visually monitor for localized dry conditions or hot spots to identify poor efficiency or a failed system device.
- Use predictive models to estimate soil moisture and best time to irrigate.
- Avoid use of a global setting; adjust watering times per head.
- Base water times on actual site conditions for each head and zone.
- Adjust irrigation run times based on current local meteorological data.
- Install rain switches to shut down the irrigation system if enough rain falls in a zone.
- Use computed daily ET rate to adjust run times to meet the turf's moisture needs.
- ET rates should be adjusted by the appropriate crop coefficient (Kc). Average Kc values are 0.80 for cool season turfgrasses and 0.60.for warm season turfgrasses. Kc values may require minor adjustment through the growing season. Average Kc values can be used when creating annual water budgets and/or as a starting point when scheduling for ET replacement.
- Manually adjust individual control stations' automated ET data with a Kc to reflect wet and dry microenvironments on the course.
- Use soil moisture sensors, or if unavailable a soil sampling tube, to assist in scheduling or to create on-demand irrigation schedules.
- Use multiple soil moisture sensors to reflect soil moisture levels. Evaluate variations in soil types across the property using the USDA Web Soil Survey when selecting locations for multiple sensors placement. https://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm
- Install soil moisture sensors in the root zone for each irrigation zone as feasible to enhance scheduled timer-based run times.
- Place soil moisture sensors in a representative location within the irrigation zone. Installing a soil moisture sensor in the driest or wettest irrigation zone of the irrigation system may lead to over or under watering on a larger scale.
- Wired soil moisture systems should be installed to prevent damage from aerification.
- Periodically perform catch-can uniformity tests.
- Reducing dry spots and soil compaction improves infiltration, reducing water use and runoff.
- Install emergency shutdown devices to address line breaks.
- Check to ensure system is operating properly after power outages.

To prevent excess water use, irrigation scheduling should consider plant water requirements, recent rainfall, recent temperature extremes, and soil water holding characteristics.

Sensor Technology

Proper irrigation management requires correctly installed monitoring and control devices, including soil moisture sensors. The use of any sensors should be supplemented with monitoring for visible indications of wilt. Multiple sensors should be used for greater accuracy (i.e., handheld in addition to an in-ground sensor). These should be installed at representative locations and depths; and maintained to provide the information necessary for making sound irrigation management decisions.

Rainfall can be tracked at specific sites using rain gauges. More than one gauge-station may be needed to gain a full measure of rainfall or evaporation loss on some courses, depending on acreage and micro-climates. Utilization of soil moisture probes and inspections for visual symptoms such as wilting turfgrass, 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 for predicting long-term turfgrass 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. These models rely on data collected and the number of assumptions made for effectiveness and accuracy – they are only as good as the information that is collected.

Best Management Practices

- Irrigation controllers/timers should be reset as often as practically possible to account for plant growth requirements and local climatic conditions.
- A rain or moisture shut-off device or similar technology is required per the TCEQ on all new irrigation systems with an automatic controller and all replacements of automatic controllers on existing irrigation systems. The rain or moisture shut-off device must be installed in accordance with the manufacturer's published recommendations.
- Properly calibrated flow meters, soil moisture sensors, rain shut-off devices, freeze sensors, and/or other automated methods should be used to manage irrigation; refer to the TCEQ and local counties for required compliance measures.
- Computerized control systems should be installed on new course irrigation systems to help ensure efficient irrigation application. These allow for timing adjustments at every head when systems are designed to provide individual head control.
- 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. Visual observation/ logging is also important beyond the use of sensors alone.
- Ensure that onsite weather stations are properly calibrated and maintained.

Reference TCEQ irrigation compliance measures for irrigation technology and system design:

https://www.tceq.texas.gov/assets/public/compliance/compliance_support/regulatory/irrigation/forms_li/irrigatorsquestionsanswers.pdf

Pond Location and Design

Lakes and ponds can add significant aesthetic value to a golf course. They can also be used as a source of irrigation water and it is important to consider this during design and construction. The size, shape and depth of a lake or pond will affect how they respond to various environmental inputs. Careful design may significantly reduce future operating expenses for lake and aquatic plant management. Most golf courses plan lakes and water hazards to be a part of the stormwater control and treatment system. This usually works well for all concerned, however natural waters may not be considered treatment systems and must be protected.

Surface water in Texas is owned by the state and held in trust for the citizens of the state. The right to use state water may be acquired by appropriation. When the right is lawfully acquired, it may be diverted from its natural channel. The Water Rights Permitting Application must be submitted through the TCEQ. Before diverting Texas state water, a declaration of intent must be made and approved by the watermaster of the designated Water Division. Reference additional information: https://statutes.capitol.texas.gov/Docs/WA/htm/WA.11.htm#11.325

Best Management Practices

- Consult with a qualified golf course architect with stormwater experience, working in conjunction with a stormwater engineer, to develop an effective stormwater management system that complies with the requirements of the DNR.
- 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 pre-treatment zones and/or vegetative buffers to help remove nutrients and sediments. Carbon filters can be added in cases where vegetative buffers are unavailable.
- 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 systems 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

Each pond has four regions or zones that significantly influence water quality and are crucial in maintaining the ecological balance of the system.

- Riparian Zone – the part of the bank slope that lies above the surface but where the soil remains permanently wet.
- Littoral Zone – the shore area of the lake or pond. Consists of the area from the dry land sloping to the open water. This area is shallow and gets lots of nutrients from runoff and non-point source pollution.
- Limnetic Zone – the open water area. The upper portion is the euphotic zone and receives sunlight. This is usually where fish populations are highest and where algae and other aquatic plants thrive. The lower zone, where no sunlight penetrates, is the profundal zone. This area has lower fish populations due to limited oxygen levels.
- Benthic Zone – the bottom of the pond or lake, consisting of organic sediments and soil. The area where bacteria decompose organic matter. Decomposition rates are significantly impacted by oxygen levels.

It is important to understand the function of each zone, and how good water quality can be maintained if these zones are properly managed.

Golf Course Ponds: Maintenance Challenges

- Low dissolved oxygen
- Sedimentation
- Changes in plant populations
- Nuisance vegetation
- Maintenance of littoral shelves
- Vegetation on the lakeshore
- Mammal intrusion

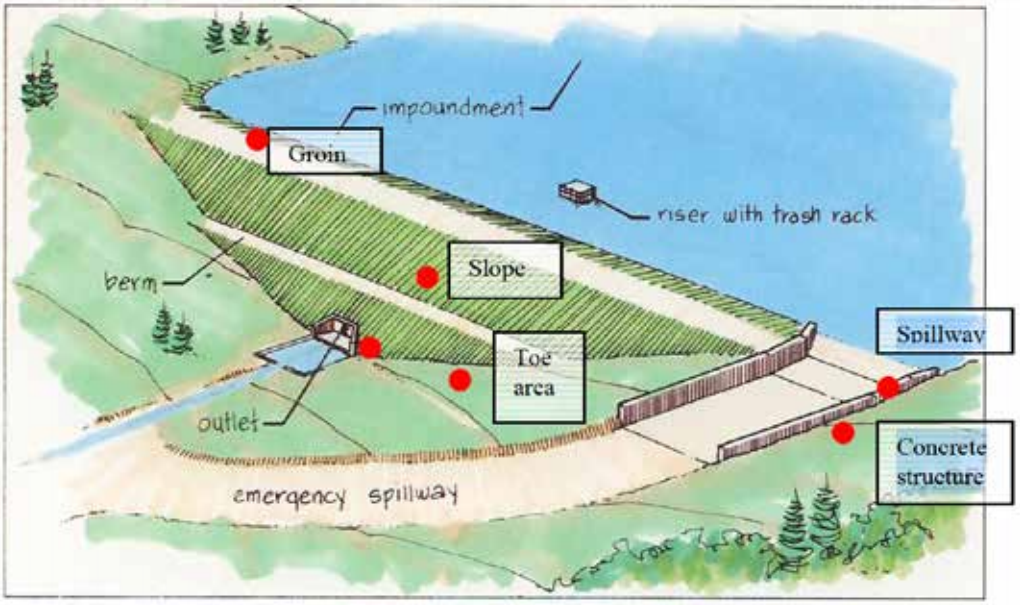
Evaporation losses are higher in some regions than others and vary from year to year and within the year. However, evaporative losses could approach six inches per month during the summer. Aquatic plants are more difficult to control in shallow water. Surface water sources can present problems with algal and bacteria growth. Algal cells and organic residues of algae can pass through irrigation system filters and form aggregates that may plug emitters. Use an expert in aquatic management to help develop and monitor pond management programs.

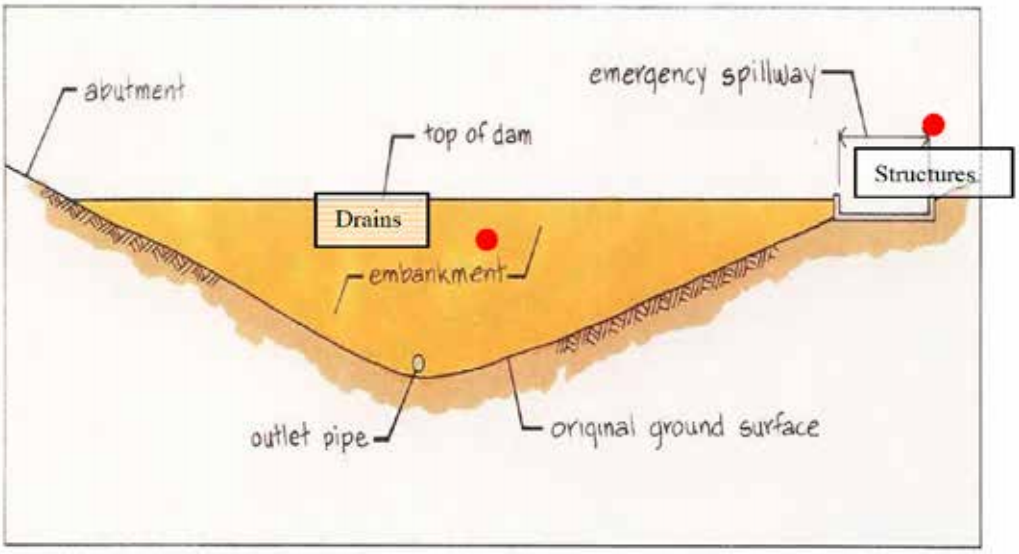
Best Management Practices

- Pond leaks should be controlled and managed properly; use leak controls in the form of dike compaction, natural-soil liners, soil additives, commercial liners, drain tile, or other approved methods.
- Maintain a riparian buffer to filter the nutrients and sediment in runoff.
- Reduce frequency of mowing along the lake edge, 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. Use drop spreaders instead of rotary spreaders near these sensitive areas.
- 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.
- Maintain appropriate silt fencing and BMPs on upstream projects to reduce erosion and 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.
- A pond should hold surplus storage of at least 10 percent of full storage; in other words, the difference between primary spillway elevation and auxiliary spillway elevation provides 10 percent of pond volume when water level is equal to elevation of the primary spillway.
- 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 and if supplied by the irrigation supply, should be included in irrigation water budgets.

More About Spillway Systems

Spillway Systems are control structures over or through which flows are discharged, they include Primary Spillways through which normal flows and small storm water flows are discharged and Auxiliary or Emergency Spillways through which storm water flows (floods) are discharged.





FEMA 534, Technical Manual for Dam Owners: Impacts of Plants on Earthen Dams, Figure 6, Page 5-19, September 2005.

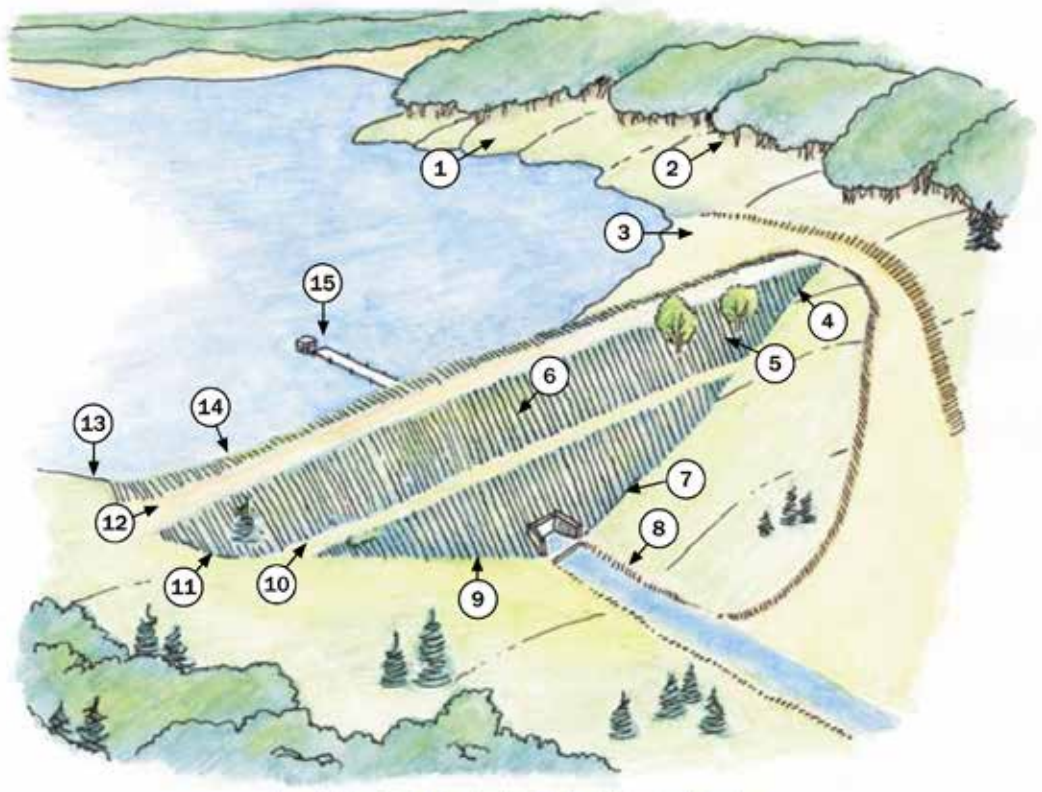


Figure 3-2. The Earthen Dam from Biological and Engineering Perspectives

1. **Upland Areas.** Many species live in the upland areas, away from the water. Even the downstream slope, abutments, and groin areas of the dam can be considered upland in terms of habitat.
2. **Forest Fringe.** The zone between two environments (the edge) is the best place to observe those species living at and around the dam. The more habitat types at the dam, the greater number of species likely to inhabit the dam. Mountain beaver or armadillo prefer forested/wooded areas.
3. **Emergency Spillway.** Beaver often dam the spillway, causing the pond water levels to rise.
4. **Left Abutment contact.**
5. **Inappropriate Vegetation on Embankment.** Many dams contain vegetation other than mowed grass. Improper vegetation provides cover and food supply, which encourage animals to inhabit the dam.
6. **Downstream Slope.** This area is often the location where groundhogs, coyote, and fox excavate burrows. Canada geese will feed on the downstream slope, which could cause loss of protective vegetative cover and associated erosion. Species that prefer upland areas could be found in this area.
7. **Left Groin.**
8. **Discharge Conduit and Outlet Channel.** Beaver can dam the outlet structure. Aquatic species may inhabit this area depending on water flow and availability of vegetation.
9. **Toe of Embankment and right groin.**
10. **Erosion Pathways on the Embankment.** Livestock traverse the embankment creating erosion pathways.
11. **Right abutment contact.**
12. **Crest.** Livestock traverse the crest which creates ruts. The ceilings of beaver and muskrat burrows in the upstream slope are often just below the dam crest.
13. **Aquatic Fringe.** The zone where the bank meets the pond usually contains aquatic vegetation preferred by many animals such as nutria.
14. **Upstream Slope.** Beaver, muskrat, and nutria prefer the upstream slope for burrow excavation. Alligators, otters, and turtles usually live in the shallow waters near the upstream slope.
15. **Principal Spillway (with riser and trash rack).** Beavers can block principal spillways by constructing dams.

FEMA 473, Technical Manual for Dam Owners: Impacts of Animals on Earthen Dams, Figure 3-2, Page 11, September 2005.

Metering

The amount of water delivered through a system is an important measure of how well an irrigation system and schedule are working. Proper use of irrigation management devices such as flow meters, rain gauges, rain shut off devices, and soil moisture sensors should be utilized to allow flow and volume levels to be managed, monitored, and compared over time.

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 - consult manufacturers recommendations for the minimum length of straight pipe required in front of the meter.
- Flow meters can be used to determine how much water is applied over the irrigated area, which can be converted to inches applied and compared to ET to confirm the average application of water applied as a percentage of ET.

Irrigation System Quality

Irrigation system maintenance on a golf course impacts the quality of the system; this involves four major efforts:

- Calibration or auditing: ensuring equipment is fit for use and correctly set up.
- Preventive maintenance (PM): the first step in good system management. Including tests, measurements, adjustments, parts replacement, and cleaning, performed specifically to prevent faults from occurring.
- Corrective maintenance: the act of fixing what is broken.
- Record-keeping: central to good system management.

Renovating a golf course irrigation system can improve efficiencies, conserve water, improve playability, and lower operating costs.

Best Management Practices

- Respond to day-to-day failures in a timely manner, maintain the integrity of the system as designed, and keep good records.
- System checks and routine maintenance on pumps, valves, control systems, adjustment of programs, fittings, and sprinklers should follow manufacturer's recommendations.
- 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.
- Exercise manual isolation valves annually by closing and reopening to prevent the threads of operating stems from corroding and seizing.
- Keep valve boxes edged regularly to quickly locate and shut a section of the system off if there is a leak.
- Annually disassemble, clean and service air and vacuum release valves, PRVs, and any other specialized components included in the design.
- Gather all the documentation collected as part of the PM program, along with corrective maintenance records for analysis.
- Correctly identifying problems and costs helps to determine what renovations are appropriate.
- Maintain written and photo records of pipe or other component failures and repairs. This can become valuable documentation when proposing system renovations and replacements.

Sprinkler Maintenance

Good sprinkler system management starts with comprehensive PM procedures and record-keeping. It includes documenting system and maintenance-related details so that potential problems can be addressed before extensive repairs are needed. It also provides a basis for evaluating renovation or replacement options. Examples include:

- Pipe failures may be caused by material failure or problems with the pump station and/or control system programming resulting in pressure surges and spikes.
- Wiring problems could be caused by corrosion, rodent damage, insulation knicks, or frequent lightning or power surges.
- Control tubing problems could result from poor filtration or water supply chemical precipitants such as calcium carbonate.

Best Management Practices

- 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.
- Part-circle sprinklers should be checked periodically for proper adjustment. Particularly important when irrigating with recycled water so that it does not spray outside of the designated use area.
- Flush drip/micro-irrigation irrigation lines and filters regularly to minimize emitter clogging. To reduce sediment build-up, make flushing part of a regular maintenance schedule. If fertigating, prevent microbial growth by flushing all fertilizer from lateral lines before shutting down the irrigation system.
- Clean and maintain filtration equipment.
- Systems should be observed in operation at least monthly or more frequently if problems are regularly occurring. This can be done during maintenance programs such as fertilizer or chemical applications where irrigation is required, or 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.
- Monitor and record the amount of water being applied, including system usage and rainfall. By tracking this information, identify areas where minor adjustments can improve performance. This information supports potential need for renovations and aids in computing current operating costs in comparison to potential future costs post-renovation.
- Factor in rainfall and compare total amount of water applied per irrigated acre to ET as a measure of application efficiency.
- Keep sprinklers edged regularly to ensure proper distribution.
- 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. For diagnosis of PVC failure causes visit: https://edis.ifas.ufl.edu/ch171

Irrigation System Inspection Checklist & Frequency

Daily

_ Visual field inspections for:
_ Leaks (in pipes or heads)
_ Stuck-on heads
_ Flow (actual vs. projected)
_ Meter readings
_ Computer logs
_ Rapid pressure loss at pump stations cycling motors
_ Visually inspect resevoir

Weekly

_ Inspect individual clocks
_ Run the system & watch sprinklers
_ Cleaning filters at the pump station to remove debris
_ Check rotation of heads
_ Make needed adjustments
_ Inspect for proper pressures at sprinklers (visual and measured)

Quarterly

_ Read electrical current drawn by pumps
_ Check voltage at breakers
_ Record run time hours
_ Inspect motors
_ Inspect PRV
_ Pressure adjustments to each zone or sprinkler

Annually

_ Inspect all sprinklers on the course
_ Replace worn parts
_ Record each head
_ Visually inspect reservoir
_ Sprinkler nozzle replacement program by zone or area
_ Clean satellite control boxes of debris, insect and/or rodent nests that may have accumulated over the previous season

Source: Hawai'i Golf Maintenance BMP Handbook, 2019

System Maintenance

Routine maintenance helps maintain water quality and ensure water is used responsibly. System checks include pumps, valves, programs, fittings, and sprinklers. An irrigation system should be calibrated regularly by conducting periodic irrigation audits to check actual water delivery and nozzle efficiency.

Best Management Practices

- Internal irrigation audits should be conducted to facilitate a high-quality maintenance and scheduling program. These should be performed by trained technicians, starting with a visual inspection to identify necessary repairs or corrective actions before carrying out other levels of evaluation.
- In addition to repair requirements - evaluate pressure, flow, and precipitation rate to determine that correct nozzles are being used and that heads are performing according to manufacturer's specifications. Pressure and flow rate checks at each head can also determine average application rate in any area.
- Interference to water distribution due to sprinklers below grade, or blockage by tree limbs and/or shrubs should be evaluated, rain sensor should be checked.
- Inspect the backflow device to determine it is in place and in good repair.
- Examine turfgrass quality and plant health for indications of irrigation malfunction or needs for scheduling adjustments, bear in mind that early symptoms of root feeding insects may initially be misdiagnosed as drought.

Preventive Maintenance

- Inspect system daily by checking computer logs and visually inspecting the pump station, remote controllers, and irrigation heads. Visually inspect for leaks, misaligned or inoperable heads, and chronic wet or dry spots.
- In older systems, inspect irrigation pipe and look for fitting breaks caused by surges. For PVC fitting and pipe failure diagnosis: https://edis.ifas.ufl.edu/ch171
- Annually service pressure regulation
- Check filter operations frequently to prolong system life and reduce costs.
- Document equipment run-time hours and monitor power consumption at pump stations to identify issues.
- Qualified pump personnel should perform quarterly checks of amperage to identify increased power usage that indicates issues.
- Increase frequency of routine inspection/calibration of soil moisture sensors that may be operating in high-salinity soils.

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

- Proper problem identification and appropriate golf course renovations can improve system efficiencies, conserve water, improve playability, and lower operating costs.
- Before starting any renovation, know the age of the system and identify renovation needs.
- Review potential steps to improve system performance by maximizing efficient use of the current system, in comparison to renovation.
- Evaluate cost of renovation and its return on investment and other benefits including financial, course playability, and turfgrass management (fewer weeds, disease, wet and/or dry spots, etc.)

Irrigation Leak Detection

Leaks in an irrigation system must be quickly detected and corrected in order to ensure efficiency, effectiveness, and minimize associated costs. Due to the complexity of irrigation systems, they require close monitoring to ensure early detection of any leaks. Golf courses without hydraulic pressure-sustaining valves are much more prone to irrigation pipe and fitting breaks because of surges in the system, creating downtime for older systems. If an area of the course is moist during dry periods and/or lush vegetation, this could indicate a leaking system.

Best Management Practices

- Monitor water meters or other measuring devices for unusually high or low readings to detect leaks or other problems in the system. Make needed repairs.
- An irrigation system should have high- and low-pressure sensors that shut down the system in case of breaks and malfunctions.
- The system should be monitored daily for breaks; log 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 by material failure or problems with the pump station.
- Ensure pump control systems provide for emergency shutdowns caused by line breaks and allow maximum system scheduling flexibility.
- Programming of central controllers with flow management software must be performed by qualified individuals who understand the relation between pipe size, flow rates, flow velocities and friction loss (of dynamic pressure) so as not to create water hammer or pressure losses by allowing zones to exceed maximum allowable values.

Winterization and Spring Start-up

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.
- Ensure irrigation buildings holding above ground pipes are heated properly and checked regularly.

Wellhead Protection

The ‘wellhead’ is the area of a well which is visible above ground – usually a PVC pipe topped with a cap. Wellhead protection is a pollution prevention technique designed to protect ground water sources of drinking water. Wellhead protection involves establishing protection zones and safe land-use practices around water supply wells in order to prevent accidental water contamination. It also includes protecting wellheads from physical impacts, keeping them secure, and sampling wells according to the monitoring schedule required by the regulating authority. When installing new wells, contact the local GCD to determine 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.

Best Management Practices

- Use backflow-prevention devices at the wellhead, on hoses, and at pesticide mix/load station to prevent contamination of the water source.
- Properly close/plug abandoned or flowing wells.
- For locations where runoff may contact and/or collect around any part of the wellhead, the area should be graded to include berms to divert surface flow away from the wellhead.
- Site new wells so surface water runoff does not contact or collect around any part of the wellhead, including the concrete pad or foundation; or construct a berm near the wellhead that is sufficient to prevent surface water runoff from contacting or collecting around wellhead.
- Surround new wells with bollards or a physical barrier to prevent impacts to the wellhead.
- Inspect wellheads and well casing at least annually for leaks or cracks; repair as needed.
- Conduct a well pump efficiency test every 1 to 5 years to monitor pump and electric motor wear. The frequency of testing should depend on the water quality with 1 or 3-year intervals for water contaminated with sand, silt, clay etc., and every 3 to 5 years for clean water.
- Maintain records of new well construction and modifications to existing wells.
- Obtain a copy of the well log for each well to determine local geology and depth; these factors have a bearing on vulnerability to contamination.
- Sample wells for contaminants according to schedule and protocol required by the DNR.
- 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.

Additional information on Texas groundwater management and regulation:

https://www.tceq.texas.gov/groundwater/groundwater-planning-assessment/gw_index.html

04

SURFACE WATER MANAGEMENT

Texas has 191,228 miles of streams, 15 major river basins, eight coastal basins, and 196 major reservoirs.

Conserving this natural resource and protecting water quality throughout the state is important for all Texans. Golf facilities can help protect waterbodies and improve surface water management through effective utilization of BMPs.

Golf courses are one link in the stormwater management chain. Stormwater that falls directly on the golf course property is supplemented by stormwater which enters from other areas, and a quantity of this water flows off the course to another area. By the very nature of water flows, golf courses are realistically capable of having a small impact on major stormwater flow. That impact should be to add only small increments of water over a given period of time; this function is referred to as “detention.”

During golf course design and construction, drainage capability is based on the average rainfall events local to the site. A typical golf course drainage system is designed to detain a two- or five-year rain event (i.e., is able to capture and manage the maximum rainfall event expected to happen over that period, based on past data). With such a system, when that rain event occurs, the golf course will be able to be reasonably drained in a matter of hours. The excess water not absorbed by the soil flows through the drainage system and is temporarily held before it finally leaves the property. In some cases, golf courses and other recreational facilities can be required to follow a design able to accommodate a 20-, 50- or 100-year rain event, which means the golf course must detain more water for perhaps a longer period of time.

All surface waters on golf courses should be managed to protect water quality and support aquatic wildlife habitats and plant species, while providing aesthetic and design features for the golf course. This is accomplished through a variety of BMPs, including incorporating natural systems for filtering to improve water quality, in addition to development of an aquatic plant management strategy for lakes, ponds, and streams located on the property.

Natural systems such as berms, swales, and buffers on a golf course can help filter pollutants from stormwater that enters the course in order to improve the quality of water leaving the property.

Regulatory Considerations

Across the state of Texas there nearly 11 million acre-feet of surface water is available for human use. There are nine major aquifers: Pecos Valley, Seymour, Edwards, Gulf Coast, Carrizo-Wilcox, Hueco-Mesilla Bolson, Edwards-Trinity, Ogallala, and Trinity. Texas receives approximately 366 million acre-feet of rain annually. Given a history of droughts and its growing population, conserving water is of critical importance for the state. All surface water in Texas is owned by the state, held in trust for the citizens of the state, and any proposed use of state water must be approved by the state through the TCEQ.

Applications for the use of state water are processed by the Water Availability Division of the TCEQ.

An uncontested application is typically processed in 300 days. Depending upon the request, an application may require one or more of the following during the Technical Review phase:

- Hydrology Review
- Environmental Review
- Conservation Review
- Dam Safety Review

Application forms and additional information:

https://www.tceq.texas.gov/permitting/water_rights/wr-permitting/wr_applications.html#process

https://www.tceq.texas.gov/assets/public/permitting/forms/10214a.pdf

Water Divisions are structured throughout the state, under Texas Water Code, a watermaster may be appointed to a Water Division to ensure compliance with water rights and coordinate diversions to prevent waste or excess use. In the Brazos, Concho, and Rio Grande River basins, watermasters allocate water between users and ensure compliance with water rights. Before diverting Texas state water, a declaration of intent must be made and approved by the watermaster of the Water Division. A water use report must be submitted to TCEQ for water rights by March 1 each year.

TCEQ Water Use Report Form

https://www.tceq.texas.gov/assets/public/permitting/forms/wur_instructions.pdf

The TCEQ regularly monitors the condition of the state's surface waters and assesses the status of water quality every two years. This assessment is submitted to the EPA and is published as the Texas Water Quality Inventory and 303(d) List of impaired waters.

Construction activities are regulated by the TCEQ to minimize contamination of water sources through the TPDES, which was established by the EPA; under provisions of Section 402 of the CWA and Chapter 26 of TWC. If the golf course is under the jurisdiction of a TPDES MS4 permit, the course should check with the permit holder if the course does not have its own SWPPP.

Additional information:

https://www.tceq.texas.gov/permitting/stormwater/construction

https://texaswater.tamu.edu/stormwater/regulations.html

https://www.tceq.texas.gov/waterquality/tmdl/nav/tmdlsegments

https://www.tceq.texas.gov/waterquality/assessment/305_303.html

Definition of State Water: Texas Water Code (TWC) § 11.021

The water of the ordinary flow, underflow, and tides of every flowing river, natural stream, and lake, and every bay or arm of the Gulf of Mexico, and the storm water, floodwater, and rainwater of every river, natural stream, canyon, ravine, depression, and watershed in the state is property of the state.

The Texas Water Development Board (TWDB) provides water planning and data collection to support the development of regional water plans covering 16 regions, which are incorporated into a state water plan for the conservation and management of the state's water resources. The TWDB also supports the development of regional flood plans, which are incorporated into a state flood plan.

Regional Water Planning Groups:

https://www.twdb.texas.gov/waterplanning/rwp/regions/index.asp

TWDB Regional Water Planning Rules & Statutes

https://www.twdb.texas.gov/waterplanning/rwp/rules/index.asp

Additional regulatory agencies which may be involved in surface water and/or stormwater management, environmental flows, floodplain management, water planning, and analysis based on jurisdiction, waterbodies, location, and legislation include the TPDW, TDA, GLO, and TSSWCB.

Texas Golf Industry BMP Guide Section references for additional regulatory considerations:

- *Irrigation: water use and reporting requirements.*
- *Water Quality Monitoring and Management: water quality regulations, regional and local administrative structure, TMDLs.*
- *Planning, Design, and Construction: stormwater and wastewater permitting during construction.*

Best Management Practices

- Adhere to federal, state, and local water management and water quality regulations.
- Golf courses must complete and submit annual water use reporting to the TCEQ annually.
- Consult federal, state, and local water management agencies, and/or consult an approved management plan before performing construction activities, irrigation installation, integrated pest management, fertilization, or aquatic plant management.
- The disposal of sediments from surface water ponds (stormwater detention) may be subject to regulation.
- 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.
- Golf course owners are responsible for adhering to TMDLs, mitigation, and WPPs; determine if waterbodies are identified as impaired and whether or not a TMDL exists; if impaired, additional BMPs may be necessary; consult with an experienced water quality professional regarding TMDL alternative plans.
- Wetlands are protected areas; consult with federal, state, and municipal agencies before altering natural aquatic areas.
- Use a meter at each source of water withdrawal. At least once per year, prior to the start of the irrigation season, calibrate meters in accordance with the manufacturer's recommendations.
- Metering of the sources should be at the discharge side of the source pumps prior to any off-take piping.
- Choose a meter that provides both a numeric cumulative volume reading and an instantaneous flow reading. This will enable the user to gauge consumption and obtain an estimation of the flow rate.

For additional regulatory considerations reference the following BMP sections: Planning, Design, and Construction; Water Quality Monitoring and Management; Irrigation; Nutrient Management, Integrated Pest Management; and Pesticide Management.

Stages of Surface Water Planning & Management

A systems approach to conserving and protecting water.

Reference Planning, Design, and Construction; Water Quality Monitoring & Management; Irrigation; Nutrient Management, IPM, Pesticide Management, and Landscape sections for additional BMPs.

Stormwater Capture

A proper golf course design allows for rain and runoff captured in water hazards and stormwater ponds to provide most or all of the supplemental water necessary for irrigation. Backup sources may be required for drought conditions. Stormwater capture allows natural systems to filter and improve water quality and is desirable where the lowest quality of water is needed. This helps to conserve potable water and maintain hydrologic balance.

Wherever possible ponds should be constructed in a series of 'train' to support treatment of stormwater runoff. Through this design the first pond will catch the "first flush", the second will provide additional filtering and the third will filter and serve as a primary withdrawal pond for irrigation; infiltrating the first inch of stormwater helps to prevent water quality impacts.

Best Management Practices

- The course site plan should maintain the natural wetland and watercourse systems and buffers, plus locate necessary stormwater management structures to upland areas. This helps maintain the natural drainage patterns and allows for recharge of runoff.
- A series or train of stormwater diversions, swales, and basins can be designed to collect stormwater runoff for use in supplementing irrigation.
- Install berms (a planted dirt mound or a log covered with soil and organic matter) and swales (trenches) to capture pollutants and sediments from runoff before these reach the irrigation storage pond.
- A swale and berm system allows for resident time (ponding) for water to infiltrate through the root zone to reduce lateral water movement to the surface water body.
- Stormwater runoff from parking lots, service areas, buildings and roadways should not be directly discharged into wetlands and watercourses. Control quality of surface runoff with appropriate filtration practices such as grassy swales, filter strips, and constructed wetlands.
- Constructed wetlands (artificial wetland to treat greywater or stormwater runoff) should have an impervious bottom to prevent groundwater contamination.
- Where seepage is discovered through pond water level monitoring, line or seal the pond or install pumps to relocate water.
- Water-intake systems that use horizontal wells placed in the subsoil below the storage basin should be installed with a post pump to filter particulate matter.
- Ensure the water management plan includes a secondary source of water as backup.
- Inspect irrigation pumps, filtration systems, conveyances and control devices to prevent and correct system issues.
- Irrigation systems should be computerized for remote monitoring and rapid shut down if needed. If a storm occurs during an irrigation cycle have the irrigation system designed to shut down automatically.

Additional stormwater information:

https://texaswater.tamu.edu/stormwater.html

Stormwater, Ponds, and Lakes

Stormwater is the conveying force behind nonpoint source pollution. Nonpoint pollution can be both manmade and natural, it comes from daily activity rather than a single outlet like a pipe from a factory or sewage treatment plant. 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. Filtration is a key ecosystem service provided by golf courses. Most golf courses plan lakes and water hazards to function as part of the stormwater control and treatment system, however natural waters of the state must be protected and cannot be considered treatment systems.

Stormwater control on a golf course involves:

- Controlling amount and rate of water leaving the course
- Storing irrigation water
- Enhancing wildlife habitat
- Removing waterborne pollutants
- Addressing aesthetic and playability concerns
- Preventing flooding of facilities and play areas
- Controlling erosion and sediment

Develop a stormwater pollution prevention plan (SWPPP), especially prior to initiating construction activities. Source control practices should limit or reduce potential pollutants at the source, which involves keeping a clean, orderly construction site. Erosion control barriers, such as silt fencing or sedimentation ponds, should be installed between ponds or streams and planned areas of turfgrass as a part of sedimentation control. The planned location of these erosion control measures should be shown in the erosion control plan and remain in place until turfgrass is matured.

Golf course stormwater management should include "soft engineering" approaches that promote the use of natural systems to filter water. The SWPPP should include establishing buffers and special management zones. Buffers should be planted with native species to provide water quality benefits, pleasing aesthetics, and habitat/ food sources for wildlife. Practices which may be included to prevent erosion can include ground covers – such as riprap, mulch or vegetation- and blankets which absorb raindrop impact, reducing erosion. Swales and ditches are also included in BMPs to prevent contact by diverting water around a site.

Stormwater management on a golf course includes storing irrigation water, controlling erosion and sediment, enhancing wildlife habitat, removing waterborne pollutants, controlling the amount and rate of water leaving the course, and addressing aesthetic and playability concerns.

Example: Steps for Maintaining A Stormwater Treatment Train

Step 1: Establish Special Management Zones defined as areas that have distinct management practices that coincide with their position in the watershed and are based on analysis of resources and habitat protection requirements.

Step 2: Use a Natural Systems Engineering Approach to stormwater management that maximizes use of natural systems to treat water. Vegetative swales, storm water ponds, marshes and wetlands can serve as habitats for many creatures, including wetland birds and other waterfowl.

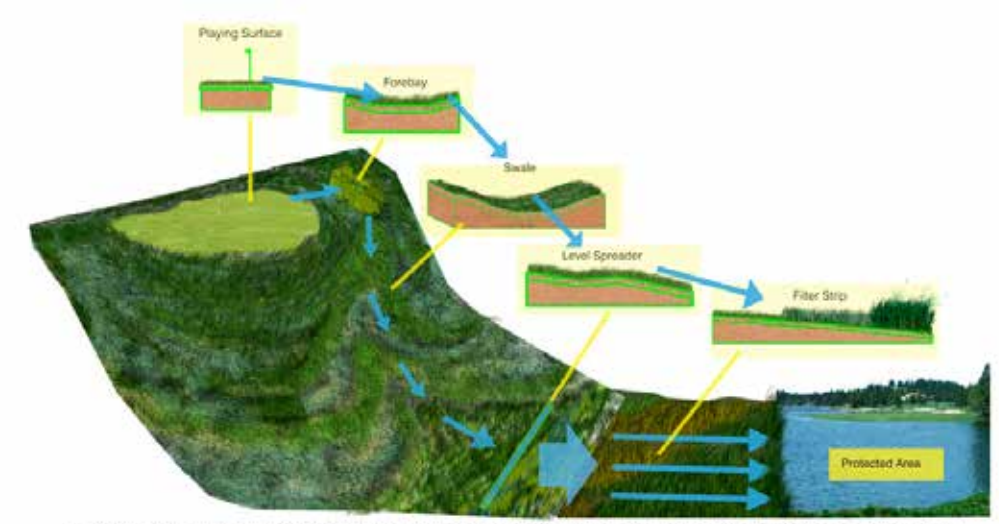
Step 3: Maximize Use of Pervious Pavements such as brick or concrete pavers separated by sand and planted with grass. Special high-permeability concrete is available for cart paths or parking lots.

Step 4: Establish BMP "Trains" for maximum environmental protection. The most effective way to protect surface water and groundwater is by using a comprehensive systems approach that includes integration of preventive practices and structural controls. Preventive measures include nonstructural practices that minimize or prevent the generation of runoff and contamination of runoff by pollutants; for example, using organic fertilizers. Structural controls are capital improvements designed to remove, filter, detain, or reroute potential contaminants carried in surface water.

A common treatment train includes turfgrass swales on side slopes designed to filter and slow stormwater, the second car in the train includes a swale or main channel that directs stormwater to the last car, often a constructed wetland. Vegetated swales slow and infiltrate water, trapping pollutants in the soil to be destroyed naturally by soil organisms. Depressed landscape islands in parking lots can catch, filter, and infiltrate water, to reduce run off. During hard rains, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediments, while allowing the overflow to drain away.

Other options to control stormwater include directing the runoff from gutter and roof drains to permeable areas where water can infiltrate near the point of generation; incorporating sand and planted grass to separate brick or concrete pavers; and using special high-permeability concrete for cart paths or parking lots.

Stormwater Treatment Train



A comprehensive systems approach uses a treatment train and the natural drainage systems to protect water quality at a high priority area.

Source: BMPs for NY State Golf Courses

Best Management Practices

- Develop a SWPPP to establish source control practices, incorporating erosion and sedimentation control measures, and special management zones.
- Organize course design to accommodate buffers and special management zones including swales and slight berms with a natural appearance where appropriate around the water's edge.
- Buffer strips can also be used to slow and subvert water and trap pollutants in the soil, where they can be naturally destroyed by soil organisms; try to utilize native species for buffers.
- Use ground covers such as vegetation, riprap, mulch, and blankets to cover bare soil and help reduce erosion.
- Sod, sprig, or reseed bare or thinning turfgrass areas.
- Direct stormwater through 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.
- Use depressed landscape islands in parking lots to catch, filter, and infiltrate water and preventing stormwater running directly off of these areas.
- Direct pipe discharges, gutters, and roof runoff to permeable areas that allow the water to infiltrate near the point of generation.
- Avoid use of impervious materials for walkways, install pervious surfaces such as brick or concrete pavers separated by sand and planted with grass.
- Discharge or divert surface runoff onto wide, relatively flat vegetated areas to promote infiltration and ground water recharge.
- Reduce frequency of mowing around lake edges and collect or direct clippings to upland areas where runoff and wind will not carry them back to the lake.
- Reverse-grade around the perimeter to control surface water runoff into ponds and reduce nutrient loads.
- 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.

Reference the Planning, Design, and Construction section for additional stormwater BMPs.

Protecting Wetlands and Environmentally Sensitive Areas

Wetlands and riparian buffers can provide enduring pollutant removal support. Preserving these areas protects the water quality of streams, wetlands, lakes, anchialine pools, coastal zones, and reservoirs.

Appropriately sized and maintained buffer strips along streambanks provide protection for stream ecosystems and can prevent erosion as well as minimize release of sediment into stream channels. Levels of suspended solids have been shown to increase at a slower rate in stream channel sections with well-developed riparian vegetation.

Buffers around the shore of a waterbody, or other sensitive area, filter and purify runoff as it passes across the buffer. Vegetative conditions and practices in construction and maintenance of buffers should include:

- Herbaceous composition of buffer strips (ideally, native species to provide filtering, habitat/food sources, and pleasing aesthetics)
- Mow herbaceous cover of buffer strips twice per year
- Remove cut material by hand

Reference Water Quality Monitoring and Management for additional BMPs and regulatory considerations regarding wetland protection.

Best Management Practice:

- Remove damage to existing landscape and ground cover conditions, including siltation, erosion, and compaction or trampling by golfers.
- Amassed silts should be removed, eroded channels filled, and compacted areas raked.
- Any repairs to buffers should be completed using hand tools only, unless a mechanical tool “arm” can reach into the wetland to perform a task.
- Damaged groundcover vegetation should be restored by seeding or planting, depending on the vegetation damaged.
- Channels which form within the filter strips should be filled and immediately reseeded.
- Utilize grading to prevent reformation of the channel and to restore sheet flows.
- Trash, golf balls, and other debris should be removed from buffers.

Designing an Aquatic Plant Management Strategy

Many aquatic ecosystems have been damaged by invasive and nuisance aquatic plant species. There are a variety of practices which may be employed to assist in restoring these aquatic ecosystems to health, including biological, mechanical, cultural, and chemical methods. An aquatic plant management strategy should address the intended uses of the waterbody to maintain water quality. Consider the site's physical attributes and location, ecosystem, watershed, presence of invasive or weedy species, aesthetics, watershed and groundwater assessments, and other environmental considerations, in addition to cost-benefit perspectives to determine management strategies.

It is also important to consider aquatic plant (and wildlife) strategy when designing and constructing ponds. Ponds that are too shallow may reach high temperatures, leading to low oxygen levels and promoting algal growth and excess sedimentation. Try to encourage clumps of native emergent vegetation at the shoreline. Ponds featuring fringes with a narrow edge of vegetation are more resistant to problems than those with highly maintained turfgrass. Plant life growing on littoral shelves may help to protect receiving waters from pollutants present in surface water runoff, and a littoral shelf may be required in permitted surface water-retention ponds. Problem plants should be selectively controlled without damaging littoral shelves.

The use of aquatic plants to improve the appearance of a pond (aquascaping) may be incorporated as part of the overall landscape design. The use of native aquatic plants promotes biodiversity and can provide benefits for pest management. Consider consulting with a professional aquatic management consultant.

Filamentous algae are usually removed by hand, or algaecide can be applied using spot treatment. Regularly assess results of invasive weed control programs (including quantitative documentation of results from control strategies) and re-evaluate management options as part of a professional plant management strategy.

Phytoplankton, which give water its green appearance, provide the base for the food chain in ponds. Floating plants suppress phytoplankton because they absorb nutrients from the pond water and create shade. 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.

Examples of Invasive and Native Aquatic Plants in Texas

Invasive Aquatic Plants

- Hydrilla
- Water hyacinth
- Giant Salvinia

Native Aquatic Plants

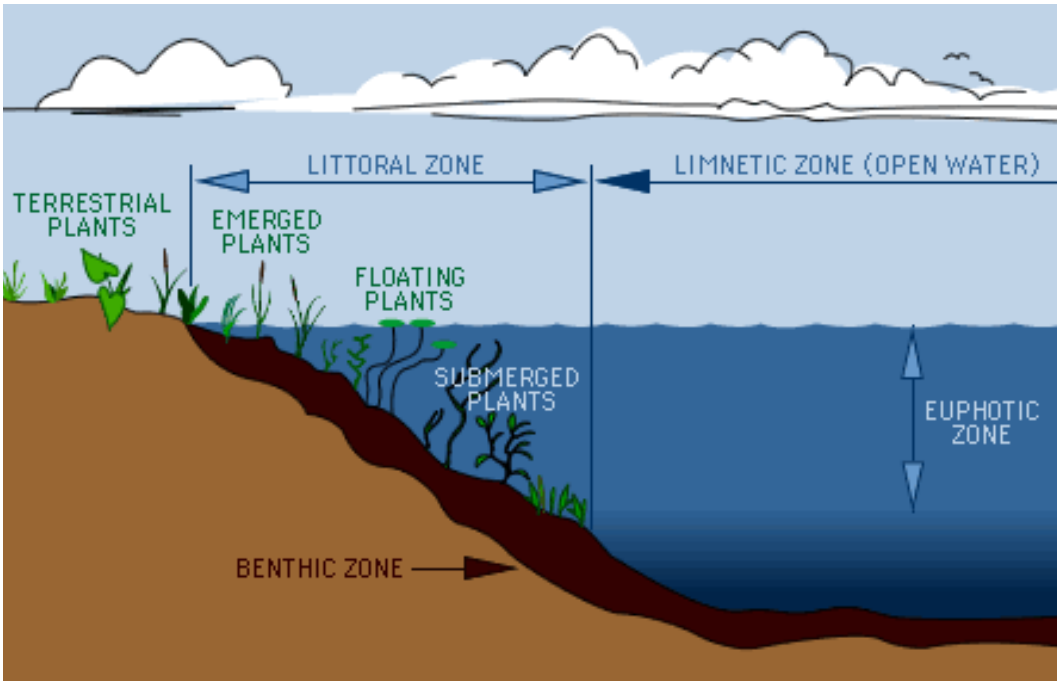
- Pickerelweed
- Arrowhead
- Water primrose

Additional information on invasive species and how to manage:

https://tpwd.texas.gov/huntwild/wild/species/exotic/index.phtml

Additional information on native and prohibited aquatic plants: https://www.tceq.texas.gov/assets/public/waterquality/swqm/monitor/training/biological/day3/AquaticPlants_Ott+Webb.pdf

Lake Zones Diagram



Source: https://www.waterontheweb.org/under/lakeecology/10_biological_lakezones.html

Best Management Practices

- Information on aquatic vegetation management in Texas, including regulations and best practice guidance is managed by TPWD: https://tpwd.texas.gov/landwater/water/environconcerns/nuisance_plants/
- 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 transport and possession 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. For information on triploid grass carp permitting reference: https://tpwd.texas.gov/landwater/water/habitats/private_water/gcarp_intro.phtml
- Native emergent vegetation should be encouraged in clumps at the shoreline.
- Ponds with narrow fringe of vegetation along the edge are more resistant to problems than those with highly maintained turfgrass.
- Littoral zone slopes should ideally be around 1-foot vertical to 6-10 foot horizontal (6% to 10%) to provide the best substrate for aquatic plant growth.
- Lake management plans should include strategies to control the growth of nuisance vegetation, which can damage a pond's water quality and treatment capacity.
- In ponds with littoral plantings, problem plants should be selectively controlled without damaging littoral shelves.
- Spot-treat filamentous algae or frequently remove algae by hand to prevent lowering oxygen concentrations in water; consider working with a reputable pond manager to strategize best ways to address.
- Where possible, allow plants such as arrowhead or pickerelweed to inhabit littoral zones to improve water quality. Beneficial aquatic plants can help filter nutrients and chemicals, stabilize shorelines, and provide important fish and wildlife habitat; consult with a professional aquatic management consultant for proper planning, permitting, and implementation.
- To reduce the risk of oxygen depletion, use an algaecide containing hydrogen peroxide instead of one with copper or endothall.

Water Quality Protection

To maintain and protect water quality and enhance endemic flora it is important to develop an aquatic/lake management plan which addresses all intended uses of the waterbody. This should include documentation of the site's physical attributes and location including the presence of invasive or weedy species, aesthetics, watershed and groundwater assessments, and other environmental considerations. Only certified applicators acting under licensed operations, whether individuals or contractors, should be allowed to select and apply terrestrial and aquatic use-site pesticides.

Courses should also develop a Stormwater Pollution Prevention Plan (SWPPP). The SWPPP describes all construction site operator activities, including sediment and erosion control measures, to prevent stormwater contamination and ensure compliance with the requirements of the CWA.

Reference Planning, Design, and Construction; Water Quality Monitoring & Management; Irrigation; IPM and Pesticide Management sections for additional BMPs.

Floodplain Restoration

Reestablishment of natural water systems helps mitigate flooding and control stormwater and should be designed based on the latest research science available. High sediment and nutrient loads and vertical and lateral stream migration should be addresses where these are causing unstable banks, flooding, and reductions in groundwater recharge.

Best Management Practices

- Use stream buffers to provide natural filtration, settling of overland flow and stabilization of banks.
- Add buffers to play areas to maintain and restore natural areas that will attract wildlife species.
- Install detention or floodwater retarding basins to store water and reduce flooding at peak flows.
- Monitor streams, creeks and rivers for debris that may inhibit or slow water flow.
- As early as possible, contact the local county (or city) floodplain manager to discuss operations and processes in the floodplain and for clarification related to local floodplain rules.

Additional information on Texas floodplain guidelines: https://www.twdb.texas.gov/flood/resources/doc/Texas_Quick_Guide.pdf

Human Health Concerns

Be sure to address areas where standing water may provide habitat for nuisance organisms.

The use of pesticides should be part of an overall IPM strategy that includes biological controls, cultural methods, pest monitoring, and other applicable practices.

Best Management Practices

- Use IPM principles to address insects that may pose a hazard to human health.
- Drain areas of standing water during wet seasons to reduce insect populations.
- Use Bacillus thuringiensis (Bt) products according to label directions to manage waterborne insect larvae.

Reference the Planning, Design, and Construction; Water Quality Monitoring and Management; Irrigation; Nutrient Management; Integrated Pest Management; and Pesticide Management sections for additional BMPs.

Ecosystem services that golf courses provide like stormwater filtration, reducing runoff, and mitigating flooding are especially critical in urban environments like Houston or Dallas-Fort Worth where greenspace is limited with office buildings, roads, sidewalks, and other impervious surfaces.

WATER QUALITY MONITORING & MANAGEMENT

Golf courses employ a variety of practices to protect surface water and groundwater quality. In Texas, these include stormwater pollution prevention plans, aquatic plant management plans, water quality monitoring plans (including water sampling), nutrient management plans, integrated pest management (IPM) plans, and other protocols incorporating BMPs designed to protect and conserve water. The following resources and references will help inform golf course water quality monitoring and management planning; owners and golf course superintendents should further investigate local surface and groundwater regulatory requirements that apply for the golf facility and its location.

Maintaining the biological soundness of Texas rivers, lakes, bays, and estuaries is of critical importance to the public's well-being and economic health of the state.

Regulatory Considerations

The TCEQ has general jurisdiction and primary responsibility over the state's water quality program including water quality management planning, issuance of permits for point source discharges, abatement of nonpoint source pollution other than from agricultural and silvicultural sources, and enforcement of water quality rules, standards, orders, and permits. The TCEQ is responsible for establishing the level of quality to be maintained in waters in the state. TCEQ Standards set explicit goals for the quality of streams, rivers, lakes, and bays. The standards were developed to support public health and enjoyment, in addition to the protection of aquatic life and its habitat. In Texas, state surface water quality standards are codified in Title 30, Chapter 307 of the TWC.

According to the TCEQ, the Texas Surface Water Quality Standards are rules designed to:

- Establish numerical and narrative goals for water quality throughout the state
- Provide a basis on which TCEQ regulatory programs can establish reasonable methods to implement and attain the state's goals for water quality

The standards are written by the TCEQ under the authority of the Clean Water Act (CWA) and Title 2, Chapter 26 of the TWC. All standards are protective to support water quality levels that are adequate to meet designated uses; monitoring determines if water quality levels are not being met.

Four general categories for water use are defined in the Texas Surface Water Quality Standards:

- Aquatic life use
- Contact recreation
- Public water supply
- Fish consumption

Some pollutants or conditions that may violate the Aquatic life use standard include low levels of dissolved oxygen, or toxic substances such as metals or pesticides.

The TCEQ regularly monitors the condition of the state's surface waters and assesses the status of water quality every two years as part of a Watershed Management Approach (WMA). Texas must identify and prepare an assessment of lakes, rivers, streams, and estuaries failing to meet or not expected to meet water quality standards and not supporting designated uses (swimming, drinking, aquatic life, etc.); this must be sent to the Environmental Protection Agency (EPA). This assessment is published as the Texas Water Quality Inventory and 303(d) List, per the requirement of the CWA, in addition to Sections 305(b) and 303(d), Title 30 of the TAC. https://www.tceq.texas.gov/waterquality/assessment

The State must then establish a Total Maximum Daily Load (TMDL) for waterbodies identified on the 303(d) List. TMDLs are scientifically derived targets that set the greatest amount of a particular substance that can be added to a waterway on a daily basis and still meet water quality standards. An Implementation Plan (I-Plan) is then developed that prescribes the measures needed to mitigate anthropogenic (human-caused) sources of the pollutant to meet the environmental target of the TMDL. The I-Plan can specify limits for point source dischargers (regulatory permits are used most often to control point sources) and recommends BMPs for nonpoint sources. It also lays out a schedule for implementation. TMDLs and I-Plans in Texas are developed by the TCEQ in conjunction with local stakeholders. Both TCEQ and TSSWCB, along with local stakeholders, initiate the development of non-regulatory Watershed Protection Plans (WPPs) to address water quality protection and restore impaired waters. There are 216 local Soil and Water Conservation Districts (SWCDs) which work with local stakeholders to promote stewardship and conservation efforts in support of WPPs. CWA Section 319 grant funds are available from each agency on an annual basis through open solicitations. Education programs alert stakeholders to watershed problems and help involve them in decision-making. These plans and implementation efforts are aligned to EPA Guidelines in support of the CWA.

Additional water quality responsibilities of the TCEQ include:

- Acting as lead agency for administering the Section 401 certification program in Texas, with the exception of oil and gas. TCEQ conducts Section 401 certification reviews of projects requiring a Section 404 permit from the U.S. Army Corps of Engineers for the discharge of dredged or fill material into waters of the U.S., including wetlands.
- The TCEQ Groundwater Planning and Assessment Team implements programs aimed at the prevention and assessment of groundwater contamination by pesticides. TCEQ monitors groundwater for pesticides and works in coordination with the Texas Groundwater Protection Committee (TGPC).

TPWD is also involved in water quality within the state. The TPWD Aquatic Resources Permitting and Consultation Program promotes conservation of the natural functions and biodiversity of aquatic ecosystems and associated riparian lands of Texas. The team reviews project proposals in the federal and state regulatory and planning processes, fish kill and pollution response, permitting, and outreach. Permitting responsibilities include activities such as introducing fish or aquatic plants into public fresh water, in addition to removal of exotic aquatic vegetation.

TCEQ surface water standards:

https://texaswater.tamu.edu/surface-water/surface-water-quality.html

https://www.tceq.texas.gov/waterquality/standards/2018-surface-water-quality-standards

https://statutes.capitol.texas.gov/Docs/WA/htm/WA.26.htm

Texas Nonpoint Source Management Program:

https://www.tceq.texas.gov/assets/public/waterquality/nps/mgmt-plan/2017_NPSManagementProgram.pdf

TPWD, SWCDs, and WPPs: https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program/watershed-protection-plan-program

Additional information on TMDLs:

https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program/total-maximum-daily-load-program

https://www.tceq.texas.gov/waterquality/tmdl

TCEQ Section 401 Certification Reviews:

https://www.tceq.texas.gov/permitting/401certification

TCEQ Groundwater monitoring for Pesticides:

https://www.tceq.texas.gov/groundwater/groundwater-planning-assessment/pesticides.html

https://www.tceq.texas.gov/assets/public/comm_exec/pubs/sfr/070_01.pdf

TPWD Permitting Responsibilities:

https://tpwd.texas.gov/landwater/water/environconcerns/permitting_consultation/index.phtml

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.
- 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.
- Golf course owners are responsible for adhering to TMDLs, mitigation, and WPPs; determine if waterbodies are identified as impaired and whether or not a TMDL exists; if impaired, additional BMPs may be necessary; consult with an experienced water quality professional regarding TMDL alternative plans.
- Wetlands are protected areas; consult with federal, state, and municipal agencies before altering natural aquatic areas.
- Constructed wetlands should have an impervious bottom to prevent groundwater contamination.
- The disposal of sediments from surface-water ponds (stormwater detention) may be subject to regulation.
- 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.
- 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

It is important to identify and explore the watershed where the golf course is located. It may be found by zip code at: https://tpwd.texas.gov/education/water-education/Watershed%20Viewer

Once the watershed is identified, check with the TCEQ and TSSWCB to see if there is a Watershed Protection Plan (WPP) for it:

https://www.tceq.texas.gov/assets/public/waterquality/nps/watersheds/wbp-listforweb.pdf

https://www.tsswcb.texas.gov/programs/water-quality-management-plan

WPPs are developed by river authorities, cities, or other local government entities; they are non-regulatory. They describe sources of pollution for a segment and define voluntary actions to reduce pollution or restore quality; they can be preventive or remedial. They are developed by TCEQ and TSSWCB in collaboration with regional and local stakeholders. WPPs are reviewed by the TCEQ or TSSWCB and submitted to the EPA for acceptance. If a WPP is in place for the site, determine overall goals and understand concerns to determine actions and tailored BMPs for the facility.

Golf maintenance practices can affect water quality both on and off-site. The site's physical attributes and location, watershed and groundwater assessments, presence of invasive or weedy species, aesthetics, and other environmental considerations, should all be identified. Trace the property's local stream to its closest outlet point and then follow it to its final destination - the major river or other waterbody into which it drains. Evaluate the site's impact and take steps to reduce pollution. To maintain water quality, surface water flows, water quality protection, and aquatic plant management strategies should be designed which address all intended uses of the waterbody.

Additional information:

https://www.tsswcb.texas.gov/programs/texas-nonpoint-source-management-program/watershed-protection-plan-program

https://www.tceq.texas.gov/assets/public/comm_exec/pubs/gi/gi-351-print.pdf

Best Management Practices

- Identify and explore the watershed within which the facility is located; determine if there is an existing WPP, determine overall goals and water quality concerns of the WPP, identify water quality actions for the facility.
- Develop a water quality monitoring plan to monitor surface water, groundwater, and pond sediments.
- Outline goals and priorities to guide the development of the BMP necessary to support the lake/aquatic management plan.
- Identify possible downstream watershed areas that could receive surface water runoff from the property.
- Indicate surface water and flow patterns, stormwater flow, as well as existing and potential
- holding capacity.
- Indicate impervious surfaces, such as buildings, parking lots, or pathways; location of all facilities, structures, treatments and measures used for soil erosion and sedimentation control and long-term stormwater management.
- Indicate major drainages and catch basins that connect to local surface water bodies.
- Accommodate/enhance natural lake processes in the construction of lakes and ponds; include herbaceous and woody vegetation and emergent and submergent shoreline plants to facilitate natural versus conventional erosion control techniques (e.g., riprap) and reduce operational costs where applicable.
- Determine groundwater locations in relation to the surface of the course, particularly in any areas that have a seasonally high-water table (<24”) or shallow bedrock (<4’).
- Identify and understand depth to bedrock, depth to water tables, and soil types.
- Establish source control practices.
- Locate and protect wellheads.
- Superintendents should monitor designated waters in their area for the persistence of highly toxic herbicides and algaecides in the environment.
- Maintain a narrow band of open water at the pond edge to control the expansion of plants into more desirable littoral plantings.
- Irrigation should not directly strike or runoff to waterbodies and no-fertilization buffers should be maintained along edges.
- Use part-circle sprinklers along perimeters of natural water features to minimize their contact with reclaimed/ fertigation overspray.
- Use IPM strategies and native or naturalized vegetation wherever practical.

- Through the IPM plan, apply appropriate herbicides to minimize damage to non-target littoral plantings.
- Use appropriate aquatic herbicides to avoid turfgrass injury.
- If possible, avoid the use of copper or aquatic herbicides; apply copper products to tie-up phosphorus and use shadding compounds to reduce light penetration as per label instructions to reduce the risk of impairing water quality and causing negative biological impacts.
- Secondary environmental effects on surface water and groundwater from the chemical control of vegetation should be monitored and recorded.
- Manage impacts from waterfowl on waterbodies; monitor for bacteria, in addition to nutrients.
- Apply fertilizer and reclaimed (reuse) irrigation/ fertigation appropriately to avoid surface and groundwater contamination.

Every golf course should have a plan to monitor the state of the environment and understand how the golf course can contribute toward environmental stewardship.

Water Quality Monitoring & Sampling

Water quality monitoring is used to determine both whether outside events are impacting the water quality entering the golf course, and whether the golf course is having a positive, neutral, or negative effect on water quality. Monitoring also provides a body of evidence on the golf course's environmental impact. It is important to include monitoring of surface water, groundwater, and pond sediments in a water quality monitoring plan.

A water quality monitoring plan should be implemented in three phases: background, construction, and long-term management. The same sites should be monitored at all stages, including preconstruction phase, although the monitoring plan can be modified based on site-specific conditions. Sampling of all watershed ingress and egress points is important to know what is flowing into the property to identify potential impacts and baseline of water quality data.

Golf course operation and basin-specific parameters of concern (including applicable WPPs and TMDLs) are used to determine sampling parameters. Typically, samples should be analyzed for nutrients, pH and alkalinity, sediments, suspended solids, dissolved oxygen (DO), heavy metals, bacteria, any pesticides expected to be used on the golf course; in addition to any other chemicals identified in TMDLs. 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. It is strongly recommended that a certified laboratory be utilized, and all QA/QC procedures followed. Consideration must be given to procedures that are simple, cost effective, and technically sound, and that minimize sampling related biases and ensure data integrity.

A single water quality sample is rarely meaningful in isolation, but regular monitoring is useful for establishing trends. Post-construction surface-water quality sampling should begin with the installation and maintenance of golf course turfgrass 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.

Seasonally the total dissolved salt concentrations (specific conductance) may become an issue if runoff from streets and highways contains deicing salts. This can potentially become a turfgrass management issue if this saline water is captured and used for irrigation. Golf courses should also sample for macroinvertebrates as determined useful by water quality specialists.

TMDL Information by Segment

Texas has more than 11,000 named water bodies. The TCEQ has divided most of the streams, lakes, wetlands, and estuaries that have large areas or are of major public interest, into segments. A segment is a water body, or portion of a water body. Segments are aggregated by basin. Texas has 23 major river and coastal basins. Contact for information on the TMDL Program: tmdl@tceq.texas.gov

TMDLs are indicated by segment as indicated on the following references:

https://www.tceq.texas.gov/waterquality/tmdl/nav/tmdlsegments

https://www.tceq.texas.gov/waterquality/tmdl/nav/tmdlsimplemented

Reference additional information:

https://www.tceq.texas.gov/assets/public/comm_exec/pubs/gi/gi-351-print.pdf

Texas 303(d) List (Category 5)

https://www.tceq.texas.gov/waterquality/assessment

Texas Accredited Water Quality Testing Labs

Reference the following link for laboratories accredited by the State of Texas under the National Environmental Laboratory Accreditation Program (NELAP). For a comprehensive list of certified analytes and methods for each laboratory, click on the "Fields of Accreditation" link at the right of the lab's information entry, contact the individual laboratory, or call the TCEQ at labprgms@tceq.texas.gov.

https://www.tceq.texas.gov/assets/public/compliance/compliance_support/qa/tx-nelap_lab_list.pdf

TWDB Groundwater Monitoring and Testing

The TWDB conducts a monitoring program for wells in the state's designated major and minor aquifers once every four years, particularly at wells previously sampled, when possible, to evaluate changes in water quality. The TWDB seeks voluntary participation in the program for identified aquifers.

Additional information:

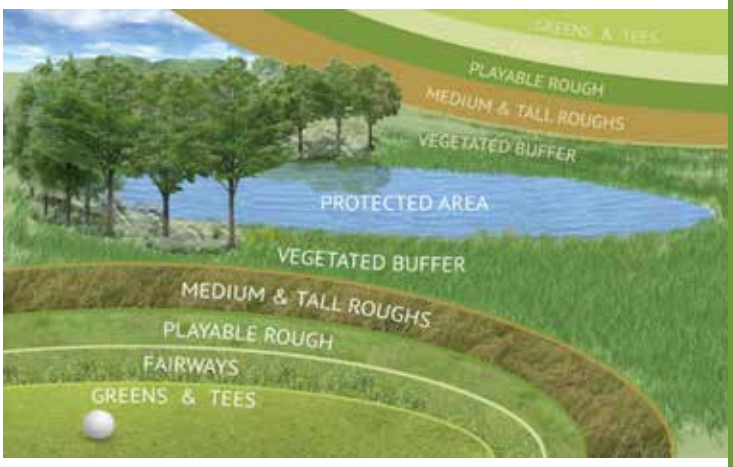
https://www.twdb.texas.gov/groundwater/data/index.asp

https://www.twdb.texas.gov/groundwater/data/doc/Well_Water_Testing.pdf

Best Management Practices

- Seek professional assistance from an environmental specialist to design an appropriate water sample collection strategy (i.e., sample water quality four to six times per year including field and lab analyses.)
- Use reputable equipment and qualified technicians to determine sites to be analyzed.
- Define data values appropriately based on the associated BMP used to protect water quality.
- Record observations of fish, wildlife, and general pond conditions.
- Generally accepted DO thresholds below which fish are stressed (3-4 ppm) or die (2 ppm) can be used as guides to implement mitigation strategies (e.g., artificial aeration). Reduce stress on fish by keeping DO levels of property ponds above 4 ppm, measured in early morning hours (between dawn and 8 am). Critical DO levels often happen at night when algae aren't photosynthesizing, a morning measurement is more indicative of whether or not there are problems.
- 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. Aeration of deep lakes is also beneficial to mix stratified layers of water of differing temperatures.
- Where applicable, aerate at night to control oxygen depletion in any pond.
- Install desirable native plants to naturally buffer DO loss and fluctuation.
- Maintain a buffer of at least 10 feet of healthy, unmowed vegetation along water edges to slow and filter overland flow to waterbodies.
- Locate littoral shelves at the pond's inlets and outlets to reduce problems with the playability and maintainability of a water hazard.
- Mow lake and pond collars at 2 inches or higher to slow and filter overland flow to water bodies.
- Avoid the use of trimmers along the edge of the water body
- Use IPM principles to limit excess use of pesticides; use a deflector shield to prevent fertilizer and pesticide spills from contacting surface waters.
- Apply algaecides to small areas to prevent fish mortality; do not treat the entire pond at once. Select algaecides containing hydrogen peroxide instead of copper or endothall to treat high populations of phytoplankton.
- Aeration and dyes have been used to maintain appropriate light and DO levels.
- Dredge excess sediments from ponds in accordance with approved plan to reduce irrigation system failures and protect beneficial organisms that contribute to the food web and overall lake health. Treat dredged materials as a toxic substance. Avoid contact with turfgrass and dispose according to approved plan.

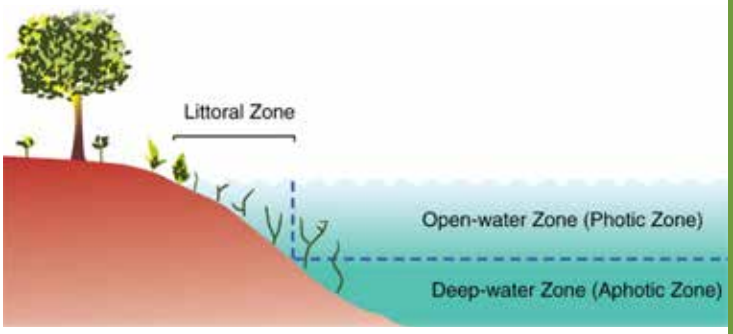
Reference the Planning, Design, and Construction and Surface Water Management for storm-water BMPs and aquatic plant management; reference IPM for pest management BMPs.



Golf Course Buffer Zones Diagram
Source: Oklahoma Golf Industry BMP Guide, 2020

Buffer Zones

Golf course stormwater management should include "natural systems engineering" or "soft engineering" approaches that maximize the use of natural systems to treat water. 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. Continue these plantings into the water to provide emergent vegetation for aquatic life, even if the pond is not used for stormwater treatment. Where possible, allow plants such as arrowhead or pickerelweed to inhabit littoral zones to improve water quality. Effective BMPs filter and trap sediment, incorporate site-specific natural/organic fertilization, and place limits on pesticide use, primarily focusing on the control of invasive species.



Littoral Zone Diagram
Source: https://www.pinellascounty.org/environment/watershed/pdf/adopta-pond/Florida_Lakes_and_Ponds_Guidebook.pdf

Best Management Practices

- Maintain a riparian buffer to filter nutrients in stormwater runoff. A riparian buffer, for the purposes of this document, is a riparian zone that is managed in a vegetated condition in order to achieve water quality protection or improvement. Riparian buffer areas are above the high-water mark and should be unfertilized and left in a natural state.
- Buffer areas of adequate size and vegetative height should be maintained along all water edges. Buffer widths should be a minimum of 5 feet but as wide as possible without impacting course difficulty, course design, or pace of play. These areas are critical in filtering overland runoff and reducing any pollutants it contains. Fertilizers and other chemicals should not be applied in these areas.
- Use turfgrass and native plantings to enhance buffer areas, provide pleasing aesthetics, habitat, and food sources for wildlife.
- Encourage clumps of native emergent vegetation at the shoreline; establish special management zones around pond edges.
- Institute buffers and special management zones up gradient of riparian buffers to protect waterbodies.
- All or most of the out-of-play waterbodies should also have shoreline buffers planted with native or well-adapted noninvasive vegetation to provide food and shelter for wildlife.
- 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.
- Increase height of cut in the riparian zone to filter and buffer nutrient movement to the water.
- Reduce the frequency of mowing at the lake edge and collect or direct clippings to upland areas where runoff and wind will not carry them back to the lake.
- An appropriate-sized buffer (steeper slope requires greater buffer width) of turfgrass mowed at a higher height of cut and minimally fertilized with enhanced-efficiency fertilizers can provide an effective buffer.
- Mow buffers on in-play areas in riparian areas to heights up to 4 inches. Mow in the direction that allows the mower discharge chute to direct clippings away from riparian areas.
- Apply fertilizer and pesticides based on the effective swath; keep application on target and away from buffers or channel swales. As a general practice, keep all chemical applications 10 to 15 feet away from the water's edge when using rotary spreaders and/or boom sprayer applications.

Wetland Protection

Texas is a large, ecologically diverse state containing millions of acres of different types of wetlands. Wetlands are the transitional zones between uplands and deep water -- they are areas that are dependent on the presence of water for all or part of the time, at or above the surface, or within the root zone. Wetland soils include soil characteristics that differ from surrounding uplands and vegetation containing plants that have adapted to the presence of water; wetlands generally lack plants that are intolerant of wet conditions. In Texas, most wetlands are categorized as: deep-water swamps, freshwater marsh, playa lakes, riparian wetlands, and saline and brackish marsh. Wetlands are recognized for their role as nurseries for many species and as filters for removal of pollutants, helping to purify surface waters. The biological activity of plants, fish, animals, insects, and especially bacteria and fungi in a healthy, diverse wetland is the recycling factory of our ecosystem.

When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turfgrass areas with native vegetation or structural buffers. Constructed or disturbed wetlands may be permitted to be an integral part of the stormwater management system. Manmade buffers should be designed to improve habitat diversity and include a mixture of fast and slow-growing native trees, shrubs, or grasses to provide a diverse habitat for wildlife.

Wetlands are protected ecosystems regulated by the US Army Corps of Engineer (USACE), as outlined in section 404 of the Clean Water Act. Activities such as filling for commercial development require a permit review process, administered by the USACE, to ensure no discharge of dredged or fill material significantly degrades the protected wetland area or to determine if a practicable alternative exists that is less damaging to the aquatic environment. Certification reviews of USACE Section 404 permit applications are conducted by the TCEQ.

Best Management Practices

- Establish, maintain, or restore wetlands where water enters lakes to slow water flow and trap sediments.
- Maintain appropriate silt fencing and BMPs 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 natural wetlands.
- Establish and maintain a 100-foot riparian buffer around wetlands, springs, and spring runs.
- Do not fertilize riparian buffer areas above the high-water mark. Leave them in a natural state.

Additional information about Texas wetlands:

https://tpwd.texas.gov/landwater/water/habitats/wetland/

https://tpwd.texas.gov/landwater/water/habitats/wetland/ecology/texas_wetlands.phtml

TCEQ Section 401 Certification Reviews:

https://www.tceq.texas.gov/permitting/401certification

https://www.epa.gov/wqs-tech/water-quality-standards-regulations-texas

Sediment

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

Best Management Practices

- Have silt fences, sandbags, hay bales or other suitable soil entrapment barriers in place at all times during construction to prevent soil and other runoff contaminant movement from unexpected rainstorms. Utilize erosion and sediment control BMPs such as wattles (logs), straw, or erosion matting as appropriate.
- Coordinate construction/renovation activities and plan in phases to minimize the amount of disturbed area and possible risk of contamination via runoff.
- 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. The drains should discharge through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments.
- Use shoreline grasses and/or other vegetation to prevent bank erosion.
- Use dry detention basins/catchments to buffer flooding and excessive runoff that may contain sediment.
- Maintain a vegetative cover on construction sites until it the site is ready for construction.
- Control cart traffic to avoid highly erodible areas.
- Use the TCEQ erosion control BMPs to guide sediment management: https://www.tceq.texas.gov/assets/public/permitting/waterquality/attachments/401certification/erosion.pdf

Sodic/Saline Conditions

Natural water contains soluble salts; however, the amount and types of salts they contain vary greatly. Reclaimed water has the potential to contain higher soluble salt concentrations than other water sources.

Pumping wells at high rates or for prolonged periods of time can degrade irrigation water. “Up-coning” can sometimes occur from pumping, which draws saline water, rather than freshwater, into the well. Typically, saline water is unsuitable for irrigation because of its high content of total dissolved solid (TDS). Saltwater intrusion from groundwater pumping near coastal areas can create a problem with some irrigation wells.

Best Management Practices

- Use surface water to mix (blend) affected groundwater to lower the total salt concentration.
- Routinely monitor water quality to ensure that salt (TDS) concentrations are at acceptable levels.
- Base management plan on routine soil tests to determine sodium adsorption ration (SAR), exchangeable sodium percentage (ESP), electrical conductivity saturated paste method/unit (ECe), and free calcium carbonate content. http://soiltesting.tamu.edu/
- Request water quality data from the reclaimed water provider to determine salt concentrations.
- Consider fertilizer that uses soluble nitrogen forms with a relatively low concentration of salts if frequent applications are necessary.
- Consider a controlled-release fertilizer to 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 by flushing soils as needed. Initiate the process with the irrigation source that is more saline and complete the process with a higher-quality water source.
- Design irrigation systems to account for flushing of salt accumulation from soil.
- Amend soil and water to lower the ESP/SAR of sodic areas.
- Evaluate BMP to determine effectiveness toward managing sodic/saline conditions.

Reference Planning, Design, and Construction; Surface and Stormwater Management; and Irrigation BMP Sections for additional information.

06

NUTRIENT MANAGEMENT

Proper golf course nutrient management is central to maintaining healthy turfgrass, reducing environmental risk, and managing expenses. Proper nutrient selection, application method, fertilizer application rates, and scheduling allow turfgrass to recover from damage, increasing its resistance to stress, and improving playability. It is important to follow a thoughtful nutrient management plan to maximize turfgrass health and minimize potential risk to the environment. Proper management helps prevent leaching or runoff in order to protect surface and groundwater resources. The goal of a nutrient management program should be to apply minimal nutrients to achieve an acceptable playing surface in the most efficient manner, helping the plant to recover from the stresses that it faces. Examples of stresses include excessive wear, drought, disease, and insect pests.

The foundation of a nutrient management program incorporates three types of professional analysis in order to ensure turfgrass health, performance, and recovery: soil, plant tissue, and water sampling.

Regulatory Considerations

The Office of the Texas State Chemist (OTSC) governs fertilizer laws and rules regarding manufacturing, distribution, and labeling of commercial fertilizers within the state. Depending on the location, regulatory agencies may include local policies. In general, if the location is regulated by nutrient policies (such as required nutrient management plans), all nutrient BMPs will need to be designed according to these policies.

Additional information on Texas Agriculture Code, Chapter 63, Sec. 63.031, Texas Administrative Code, Title 4 Agriculture, Chapter 65, and OTSC laws and rules:

https://otscweb.tamu.edu/Laws/FertLaws.aspx

https://statutes.capitol.texas.gov/Docs/AG/htm/AG.63.htm

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 while reducing their loss to the surrounding environment.

Soil Testing and Soil Health

Texas climate and parent materials produce extremely diverse soils. With 15 land resource areas across Texas and approximately 1,300 mapped soil series there is significant variation in soil health and requirements. Most Texas soils are classified into 7 major soil orders: Alfisols, Aridisols, Entisols, Inceptisols, Mollisols, Ultisols, and Vertisols. There are also small areas of two other orders (Histosols and Spodosols).

Although soils are acidic in the eastern part, most Texas soils have neutral or alkaline pH, and the majority of native soils have low phosphorous availability and high potassium (except those in the eastern portion of the state). Soil testing is an important step to aid with diagnosis, treatment, and maintenance of healthy turfgrass.

Soil in good health retains water, releases nutrients, and drains well. A well-balanced soil must contain adequate nutrients, optimum pH, and organic matter to produce high-quality playing surfaces and turfgrass health. The purpose of soil sampling is to provide a detailed report of variables such as the soil's microbiology, composition, pH, organic matter content, salinity, and nutrients available for plant use. It also offers a prediction of how a plant will respond to applied nutrients. Proper use of testing results includes analysis, interpretation, and recommendations.

Determine management areas of the golf course and take 10 to 15 random soil core samples from each area. Each sample should be from the same depth, a six-inch depth (or four-inch for golf greens and tees). Break the cores and mix them together in a clean plastic bucket, removing debris. Determine a labeling system and place three cups of the mixed soil in a labeled bag for the soil testing lab.

Select a laboratory which uses a nutrient extraction method appropriate for the soils. The Mehlich-3 soil tests are common in Texas. Texas A&M University AgriLife Extension Service may be consulted to get the most current information and to better understand which soil test values are relevant for the location. The local conservation district and or USDA Natural Resources Conservation Service may also be able to provide technical assistance to help understand local soil processes and health:

https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=TX

Best Management Practices

- Accurate and consistent sampling is essential to providing useful soil test information over time.
- Divide the course into logical components such as greens, fairways, tees, roughs, etc., for each hole.
- Randomly collect 10 to 15 soil samples from each section, at the same depth (6” depth or 4” for golf greens and tees), and blend together to provide a representative, uniform soil sample.
- The same extraction method must be used for each test in order to compare results over time.
- If the location has correlation data between a given nutrient applied to soil and a response to that nutrient by turfgrass, then recommendations may provide expected results.
- If the location does not have correlation data, then soil test recommendations may be of little value.
- Maintain soil test records from prior years to allow observation of changes over time.
- This practice can provide good evidence of the impact of the nutrient management plan

Soil Sampling / Testing in Texas

Soil tests can be used to estimate the kinds and amounts of soil nutrients available to plants. They also can be used as aids in determining fertilizer needs. Properly conducted soil sampling and testing can be cost-effective indicators of the types and amounts of fertilizer and limestone needed to improve crop yield.

Soil, Water and Forage Testing Laboratory
2478 TAMU
College Station, Texas 77843-2478

Address for all other couriers (FedEx, UPS and etc.):
Soil, Water and Forage Testing Laboratory
2610 F&B Road
College Station, Texas 77845
http://soiltesting.tamu.edu/

Stephen F. Austin University
Soil Testing Lab
Ag Building Room 122
Wilson Drive, P.O. Box 9020
Nacogdoches, TX 79562
(936) 568-4500
http://www.sfasu.edu/academics/colleges/forestry-agriculture/academics/agriculture/research-outreach/soil-plant-water-analysis-lab

A & L Ag laboratories
302 34th Street, P.O. Box 1590
Lubbock, TX 79408
(806) 763-2760

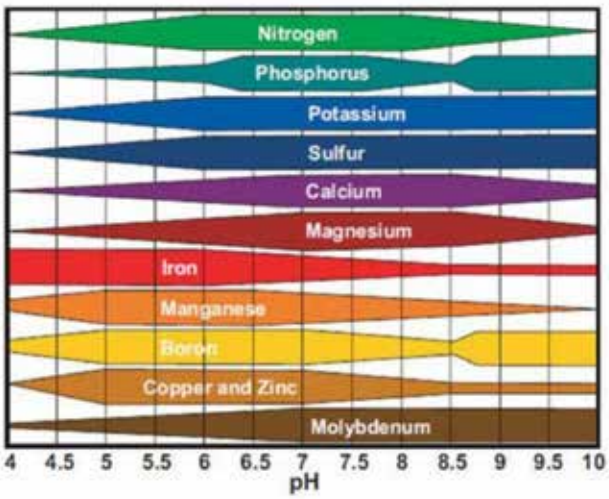
High Plains Laboratory, Inc
1502 W. Park, P.O. Box 791
Hereford, TX 79045
(806) 364-0242
http://www.highplainslab.com

Texas Plant and Soil Lab
4915 W. Monte Cristo Rd.
Edinburg, TX 78541
(956) 383-0739
https://www.tpslab.com/soil-testingf0866a47

Thomas Turf Services
11183 State Highway 30
College Station, TX 77845
Attn: Bob Yzaguirr
(979) 774-1600
http://thomasturf.com/

Nutrient Availability Relative to Soil pH

In most cases, a pH of 6-7 is ideal because it provides the greatest availability of all essential nutrients for turfgrass.



Source: R. Goldy, Michigan State University Extension

Soil pH

Identifying pH levels may be the most important soil test results for turfgrass managers. The pH scale varies from 0 to a high of 14 with 7 considered being neutral. The pH value represents how much Hydrogen (H+) is present in the soil. Values below 7 contain more H+ and are considered more acidic and values above 7 have less H+ and are considered more alkaline. It is worth noting that pH is a logarithmic scale, meaning each change in one whole number signifies a tenfold increase/decrease in value. Therefore, a soil with a pH of 6 is ten times more acidic than a soil with a pH of 7. Typically, soil pH can vary from 4 to 10.

The soil pH is usually a function of precipitation which induces more leaching of Ca, Mg, and K ions which are replaced with H and Al ions. Other factors that affect soil pH are parent material of the soil, organic matter content, and fertilizing practices. Nitrogen applications generally have an acidifying affect because of the release of H ions.

Soil pH adjustments are difficult on established turfgrass. Often, large quantities of certain elements are needed to see significant changes in soil pH and therefore are best accomplished before turfgrass establishment. The pH of irrigation water can have a cumulative effect on soil pH since it is the input that is applied most often throughout the growing season.

In some cases, it may be necessary to correct for acidity or alkalinity. The Texas Almanac has a full list of the different soil types found in Texas: https://texasalmanac.com/topics/environment/soils-texas

When a soil test indicates an acidic soil, the following materials are most commonly used as amendments:

- Calcitic limestone- CaCo3
- Dolomitic limestone- CaMg (CO3)

Soil tests are the only way to determine if the turfgrass soil requires limestone. The rate required for liming materials is determined both by the starting pH and by the soil texture. Soils with more clay and silt require more limestone than sandier soils. Soils with higher organic matter content may also require more limestone than a soil with a lower organic matter content.

If a soil test shows a pH of above 8.0, it is considered alkaline and the pH should be lowered when possible. In this situation, an application of Sulfur (S) at the appropriate rate (depending on if it is pre-plant or post-plant) can help decrease pH to more favorable levels. Sulfur can be applied by using elemental Sulfur, Ammonium sulfate, iron sulfate, or potassium sulfate. Based on area soils, it may be easier to raise the pH than to successfully and consistently lower it. Consult a soil specialist in the case of high alkalinity to ensure a strategic plan is in place.

Best Management Practices

- Maintain a pH in the range of 6.2 to 7.0 to optimize nutrient availability and reduce fertilizer requirements.
- A liming material (calcium carbonate, calcium oxide, dolomitic limestone) that contains Ca and neutralizes acidity can be applied to increase soil pH.
- Limestone moves slowly through the soil profile at a rate of .5 inch to 1 inch per year. It may take two or more years for limestone to increase the pH of the rootzone. Test soil every two years to determine pH and make corrective applications.
- Products containing elemental sulfur (calcium sulfate, magnesium sulfate, potassium sulfate) should be applied when soil pH needs to be lowered.
- Regular nitrogen fertilization will slowly reduce the soil pH over time.
- In some cases, utilizing injection pumps into irrigation water to address pH can be beneficial.
- Often, high pH soils (above 8) contain excess sodium (Na), in which case gypsum (CaSO4) would be useful to improve soil structure, nutrient availability, and plant health.

Plant Tissue Analysis Labs in Texas

Soil tests can be used to estimate the types and amounts of soil nutrients available to plants. They also can be used as aids in determining fertilizer needs. Properly conducted soil sampling and testing can be cost-effective indicators of the types and amounts of fertilizer and limestone needed to improve crop yield.

Texas A&M AgriLife Extension Service
Diagnostic Testing Lab
1500 Research Parkway, Suite A130
College Station, TX 77845
(979) 845-8032
https://agrilifeextension.tamu.edu/browse/diagnostic-labs-services/
http://soiltesting.tamu.edu/webpages/swftlmethods1209.html

TPS Lab
4915 W. Monte Cristo Rd.
Edinburg, TX 78541
(956) 383-0739
https://www.tpslab.com/plant-testing

Plant Tissue Analysis

Nutrient management decisions should be guided with plant tissue analysis in conjunction with soil samples taken from the same areas. Plant nutrient content can be analyzed from clippings for nutrient concentration levels. These values are compared to a critical level range indicating deficiency, sufficiency, or excess. The following should be monitored: turfgrass quality, clipping yield, and performance. Analysis of these variables can be used to support nutrient management decisions. Low nutrient levels in tissue may indicate compromised root health/uptake that may be caused by other biotic and abiotic issues (nematodes, compaction, disease, etc.) Tests every three to six months is recommended on greens and every six to twelve months on tees and fairways.

Best Management Practices

- Tissue samples may be collected during regular mowing.
- Do not collect tissue after any event that may alter nutrient analysis.
- Place tissue in paper bags. Do not use plastic.
- If possible, allow tissue samples to air dry before mailing them.
- Sample poor quality turfgrass that is of concern separately from higher quality turfgrass.
- Collect a sample as soon as turfgrass begins to show signs of nutrient stress.
- More frequent tissue sampling allows more accurate assessment of turfgrass nutrient status and how it changes over time.
- The quantity of tissue analysis should be based on individual site needs. Two to four site tests per year are common on greens while 1 to 2 tests per year are common on fairways and tees.
- Keep tissue tests from previous years for observation of changes over time.
- Tissue testing can provide good evidence of the impact of nutrient management programs.

Water Sampling

The largest input to turfgrass is often water applied through irrigation. Impacts of water quality can have significant impacts on soil nutrients, soil structure, and nutrient availability. Water tests, along with soil sampling, will provide the greatest level of understanding to the proper ratios of applied nutrients required. Keep accurate records to show impact from the NMP. Managing a spreadsheet of sampling over time assists in understanding long-term impact on soil and plant health.

Reference Water Quality Monitoring and Management, Surface Water Management, and Irrigation (accounting for nutrients in reclaimed water) for additional BMPs.

Fertilizers Used in Golf Course Management

The components of fertilizers are important to understand in order to make informed decisions and appropriate applications. Carbon, oxygen, and hydrogen are among the 18 nutrients considered to be essential for the growth of plants. Natural processes within the plant allow for these three elements to be provided and they are generally not supplied as fertilizer.

The remaining 14 essential elements are further classified as either macronutrients or micronutrients.

Macronutrients:

- Nitrogen (N)
- Phosphorus (P)
- Potassium (K)
- Calcium (Ca)
- Magnesium (Mg)
- Sulfur (S)

Micronutrients:

- Iron (Fe)
- Manganese (Mn)
- Boron (B)
- Copper (Cu)
- Zinc (Zn)
- Chlorine (Cl)
- Nickel (Ni)
- Molybdenum (Mo)
- Cobalt (Co

Each of these nutrients are essential and used in various amounts within the turfgrass plant. Those used in the greatest quantities are nitrogen (N), phosphorus (P), and potassium (K). These three nutrients are often found at levels insufficient for optimum growth and therefore, they are often the largest component of turfgrass fertility programs. Note that it is important to understand that “greater quantities” doesn’t necessarily mean “more important”. Justus von Liebig’s Law of the Minimum states that yield is proportional to the amount of the most limiting nutrient, whichever nutrient it may be – in other words, a nutrient management program is only as strong as its weakest link. Meaning if N, P, and K are all there – but iron isn’t, the turf will still suffer.

Nutrient Management Terminology

Developing an efficient nutrient management program requires a good understanding of the components of fertilizers, the fertilizer label, and the function of each element within the plant.

- Grade or analysis is the percent by weight of Nitrogen (N), Phosphorous fertilizer (P_2O_5) and Potassium fertilizer (K_2O) that is guaranteed to be in the fertilizer.
- A complete fertilizer contains N, P_2O_5, and K_2O.
- The laws governing the labeling of fertilizer vary greatly among states. Consult https://otscweb.tamu.edu/Laws/FertLaws.aspx

Label

The label is intended to inform the user about the contents of the fertilizer which, if understood and followed, will result in little to no environmental risk. The fertilizer label may contain:

- Brand
- Grade
- Manufacturer’s name and address
- Guaranteed analysis
- “Derived from” statement
- Net weight

Best Management Practices

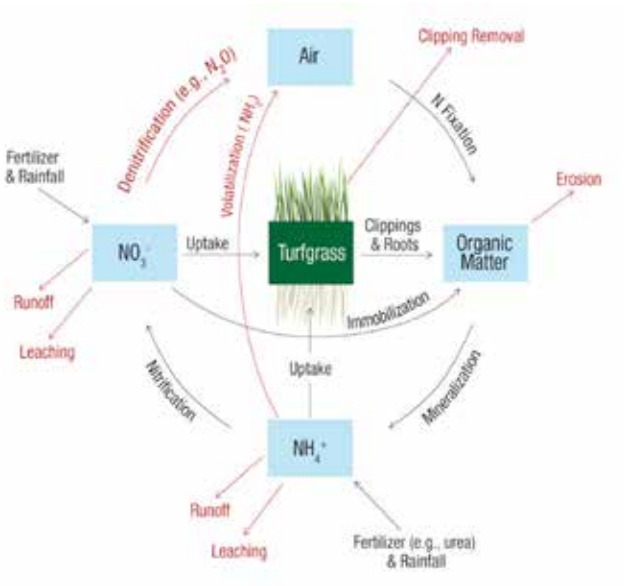
- Understand the importance of application timing for effective use of applied nutrients.
- The objective of all nutrient applications is to maximize plant uptake and the corresponding desirable response. Remember the 4R's: right source, right rate, right time, right place; a general guide to help keep nutrients on and in the area of application.
- Conduct soil testing to determine exact nutrient or other soil needs.
- Apply soluble/quick-release nutrients when turfgrass is actively growing.
- Apply slow-release nitrogen fertilizers at the appropriate time of year to maximize the products' release characteristics. Nitrogen application rates from slow-release materials should take into consideration the release rate of the chosen material. If insufficient material is applied, the desired response may not be observed.
- Consult Texas A&M University AgriLife Extension for efficient nutrient application levels in the location.
- Excessive traffic damage on putting greens or tee boxes and compaction due to cart traffic on fairways can affect turfgrass health, which may result in an increased need for nutrition; monitor wear and provide nutrients as needed to promote recovery.
- Fairways and roughs often require fewer nutrient inputs than other locations because of their increased height of cut, lower levels of damage, clipping return, and base of native soils.
- Exercise caution when applying nutrient applications during turfgrass establishment as these applications are particularly susceptible to loss via leaching and runoff; consider "spoon-feeding" areas during establishment (lower rates, increased frequency) until a more robust root system is developed.
- Apply appropriate rates and products to minimize N loss without reducing turfgrass establishment.
  - Increased water applications
  - Increased nutrients to hasten establishment
  - Reduced root mass
- Be aware of the different types of spreaders and understand the advantages and disadvantages of each.
- Not all fertilizers can be spread with every spreader. For example, if sulfur-coated urea was spread through a drop spreader, the sulfur coating could be damaged, essentially leading to an application of soluble urea. Be sure to consult the product label, many products will be explicit on the label regarding what kind of equipment should be used.

- Choose the appropriate application equipment, correctly calibrated, for a given fertilizer material.
  - Walk-behind rotary
  - Drop spreader
  - Bulk rotary
  - Sprayer
- Proper fertilizer storage, loading, and clean-up reduce environmental risk.
- Avoid applying fertilizer to wet soils that are at, or near, field capacity or following rain events that leave the soils wet.
- Do not apply fertilizer when the National Weather Service has issued a flood, storm watch or warning, or if heavy rains are likely.

Reference additional information:

https://soils.wisc.edu/facstaff/barak/soilscience326/lawofmin.htm

Simplified conceptual model illustrating the nitrogen cycle.



Source: https://www.gcmonline.com/course/environment/news/turfgrass-nitrous-oxide

Nitrogen Cycle

Environmental factors and management practices at the time of fertilizer application may influence nitrogen processes on the turfgrass and in the soil; these practices may cause nitrogen loss through multiple nitrogen pathways in the soil-plant-atmosphere system. Proper management of the source, rate, timing, and method of N application can help reduce N loss to prevent potential negative environmental effect due to leaching, denitrification, and volatilization.

Macronutrients

Macronutrients are required in greater quantities and include Nitrogen (N), Phosphorous (P), and Potassium (K). Understanding the role of each of these macronutrients within the plant will provide a greater understanding of why these nutrients play such a key role in proper turfgrass management.

Role of Nitrogen

- Nitrogen (N) is typically required in greater quantities by turfgrasses than any other element except carbon (C), hydrogen (H), and oxygen (O). N plays an important role in numerous plant functions including being an essential component of amino acids, proteins, and nucleic acids.
- The goal of all applied nutrients is to maximize plant uptake while minimizing nutrient losses. Understanding each process will increase ability to make sound management decisions and increase profitability while reducing environmental risk.
- To aid in this, understand the fate and transformation of N along with the release mechanisms and factors affecting N release from various N sources.

Nitrogen Processes

Mineralization	microbial mediated conversion of organic N into plant-available NH_4
Nutrification	microbial-mediated conversion of NH4 to NO3
Denitrification	microbial mediated conversion of NO3 to N gas; this primarily occurs in low-oxygen environments and is enhanced by high soil pH
Volatization	conversion of NH4 to NH3 gas
Leaching	downward movement of an element below the rootzone
Runoff	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 how they are released. Each N source is unique and should be managed accordingly. Applying a polymer-coated urea (PCU) in the same manner as a sulfur-coated urea (SCU) greatly reduces the value of the PCU. Similarly, applying 2 pounds of N from ammonium sulfate may cause burning, while applying 2 pounds of N from certain PCUs may not provide the desired turfgrass response. Rate, release curve, application date, location, and turfgrass species should all be considered in the nutrient application decision.

Soluble nitrogen sources:

- Urea (46-0-0)
- 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)

Advantages and disadvantages of soluble, quick-release nitrogen sources

Advantages:

- High percentage of N by weight.
- Provides an immediate response.
- Minimal temperature dependency that provides good response under cold temperatures in spring and fall.
- Relatively inexpensive per unit of N.

Disadvantages:

- Provide only a short-term response. Effectiveness typically lasts only four weeks or less, which necessitates more frequent applications.
- High salt index and a high foliar burn potential. It needs to be watered in immediately after application.
- Higher leaching potential because of solubility, particularly in sandy soils.
- Higher volatilization potential especially with the ammonium-containing forms.
- Higher denitrification potential especially with the nitrate containing forms.
- Impart an acidifying effect in the soil solution.

Quick-release sources of N are often characterized by short bursts of growth followed by slow growth resulting in a peak and valley growth response by turfgrasses that may result in compromised root growth.

Slow-release nitrogen sources:

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

Advantages and disadvantages of slow-release N formulations

Advantages:

- Provides more uniform turfgrass response during the growing season and does not produce peak and valley growth.
- Lower salt index and a lower foliar burn potential in most situations. Minimal temperature dependency that provides good response under cold temperatures in spring and fall.
- Has a long-term turfgrass response and can carry over from year to year.
- Lower potential for leaching, denitrification, and volatilization losses.
- Needs to be applied less frequently; and with the natural organic forms, they often supply other nutrients.

Disadvantages:

- Higher cost per unit of N.
- May not supply sufficient N needed by the grass.
- Some are more dependent on temperature for release than the quick-release forms.

Slow-release fertilizers are any fertilizer where the release of the N into the soil is delayed either by requiring microbial degradation of the N source, by coating the N substrate which delays dissolution of N, or by reducing the water solubility of the N source. These products are dependent on microbial activity, so there can be some variability in their performance as a function of soil ecology, moisture, and temperature.

Some fertilizers combine both slow- and quick-release forms combining the advantages of both.

Urease and nitrification inhibitors:

- Urease inhibitors reduce the activity of the urease enzyme resulting in a reduction of volatilization and 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 loss via denitrification and an increase in plant available N.

Role of Phosphorous

- Phosphorus (P) is essential for plant growth and is involved in the transfer of energy within the plant. The role of phosphorous is important in seed germination, seedling vigor, and rooting responses. P is critical in turfgrass establishment and should be incorporated during establishment when soil tests indicate a deficiency.
- P can be a growth limiting factor for many organisms and is a major contributor to eutrophication of water bodies. Proper timing and rates should be adhered to in order to reduce the risk of off-site movement. P loss often occurs with sedimentary runoff loss caused by sparse vegetation and exposed soil; take steps to mitigate soil loss and avoid application to bare soil.
- P may remain in an organic form or may become incorporated into organic compounds and application rates should be based upon soil test results from documented correlations demonstrating a turfgrass response to soil test phosphorous levels.

Phosphorous deficiency symptoms:

- Deficiency symptoms include slow growth and weak stunted plants.
- Initially, reduced shoot growth and dark green color may be observed.
- Subsequently, lower leaves may turn reddish at the tips and then the color may progress down the blades.

Phosphorous fertilizer sources:

- Diammonium phosphate (18-46-0)
- Concentrated superphosphate (0-46-0)
- Monoammonium phosphate (11-52-0)
- Natural organics

Role of Potassium

- Potassium (K) is an essential element directly involved in maintaining the water status of the plant, turgor pressure of cells, and opening and closing of the stomata. K is of no environmental concern, but can be an economic concern, especially when K is over-utilized, which is quite common. As a general rule, concentrations of K are about 1/3 to ½ of N.
- K is not a component of any organic compound and moves readily within the plant. K is a key driver of osmoregulation which has been documented to increase stress tolerance.
- K deficiencies are generally a greater concern in sand-based root zones prone to leaching as K is highly soluble, monitor K levels more closely in greens and tee boxes.

Phosphorous deficiency symptoms:

- Except under severe, documented deficiencies, K may not have an observable influence on turfgrass appearance. Yellowing of older leaves followed by tip dieback and scorching of leaf margins have been reported.
- Tissue concentrations of less than 1% are considered deficient.

Potassium sufficiency ranges:

Consult TAMU for sufficiency ranges for the specific location.

Potassium fertilizer sources:

- Potassium sulfate (0-0-53)
- Potassium chloride (0-0-62)
- Potassium nitrate (13-0-45)Natural organics

Secondary Macronutrients

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

Role of Secondary Macronutrients

Calcium (Ca)	• Primary component of cell walls and structure. • Found in gypsum, limestone, and calcium chloride.
Magnesium (Mg)	• Central ion in the chlorophyll molecue and chlorophyll synthesis. • Found in S-Po-Mg, dolomitic limestone, and magnesium sulfate.
Sulfur (S)	• Metabolized into amino acid, cysteine, used in various proteins and enzymes. • Found in ammonium sulfate, elemental sulfur, gypsum, potassium sulfate.

Micronutrients

- Understanding the role of micronutrients within the plant should provide a greater understanding of why these nutrients play such a key role in proper turfgrass management.
- Micronutrients are just as essential 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 TAMU for sufficiency ranges of micronutrients in the specific location.

Role of Micronutrients

Iron (Fe)	• Is part of catalytic enzymes and is required for chlorophyll synthesis • Affects photosynthesis, nitrogen fixation, and respiration
Manganese (Mn)	• Involved in photosynthesis • Required as a cofactor for ~35 enzymes • Lignin biosynthesis depends on Mn
Boron (B)	• Found in the cell wall: probably required for the structural integrity of the cell wall.
Copper (Cu)	• Cu-protein is involved in photosynthesis • Cofactor for variety of oxidative enzymes.
Zinc (Zn)	• Structural component of enzymes • Protein synthesis requires Zn • Carbohydrate metabolism affected by Zn
Molybdenum (Mo)	• Primarily related to nitrogen metabolism • Structural and catalytic functions of enzymes.
Chlorine (Cl)	• Required for oxygen-evolving reactions of photosynthesis • Also appears to be required for cell division in both leaves and shoots.

Biostimulants to Reduce Environmental Stress

A biostimulant is an organic material. When applied in small quantities it enhances plant growth and development. Biostimulants are thought to alter physiological plant processes and regarding turfgrass are usually marketed as soil amendments or as an additive to fertilizers. They are used to reduce environmental stress effects on grasses and have also been found to improve grass growth and root development.

Seaweed extracts, humic acids, triazole fungicides, amino acids, potassium silicate, and salicylic acid are among the natural materials have been shown to have biostimulant effects. Products that contain acibenzolar, various pigments, fosetyl and cytokinins also have stress reducing properties.

Best Management Practices

- Seek out the best biostimulants by reviewing data from university studies, independent research, and talking with peers.
- Include amino acids and products containing humic acids and cytokinins, such as seaweed extracts in sprays on fine turfgrass.
- Begin spraying biostimulants just prior to the onset of the hottest months of the summer to condition turfgrass.
- Use biostimulants as an additive to spoon feeding fertility programs for highly stressed areas like greens.
- Mineral fertility inputs can be reduced when using biostimulants to help improve environmental conditions.

Calibration and Equipment

It is important to be clear on the amount of fertilizer used in any application. This can be managed through regular calibration of application equipment, administered with preventive maintenance in accordance with manufacturer's recommendations or whenever wear or damage is suspected. Sprayer and metering pumps on liquid systems need to be calibrated regularly to save costs and minimize risks of environmental damage.

Application equipment should be selected according to the fertilizer material being used. Walk-behind rotary, drop spreader, bulk rotary or vicon, and spray spreaders all have different purposes. For example, a rotary spreader is usually used for granular fertilizers, whereas foliar feeding and liquid fertilization require use of a soluble nutrient. When applying granular fertilizer close to waterways or other non-target areas, always use a deflector shield to prevent inappropriate distribution. Avoid application onto impervious surfaces – minimize overspray and sweep granules back onto the turfgrass to reduce environmental loss and waste.

With foliar feeding and liquid fertilization, lower weighted quantities are applied at any one time, nutrients are used more rapidly, and deficiencies are corrected in a quicker amount of time. Frequent "spoon feeding" is most effective for avoiding accidental fertilizer losses to the environment while reducing potential for spikes or low growth rates that impact play, turfgrass recovery, clipping yield, weed establishment, disease outbreaks, and aesthetics.

Schedule and Timing

An application schedule by area should be developed for fertilizer application. Incorporate this into the nutrient management plan, showing the monthly amounts of N and P to be applied during the growing season. Maintain records of fertilization (including date, location, fertilizer applied, rates, grade, N source, percentage of slow-release N, form, and applicator).

Putting greens, due to their reduced height-of-cut and excessive traffic, have a higher need for growth and increased nutrition needs. Fairways and roughs generally have lower fertility requirements and require fewer nutrient inputs than tees and landing areas, which suffer constant divot damage.

Avoid applying fertilizer to soils that are at, or near, field capacity or following rain events that leave soils wet. Do not apply fertilizer when the National Weather Service has issued a flood warning or if heavy rains are likely.

Storage and Transport

Improper fertilizer storage, loading, and clean-up contribute to increased environmental risk levels. Fertilizer should be loaded into application equipment away from wells or surface water bodies. If a hard surface pad is unavailable, a tarp should be spread to collect spillage. All spillage material should be immediately cleaned up and applied as fertilizer. If fertilizer is deposited on cart paths, parking lots or other impervious surfaces, sweep the material onto the turfgrass to be properly absorbed.

07

CULTURAL PRACTICES

Cultural practices such as mowing, soil aerification, tree and shade management, and organic matter management (i.e., verticutting and other methods of thatch management) are essential to providing a high-quality playing surface. Turfgrass cultivar, climate, budget, and golf course expectations are all important aspects of necessary BMPs and inform how they are best carried out.

Mowing

When developing a management plan, mowing is one of the most fundamental cultural practices to include. Turfgrass growth rate, texture, density, color, wear tolerance, and root development are all affected by mowing practices.

When it comes to turfgrass, mower types, frequency, and mowing height matter. More frequent mowing increases shoot density and tillering, but it also decreases root and rhizome growth due to the stress related to leaf tissue removal. Conversely, mowing too infrequently leads to alternating vegetative growth cycles followed by scalping which can further deplete the plant's food reserves.

There are several factors that determine proper mowing height including frequency, shade, root growth, abiotic and biotic stress, mowing equipment, and season of the year. The impact of these factors depends on which turfgrass species and/or cultivar is being managed and the intended use of the area. Improper mowing practices can result in weakened turfgrass with poor quality and density.

Maintaining an optimal root-to-shoot ratio is crucial. Mowing turfgrass too low at one time can cause an imbalance between the root system and the residual vegetative tissue. This will leave more roots present than the plant physiologically needs and cause the plant to shed unnecessary roots. Turfgrass cut too short will result in plants that need ample time to provide enough food to produce shoot tissue for future photosynthesis. It is best not to remove more than 30 to 40 percent of the leaf area in a single mowing as the root growth will be least affected.

Mowing frequency required during active growth, conforming to 1/3 rule based on mowing heights

Mowing Height (Inches)	1/3 rule Height (inches)	Frequency
0.12	0.18	Every 1-1.15 days
0.25	0.37	Every 2 days
0.50	0.75	Every 2-3 days
1.0	1.5	Every 3-4 days
1.5	2.25	Every 4-5 days
2.0	3.0	Every 5-6 days
3.0	4.5	Every 6-7 days

Common recommended golf course mowing heights, by area

Species	Greens Regular Membership play	Greens Tournament conditions	Collars, Tees, and Approaches	Fairways	Rough (primary)
	inches				
Creeping bentgrass	0.1 - 0.14	0.09 - 0.125	0.25 - 0.4	0.35 - 0.5	-
Velvet bentgrass	0.1 - 0.14	0.09 - 0.125	0.25 - 0.4	-	-
Perennial ryegrass	-	-	0.4 - 0.5	0.4 - 0.5	1.5 - 3
Kentucky bluegrass **	-	-	0.5	0.5 - 0.65	1.5 - 3
Fine Fescue	-	-	0.4 - 0.5	0.4 - 0.5	-
Tall fescue (turf-type)	-	-	-	-	1.5 - 3

**Variables that often dictate mowing heights include playing surface, turfgrass species and/or cultivar, foot traffic (amount of play), budget, rolling, and whether the golf course is set up for tournament play or regular play.*
***When selecting Kentucky bluegrass varieties for tees and fairways, select cultivars that are tolerant of 0.5-inch mowing heights.*

Source: Adapted from Best Management Practices for New England Golf Courses, February 2020

Proper mowing and rootzone management are foundational practices for healthy turfgrass.

Best Management Practices

- Maintain proper mowing heights and frequency within the ranges adapted for the species and cultivars being managed.
- Increase mowing frequency during periods of rapid growth and decrease frequency during dry and stressful periods.
- For turfgrass that has grown too tall, avoid mowing down to the proper height all at one time. Severe scalping reduces density and can result in significant reduction in root growth. Mow tall grass frequently, gradually decreasing height until the proper height of cut is reached.
- To aid and improve the health of shaded turfgrass, mowing height should be increased by a minimum of 30%. When turfgrass is shaded, growth is affected by the plant filtering out photosynthetically active radiation. This causes turfgrass to grow upright in an effort to consume the light to meet the plant's photosynthetic needs.
- Using plant growth regulators (PGRs) for grasses grown in shaded areas has been shown to improve overall turfgrass health.
- Prolonged cloudy weather and periods of drought significantly impact turfgrass health. During these periods, increasing mowing heights to the maximum that use will allow will increase the plant's rooting depth and photosynthetic capacity.
- Use proper mowing equipment; reel mowers produce the best quality and are suited for maintaining a height of cut below 1.5 inches.
- Rotary mowers deliver adequate cutting quality for maintaining turfgrass at a height of cut above one inch and are more versatile when compared to reel mowers on uneven terrain.
- Maintain clean, sharp blades and proper adjustment. Dull blades will shred leaf tissue resulting in increased water loss and potential for diseases to develop.
- Flail mowers are most commonly used for maintaining utility turfgrass areas that are rarely mowed and have low aesthetic requirements.
- Mowing patterns influence functional characteristics of a turfgrass surface in addition to aesthetic.
- Alternating between mowing and rolling can reduce stress on turfgrass, especially putting greens.
- Turfgrass clippings contain significant amounts of potassium and phosphorus in addition to 2%-4% nitrogen on a dry-weight basis which is a source of nutrients. Clippings should be properly handled as nutrients can be a source of stormwater pollution.

- Return grass clippings to the site during mowing, except when underlying turfgrass plants could be smothered by a large number of clippings and when clippings on greens have a negative impact on play and functional use, such as affecting ball roll. In such cases, grass clippings should be removed.
- Grass clippings should be removed during periods of pest infestation and/or weed seed production to reduce the spread of weeds, diseases, and insects. Mowers should be cleaned following use on an area infested with a pest issue. In the case of disease (e.g., Pythium), sterilization may be recommended using a bleach dilution.
- Properly dispose of collected clippings in order to avoid unpleasant odors near play areas and prevent fire hazards. Consider composting or dispersing healthy clippings evenly on natural areas where they can organically decompose. Do not compost or dispose of clippings on impervious surfaces or near ponds and streams.

Mowing Directions

It is important for growing grass to keep an upright growth habit, which provides a smooth playing surface. This can be achieved with varying mowing directions. Rotating directions prevents turfgrass from lying over which will cause it to grow in the direction that it is being mowed. This practice prevents other issues such as rutting and “grain.” “Grain” is the result of lateral growth habit. This effects the playing surface by influencing the ball to roll in the same direction the grass is growing and causes inconsistent ball roll speed. In addition, this impedes the mower’s ability to cut effectively which leads to the accumulation of thatch.

Another downside of a singular mowing direction is rutting. This causes wear and soil compaction due to driving the same area repeatedly. As a solution, golf courses can provide a chart of daily mowing directions. Using clock positions as a template is one method to creating a daily varied mowing pattern. For instance, Monday’s direction is 12 to 6, Tuesday is 3 to 9, Wednesday is 8 to 2, and Thursday is 10 to 4. By varying mowing directions, operators can also create a checkerboard pattern, giving them more visibility of the lines.

Avoid the use of heavy mowers or other equipment on saturated soil – as this can increase the likelihood of rutting/compaction.

Types of Mowers

When it comes to best practices for mowing turfgrass, using appropriate equipment is essential. Rotary mowers and reel mowers are the best cutting units to get the job done.

Rotary mowers are best suited for maintaining grass at a higher height-of-cut. This mower’s blades are mounted horizontally to a vertical shaft that spins at high speeds. The sharp, highspeed blade cuts through the leaf blade like a knife as opposed to a scissor cut. Rotary mowers are not able to mow shorter than one inch, which can be a disadvantage. Maintain a sharp blade for best results, however it is always important to be cautious of swinging blade-related danger.

Reel mowers are best for areas maintained at a shorter height-of-cut like golf course greens. This is a cylinder mower with eight to 16 evenly spaced blades and a sharp stationary bedknife mounted beneath the reel. As the cylinder spins, the reel mower creates a scissor cut between the blade and bedknife. These mowers have the advantage of saving fuel and allowing for battery operated options as they require less power. Reel mowers will need frequent adjustment and maintenance in order to get the lowest mowing height and highest cut quality. The skill needed for proper adjustment and maintenance can be a disadvantage in addition to the reel mowers limited range of height-of-cut options.

Height of Cut

There are various types of playing surfaces on every golf course. Each surface requires different mowing frequencies and height-of-cut. Factors that influence mowing practices include seasonal changes, air and soil temperatures, and how quickly the grass is growing. For example, cooler temperatures and shorter days in the winter reduce the plant's opportunity for photosynthesis. This results in slower growing speeds that require less mowing. Warmer temperatures and longer days in the summer months allows turfgrass the opportunity to photosynthesize which creates rapid growth. These conditions create the need for additional mowing. As a general guideline, it's important not to remove more than one-third of the top growth in a single mowing. To achieve the desired height-of-cut, this may require more frequent mowing.

Each surface will require appropriate equipment in order to maintain an optimal golf course. The best equipment for roughs is a rotary mower set between one and two inches for height of cut and mowed once or twice weekly on average. Other areas of the course require reel mowers. Fairway, tee, and approaches should be kept at a height-of-cut of 0.5 inches or less for ideal playability. Depending on the turfgrass' growing speed, these areas will likely need mowing two or three times weekly.

Putting greens are the most important feature of the golf course. To ensure an ideal playing surface, greens demand the highest priority and maintenance. The average mowing height for greens ranges from .07 to .125 inches. Maintaining this height-of-cut means daily upkeep and mowing are needed. Reel mowers are best suited for the job. Keeping the equipment's blades sharpened and regular adjustments will result in a quality cut.

Rolling

Rolling putting greens daily will push down imperfections, keeping the surface smooth. This helps increase putting speeds for improved ball roll all without the need to lower the height-of-cut. Supplementing rolling with mowing allows one to raise the height-of-cut which will result in healthier turfgrass.

Research has found that preventing weeds and occurrence of disease are other benefits of rolling. Lightweight rollers are recommended. If a heavy roller is used, there are risks of soil compaction and additional aerification may be required to relieve soil issues.

Plant Growth Regulators (PGRs)

Golf course superintendents commonly use PGRs on putting greens to reduce turfgrass shoot growth to reduce mowing requirements, which can improve ball roll. Another benefit is the maintenance of green speed throughout the day, which can be enjoyed by golfers playing later in the evening. PGRs are also used to reduce irrigation, and fertility needs; control seed heads; as well as improve density, color, stress tolerance, and overall turfgrass quality. PGRs are divided into six classes based on mode of action. Table 1 shows the most widely used PGRs.

Gibberellic acid (GA) inhibitors suppress GA in the plant, reducing turfgrass clipping yield. GA suppression will wane after time causing a potential rebound effect where the turfgrass goes through a period of increased clipping yield. Reapplications before the rebound phase occurs are necessary to help maintain suppression.

Track growing degree days (GDDs) following the application of a PGR. Using GDDs prevents the over-regulation of turfgrass, which can cause significant damage, or conversely, the rebound phase. Degradation levels of each PGR type are based on the rate applied and seasonal temperature levels. Charts showing PGR reapplication thresholds are available to help determine the number of GDDs before applying the next application.

Best Management Practices

- Use PGRs on playing surfaces to aid with improving overall turfgrass quality and reduce irrigation needs.
- To find the most effective PGR application timing, use GDDs thresholds indicated on published charts.
- Use PGRs to help gain green speed; this is more effective and results in healthier turfgrass than excessively low cutting heights or very frequent mowing schedules.
- Use GA inhibitors to reduce clipping yields, improve turfgrass quality, and help lower maintenance costs.
- Use seaweed extracts and humic acids to help improve turfgrass quality while reducing N inputs and avoiding excessive growth.

Table 1. PGR chemical classes, modes of action, chemical names, and products.

PGR Class	Mode of Action	Chemical and Trade names
A	Late gibberellic acid inhibitor	Trinexapac-ethyl (Primo Maxx) Prohexadione-Ca (Anuew)
B	Early gibberellic acid inhibitor	Flurprimidol (Cutless) Paclobutrazol (Trimmit 2SC)
C	Cell division inhibitor	Mefluidide (Embark)
D	Herbicide	Methiozolin (Poa Cure) Glyphosate (Roundup)
E	Phytohormone	Ethephon (Proxy)
F	Natural growth regulator	Seaweed extracts, humic acids

Source: Adapted from Connecticut Golf Industry Best Management Practices Guide, 2020

Cultivation

Cultivation practices are essential to golf course management. High traffic areas like putting greens, fairways, and tees will experience deterioration with routine use. Soil issues related to everyday use will be limited to the top three inches of the soil profile. Other negative impacts of routine use include compacted soil and thatch accumulation. Properly managing these issues will enhance plant health by increasing nutrient and water uptake, encouraging root growth, promoting atmospheric gas exchange, and reducing thatch accumulation.

Aerification

Occasional tilling is a customary soil practice for correcting problems related to soil compaction. Turfgrass will not allow for serious physical disruption from tilling without destroying the playing surface. Core aerification is used for managing thatch and soil compaction with reduced physical disturbance. This method also successfully improves drainage. In conjunction with core aerification, applying light sand frequently will help control thatch, smooth playing surfaces, and potentially alter the soil's physical characteristics.

Solid tine aerification is also a method to reduce soil compaction. Other forms of aerification and cultivation include air-injection, sand-injection, water-injection, slicing, drill-and-fill, and fraise mowing.

Vertical Mowing

Thatch accumulation can commonly occur in areas with less traffic. Over accumulation of thatch and other organic matter can cause a host of challenges including increased insect activity, disease, scalping, reduced water infiltration, root growth reduction and an overall undesirable playing surface. Vertical mowing is the best method for managing grain and removing accumulated thatch. Mower groomers serve as small vertical mowers attached to the front of the reels which serrate stolons to improve plant density and manage grain.

Best Management Practices

- Core aerification is the removal of small cores, typically 0.25 to 0.75 inch in diameter, from the soil profile. Core aerification programs should only remove 15% to 20% of the surface area on an annual basis. High traffic areas may need two to four or more core aerifications annually. For help determining the area's specific needs reference the International Sports Turf Research Center (ISTRC) http://www.istrc.com/.
- Watch for wear patterns that affect the quality of the turfgrass, cart traffic on fairways may cause compaction which can affect turfgrass health.
- Perform core aerification when turfgrass is actively growing for quicker surface recovery.
- To prevent the formation of compacted layers in the soil profile from cultivation, vary the depth of aerification by changing tine length during each event.
- Solid-tine aerification is a method to manage soil compaction with minimal surface disruption. Since this method does not remove soil from the profile, it is only a temporary solution and does not aid in thatch management.
- Drill-and-fill aerification brings soil to the surface and distributes it into the canopy by drilling deep holes in the soil profile with drill bits. Using sand or other root-zone materials to backfill holes allows the replacement of heavy soil in an effort to increase water infiltration in the soil profile.
- Slicing is best performed on moist soil and can reduce soil compaction and promote water infiltration with little surface damage. It is faster than core aerification but not as effective.
- Spiking also reduces soil compaction by breaking up crusts on the surface and disrupting algae layers to allow better water infiltration.
- Setting a vertical mower to a depth that light cuts the surface can reduce the grain of putting greens. To stimulate new growth, set the verticutter to a deeper depth penetration to cut through stolons and rhizomes. Depth for thatch removal should be set to reach the bottom of the thatch layer extending beneath it into the soil surface.
- Vertical mowing should be initiated when thatch level reaches greater than 0.25 inch in depth; for putting greens, shallow vertical mowing should be initiated at least monthly to avoid accumulation.
- Aggressive dethatching with a verticutter is not recommended for putting greens as this causes damage that requires extensive recovery time.
- Topdressing playing surfaces with sand after heavy vertical mowing and core aerification help turfgrass to recover. Rates are determined by how well the turfgrass canopy absorbs the material without risk of burying the plant. Typical rates range from a depth of 0.125 to 0.25 inch.

Comparison of Methods Used to Selectively Cultivate Turf

Cultivation method	Soil penetration (inches)	Spacing between blades or tines (inches)	Relative level of soil loosening	Relative disturbance of the turf surface
Core aerification: conventional and deep-tine, hollow-tine	2 to 12	1 to 8	Minimal to high	Moderate to high
Deep-tine, solid-tine aerification	2 to 16	1 to 8	Minimal	Minimal to moderate
Water injection	4 to 20	3 to 6	Minimal to moderate	Minimal
Spiking	¼ to 12	1 to 2	Minimal	Minimal
Slicing	2 to 8	4 to 12	Minimal to moderate	Minimal

Source: https://extension.tennessee.edu/publications/Documents/W161-B.pdf

Topdressing

Topdressing is the application of desirable rootzone material, rootzone amendment, or pure sand to the turfgrass surface to help the crown of the plant remain as close to the soil surface as possible. This practice encourages maximum root development, water, and air movement; and minimizes pest susceptibility. Before application, remove thatch and other organic matter through appropriate cultivation practices.

Particle size must be compatible with the existing rootzone material in order to be effective. In other words, the topdressing should have the same size distribution as the construction mix or have a coarser texture. If the grain used is finer than the original sand mix material, it can have the undesired result of excessive moisture retention in the topdressing layer, due to low rootzone infiltration rates. Modifying the top three inches of soil with topdressing increases infiltration rates and reduces runoff.

Objectives of Sand Topdressing

- Dilute thatch accumulation
- Smooth the playing surface
- Maintain surface drainage
- Increase infiltration
- Increase soil macroporosity at the surface
- Increase surface firmness

Best Management Practices

- Throughout the growing season, apply light topdressing sand frequently (every seven to 14 days) or match the applications with the plant growth potential. This will help control thatch and smooth uneven playing surfaces on putting greens.
- Using finer materials may cause layering and reduce water infiltration.
- Weed-free topdressing material with a similar particle size to the underlying root is recommended.
- During active turfgrass growth, increase the amount of topdressing to putting greens in conjunction with aggressive cultivation practices. Harvest cores and refill the holes with topdressing.
- Lab test topdressing material with the Standard Test Method for Particle Size Analysis and Sand Shape Grading of Golf Course Putting Green and Sport Field Rootzone Mixes known as ASTM F1632.
- Include 15 to 20 subsamples at 4-inch depth. If previously top-dressed, use the current topdressing layer depth. To determine suitability of topdressing material, compare test results to USGA guidelines and the prospective topdressing material to determine compatibility.
- To ensure the topdressing material meets USGA guidelines for hydraulic conductivity, lab test the material with the Standard Test Methods for Saturated Hydraulic Conductivity, Water Retention, Porosity, and Bulk Density of Putting Green and Sports Turf Rootzones or ASTM F1815.

Accredited labs for testing:

- *International Sports Turf Research Center http://www.istrc.com/*
- *Turf & Soil Diagnostics https://www.turfdiag.com/*
- *Thomas Turf Services soiltest@thomasturf.com*

Overseeding Warm-Season Turfgrass

Overseeding can help maintain turfgrass color and playability during the fall and winter by establishing a temporary cool-season grass into the warm-season base when the warm-season grass enters dormancy. This process can also improve the biological and microbiological soil activity by prolonging the period of time turfgrass is actively growing throughout the year.

Effective overseeding programs require year-long planning and involve all facets of root-zone cultivation and weed control with the goal of upholding warm-season turfgrass health while allowing the cool-season grass species to be established. Overseeding increases the need for irrigation and routine mowing which can cause significant thinning of the base grass during spring transition. The cool-season overseed also acts as a shade crop restricting sunlight for the warm-season base grass to reestablish in the spring.

Best Management Practices

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

Bunkers

Bunkers are designed specifically for the golf course based on playability and level of management desired. These hazards serve more than one purpose by providing an obstacle for golfers while offering aesthetic appeal. Some consider bunkers to be the course's personality.

A bunker is made up of a drainage component, a liner, and top sand. The drainage system is installed on the bunker floor followed by the liner installed on the base. Liners aid in the prevention of contaminated sand and reduce sand from washing down banks from heavy rain. The top sand layer can be firmer or softer depending on the drainage capacity, or how quickly moisture clears the bunker floor.

When selecting sand, it is recommended to perform a sand analysis with an accredited lab as sand selection influences playability. There are several important parameters to consider when selecting potential sand. Infiltration rate determines favorable sand with a recommended rate of at least 30 inches per hour. A penetrometer reading is a good predictor of the sand's tendency to result in fried egg or plugged lies. Sand depth with an average of 4 to 6 inches at the base of the bunker and 2 to 3 inches on the faces is recommended by the USGA. Weather and maintenance are other parameters to consider. To ensure the best sand selection, acquire several potential sands and construct test bunkers or test bunkers at other golf courses. Angle of repose should be tested for the sand that is to be used to ensure the bunker "faces" are not too steep to hold the desired sand in place.

Bunker maintenance includes regular raking. There are many types of rakes and methods that create an optimal playing surface. Motorized raking equipment can be used on large bunkers, while small bunkers will need to be raked by hand. Firm bunker surfaces develop as a result of regular rainfall or irrigation and shallow raking. Soft bunker surfaces tend to develop from dry weather and deep raking.

Best Management Practices

- Golfer clientele and maintenance costs will influence bunker designs. Constructing numerous bunkers and features such as intricate edges, revetted, and high flashed faces will increase costs and difficulty.
- Extensive herringbone drainage and a quality bunker liner is recommended.
- Avoid washout by shaping bunker surrounds so that surface water doesn't drain into the bunker.
- Install irrigation to water bunker banks and keep the sand from becoming too dry.
- Construct test bunkers or visit other golf courses to help with sand selection.
- Lab test prospective sand with an accredited lab when selecting bunker sand.
- Sand depth of 4 to 6 inches on the bunker floor and 2 to 3 inches on the banks is best for playability.
- Maintaining firmer bunker banks and a smooth, weed-free surface helps prevent "fried egg" lies.
- Rake bunkers four times weekly for a consistent surface, with touch-ups in between to save labor.
- Bunker banks should be mowed weekly and edged on a two to four-week interval.
- Maintain proper depths by probing the sand about every two weeks depending on whether the bunkers are highly contoured or flat.
- Dirty and contaminated bunkers can be refreshed by removing the top one or two inches of sand and replaced with new sand.
- Fluff sand and improve playability when bunkers are too firm by using a motorized bunker rake with cultivating tines.
- Golf course architects recommend rebuilding bunkers every seven years depending on condition.

Resources for Sand Analysis:

Turf & Soil Diagnostics

613 E. 1st Street
Linwood, KS 66052
Phone: (855) 769-4231
lab@turfdiag.com
http://www.turfdiag.com/

Thomas Turf Services

11183 State Highway 30
College Station, TX 77845
Attn: Bob Yzaguirre
Phone: (979) 774-1600
Mobile: (979) 575-5701
soiltest@thomasturf.com
http://thomasturf.com/

Shade Tree Management

Full sun is ideal for most turfgrasses. Heavily shaded areas have decreased air circulation and lack the opportunity for photosynthesis, leading to disease and pests. Problems should be identified and monitored with annual shade audits. Survey sun patterns throughout the year to determine which trees are blocking light from desired areas. Note the tree species, value, health, life expectancy, location, maintenance requirements, and safety concerns.

Increase airflow and light by removing branches as necessary. In the case of severe issues, select trees may also need to be removed. When planning tree planting, it is crucial to consider turfgrass plant health. Competing tree roots can cause turfgrass health and performance to suffer.

Best Management Practices

- Tree limbs and roots can be pruned to reduce competition for nutrients, sunlight, and water.
- Trees located near low mowed areas like greens and tees can disrupt turfgrass growth. Thin the tree's canopy to promote growth or remove and/or relocate the tree if possible.
- Survey sun angles throughout the year to understand how it affects plant health.
- Annual shade audits should be performed to identify problems. Apps like "Sun Seeker" can be used to pinpoint the shade-causing trees.
- Tree surveys can be conducted with an arborist to identify tree species, value, health, life expectancy, location, maintenance requirements, and safety concerns.
- Where trees are intricate to design and playability; circulation fans are recommended to improve air circulation.

06

INTEGRATED PEST MANAGEMENT

An IPM approach requires understanding the life cycle of pests – insects, weeds, diseases, etc. – and how they interact with the environment. This information, combined with active scouting and monitoring, helps to prevent and control pests when they pose a problem.

IPM aims to reduce conventional pesticide use, when feasible, using an integration of multiple tactics including preventive, cultural or mechanical, biological, genetic, and chemical controls. It also helps to improve pesticide efficacy by encouraging appropriate timing and application methods. For golf course superintendents a strong understanding of IPM is crucial to ensuring the most safe, effective, and efficient approach to pest management is followed.

Correct use of IPM includes:

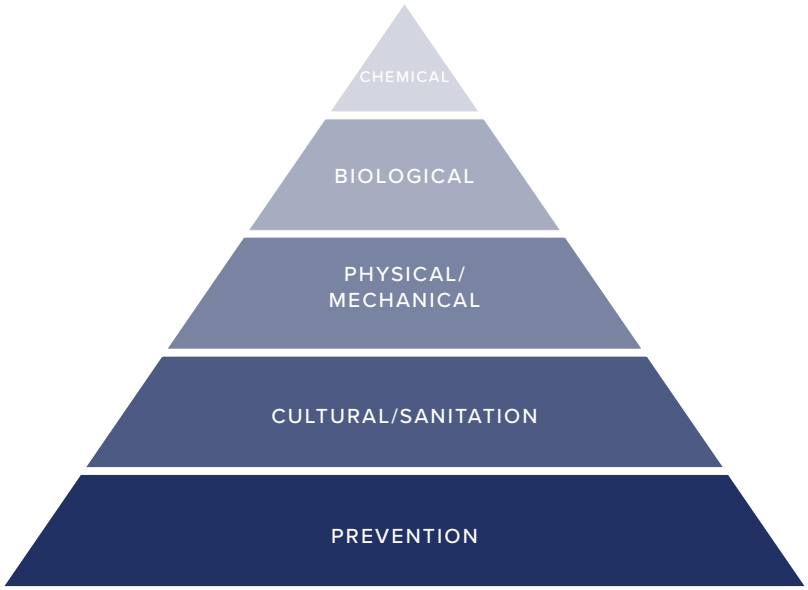
- Properly identifying pests.
- Choosing pest-resistant species and/or varieties of turfgrasses and other plants.
- Enhancing the habitat for natural pest predators.
- Scouting to determine pest populations and determining acceptable thresholds.
- Utilizing alternatives methods to chemical pesticides (such as preventive, cultural, mechanical, or biological controls) whenever possible.
- Minimizing impacts of chemical controls on the environment and reducing the potential for development of pesticide resistance.

As the IPM pyramid demonstrates, the aim is to make the greatest impact through prevention and other passive interventions, with biological and chemical interventions kept to the minimum level required for effective pest management. This helps reduce risk of pesticide exposure to people, animals, and the environment. It also helps with managing expenses and conserving energy

Integrated Pest Management (IPM) is an environmentally-sensitive science-based approach using a variety of strategies for pest management.

5 Key Steps for IPM

1. Scouting, Identification, Monitoring
2. Setting “Action Level” or Thresholds
3. Making Decisions - controlmethod(s)/timing
4. Evaluation
5. Education



IPM Pyramid

Best Management Practices

- Always adhere to local, state, and federal regulations for pesticide application and biological controls; this includes reading and following the label for any product used - the label is the law. Proper records of pesticide applications should be kept according to local, state, or federal requirements.
- Establish a written IPM plan. Monitor, observe, and document turfgrass conditions regularly (daily, weekly, or monthly, depending on the pest), scouting which pests are present, how damaging they are, determining pest thresholds, and necessary control strategies.
- Collect soil samples annually to assess soil nutrient availability and pH; maintaining an optimal soil pH and appropriate fertilization practices help prevent diseases and promote plant health to reduce potential for insect and weed invasion.
- Identify key pests and understand their lifecycle. This helps to know which life stage to target (for an insect pest, whether it is an egg, larva/nymph, pupa, or adult).
- Decide which pest management practice (mechanical, chemical, biological) is appropriate and carry out corrective actions. Direct control where the pest lives or feeds.
- Use preventive chemical applications only when professional judgment indicates that properly-timed preventive applications are likely to control the target pest effectively while minimizing economic and environmental costs.
- When chemical pesticide applications are necessary, they should be carefully chosen for effective and site-specific pest control with minimal environmental impact.
- Rotate pesticide modes of action to reduce resistance in pests; always follow label instructions with respect to appropriate rates and timing.
- Regularly review the IPM approach to determine whether corrective actions have reduced or prevented pest populations; evaluate if they were economical and minimized risks. Record and use this information when making similar decisions in the future.
- Maintain a supply of appropriate personal protective equipment (PPE) for use when handling pesticides or working on pesticide application equipment.

IPM Plan & Monitoring

A written IPM plan is critical to ensuring guidance is clear and that team members have an aligned understanding. All elements of the IPM pyramid should be included in this plan, which must also establish responsibilities, pest action thresholds, a system of communication, and pesticide-use hierarchy. Decisions to implement pest control actions should be based on a full understanding of key factors such as site characteristics, environmental conditions, and current or historic detection of the pest and/or damage occurrence and not on a scheduled, preventive pesticide-based treatment regimen. If preventive chemical control is used, it should be well-timed, informed, and should be developed with a comprehensive understanding of these key factors so as not to over-apply pesticides unnecessarily. A well-timed, informed chemical control can be effective in reducing significant aesthetic or economic loss. Many preventive applications will be most effective when the lifecycle of the pest is well-understood and environmental conditions (e.g., temperatures, precipitation) that may promote pest infestation are closely monitored. Very often, basic agronomic steps (altering fertilizer use or changing watering habits, etc.) can prevent further pest outbreaks without the use of pesticide-based treatment regimes.

Plans, scouting and monitoring should all be recorded, together with records of pesticide use. This will aid in decision-making in the future by providing information about successes and challenges in pest management. In Texas all applications of Restricted Use and State-Limited-Use Pesticides should be recorded, and records maintained for a minimum of two years. If a TDA Pesticide License is maintained, then ALL pesticide applications must be recorded, regardless of classification. In 54 Texas counties there are "Regulated Herbicides", which are State-Limited-Use pesticides requiring additional use restrictions, TDA notification and approval.

Additional record-keeping information:
https://www.texasagriculture.gov/Portals/0/Publications/PEST/pes_rkbroch.pdf

Pest Thresholds

In order to help alleviate concerns over potential aesthetic damage to the appearance of turfgrass or ornamental plants, it is important to educate golfers and maintenance personnel on IPM programs. Effective communications and education can raise tolerance of minor aesthetic damage without compromising plant health, play, and aesthetics. Use of pest thresholds can help guide application decisions and associated education activities, while minimizing economic and environmental costs.

Prescribed Burning

As part of an IPM program to control weeds and growth in native areas, prescribed burning may be employed. Texas regulations prohibit outdoor burning, exceptions for prescribed burns may be provided.

Reference Texas Administrative Code:

https://statutes.capitol.texas.gov/Docs/AG/htm/AG.76.htm#76.114

Determining Pest Thresholds

A pest threshold is determined by the number of pests or the amount of pest damage that can be sustained before turfgrass quality is reduced to an unacceptable level. Thresholds vary by site, use of the turfgrass area, the specific pest being scouted, expectations of golfers, and budget constraints of the course.

Source: Leslie, A. 1994. Handbook of Integrated Pest Management for Turf and Ornamentals. Lewis Publishers, CRC Press, Inc.

Scouting & Monitoring

Golf course superintendents should include scouting activities in the IPM written plan. Scouting involves inspecting all areas of the course to identify populations and pest damage. Effectively scouting provides information to help determine acceptable thresholds and what control strategies are necessary. Methods include visual inspection, soil sampling, soap flushes, and insect trapping. Scouting results should be recorded to develop a historical record and allow for identification of patterns in pest activity together with IPM successes and failures. This information should be used when making similar future decisions.

Monitor, observe, and document the presence and development of pests regularly - anything from daily to monthly depending on the pests. Problem areas might include the edges of fairways, shady sites, or poorly-drained areas. Signs of the pest may include appearance and variance in size, shape, and color of spots, patches, rings, or circles; areas of thin turfgrass; mushrooms; animal damage; insect frass or webbing. Symptoms of the pest may include leaf spots, leaf blight, wilt, stunt, yellowing, root discoloration, rot, chlorosis, dieback, growth reduction, defoliation, mounds, or tunnels. Use Growing Degree Day (GDDs) calculations for assistance in monitoring for pest presence.

Growing Degree Days

Growing degree days are heat units used to estimate the development of plants and pests during the growing season. This method is more reliable at predicting insect development than calendar days.

Temperature averaging
GDD = [(Maximum Daily Temperature + Minimum Daily Temperature) / 2] - Base Temperature

Negative values are recorded as zero.

Additional Resources:

https://mrcc.illinois.edu/gismaps/info/gddinfo.htm

Best Management Practices

- Note how different weather conditions affect outbreaks throughout the year. Record observations, keeping a record of the time of day, month, year, weather, and flowering stages of nearby plants.
- Map pest outbreak locations (including disease patch size, number of insects per unit area, and percent of area affected) to identify patterns and susceptible areas for future applications.
- Document pest management objectives, pest monitoring methods, and data collected with photos when possible; use GDDs for assistance in monitoring.
- Train personnel to determine the pest's lifecycle and know which life stage to target.
- Personnel should be trained to document, identify, and record key pest activities on key plants.
- Train personnel to identify which corrective actions reduced or prevented pest populations; understanding what actions are most economical, while minimizing risks.

Common Insect Pests in Texas

- White Grubs
- Chinch Bugs
- Fire Ants
- Bermudagrass and Zoysiagrass Mites
- Rhodesgrass Mealybugs
- Scale Insects
- Fall Armyworms
- Cutworms
- Sod Webworms
- Hunting Billbugs
- Mole Crickets

References for Texas insect pests:

https://aggieturf.tamu.edu/turfgrass-insects/

https://landscapeipm.tamu.edu/ipm-for-turfgrass/pests-turfgrass/

https://www.uaex.edu/farm-ranch/pest-management/docs/training-manuals/AG1159.pdf

Pest Groups

Insects

Insects can be destructive to turfgrass and disruptive to play. It is important to correctly identify the responsible insect pest and pest lifecycle to determine the best course of management. This often involves sending samples to diagnostic clinics. Entomologists are available at https://entomology.tamu.edu/insectquestions/ and the Texas A&M AgriLife Extension offices for assistance with insect pest identification https://citybugs.tamu.edu/idhelp/. Turfgrass managers have multiple tactics and tools that can be used to control turfgrass insect pests, including cultural and chemical practices. Monitoring GDD accumulation can help determine when specific insect pests are likely to be present in order to determine best control strategy.

Several available tools and resources may be found at:
http://uspest.org/cgi-bin/ddmodel.us
http://gddtracker.msu.edu/

Best Management Practices

- Ensure proper cultural practices to reduce turfgrass stress are used.
- Correct any conditions that produce stressful environments for turfgrass. (e.g., improve airflow and drainage, reduce or eliminate shade, etc.)
- Insecticide use may be integrated into an overall management strategy for a golf course. The appropriate (most effective) preventive insecticide can be applied to susceptible turfgrasses when unacceptable levels of insect damages are likely to occur. The use of preventive insecticides can also reduce the need of post-emergent applications that require higher use rates.
- Record and map insect outbreaks. Identify trends to help guide future treatments and focus on changing conditions within susceptible areas to reduce insect outbreaks.

Information on common Texas insect pests:
https://takecareoftexas.org/sites/default/files/publications/gi-405.pdf

Diseases

With the right conditions and plant availability, plant pathogens can disrupt play by damaging and destroying turfgrass. Sound cultural practices are important for maintaining healthy turfgrass to prevent disease outbreaks. There are three components to consider with disease outbreaks: the host, pathogen, and environment – referred to as the “disease triangle”. Various conditions including excess soil moisture or mowing when turfgrass is wet can impact fungal disease outbreaks. Correctly identify the disease pathogen; this often involves sending samples to diagnostic clinics. Contact the Texas Plant Disease Diagnostic Laboratory at Texas A&M University for diagnosis: https://plantclinic.tamu.edu/

Fungicide use should be integrated into an overall management strategy for a golf course. The appropriate (most effective) preventive fungicide can be applied to susceptible turfgrasses when unacceptable levels of disease are likely to occur based on site history and environmental conditions.

Multiple tactics and tools may be used to reduce turfgrass disease on the golf course. Organic layer and thatch management, fertility programs, water management, mowing height selection, and equipment maintenance (i.e., sharp blades and sterilizing equipment where disease is present) are some of the practices that can support reductions in turfgrass disease occurrence and impact. Healthy, well-managed turfgrass has better recuperative potential, which helps prevent against disease.

Reference the Texas Plant Disease Handbook for common plant diseases and associated host grasses in the state:

https://plantdiseasehandbook.tamu.edu/landscaping/lawn-turf/

Common Turf Diseases in Texas

- Large Patch (fungus - *Rhizoctonia solani*)
- Algal Scum (algae – *Nostoc* spp., *Oscillatoria* spp., *Chlamydomonas* spp., *Hantzchia* spp., others)
- Anthracnose (fungus – *Colletotrichum graminicola*)
- Bipolaris, Drechslera and Exserohilum Leaf Spot, Crown and Root Rot (fungi – *Bipolaris cynodontis, Drechslera gigantea, Bipolaris stenospila, Curvularia* spp. and *Exserohilum* spp.)
- Brown Patch (fungus – *Rhizoctonia solani*)
- Dollar Spot – Small Brown Patch (fungus – *Sclerotinia homeocarpa*)
- Downy Mildew (fungus – *Sclerophthora macrospora*)
- Fairy Ring (fungi – *Agaricus* spp., *Marasmius oreades*)
- Gray Leaf Spot (fungus – *Pyricularia grisea*)
- Necrotic Ring Spot (fungus – *Leptospheria korrae*)
- Nematodes (fungus – *Microdochium nivale*)
- Pink Snow Mold (fungus – *Microdochium nivale*)
- Powdery Mildew (fungi – *Erysiphe* spp.)
- Pythium Blight, Cottony Blight, Greasy Spot (fungus – *Pythium aphanidermatum*)
- Rust (fungus – *Puccinia cynodontis*)
- Seedling Disease (fungi – *Pythium* spp. and *Rhizoctonia* spp.)
- Slime Mold (fungi – *Physarum* spp. and *Fuligo* spp.)
- Smut (fungus – *Ustilago cynodonis*)
- Spring Dead Spot (Disease complex (fungi) – *Leptosphaeria korrae, Gaeumannomyces graminis var. graminis, Ophiosphaerella herpotricha*)
- St. Augustine Decline, Centipede Mosaic (virus – SAD)
- Summer Patch (fungus – *Magnaporthe poae*)
- Take-all Patch, Bermuda Decline, Take-all Root Rot (fungi – *Gaeumannomyces graminis* var. *graminis* or *avenae*)

Nematodes

Plant-parasitic nematodes are microscopic roundworms which are difficult to control. They have a particularly adverse effect on susceptible turfgrasses by weakening the root system. This causes turfgrass to be less efficient in uptake of both water and nutrients, making it more susceptible to environmental stresses. Weakened turf is also more prone to pest infestation, especially troublesome weeds that necessitate herbicide applications.

Over time, turfgrass in the affected areas thins out and, with severe infestations, may die. The roots of turfgrasses under nematode attack may be very short, with few, if any, root hairs, or they may appear dark and rotten. Turfgrasses usually begin showing signs of nematode injury as they experience additional stresses, including drought, high temperatures, low temperatures, and wear. These can be especially problematic in coarse, sandy soils meaning that greens/tee boxes may need to be closely monitored.

Contact the Texas Plant Disease Diagnostic Laboratory at Texas A&M University for nematode detection: https://plantclinic.tamu.edu/forms/d827/

Best Management Practices

- If nematode activity is suspected, it is recommended to test a combination of soil and turfgrass roots to understand the extent of the problem.
- The application of a nematicide on golf course turfgrass should always be based on assay results.
- Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
- Increase mowing height to reduce plant stress associated with nematodes, root-feeding insects, disease outbreaks, or peak weed-seed germination.

Additional information on nematodes in Texas:

https://aggieturf.tamu.edu/wp-content/uploads/E-294-Nematode.pdf

Weeds

Weed infestations can disrupt turfgrass by negatively impacting plant health and the playing surface. Weeds can be spread via seeds – often carried on footwear or blown in from nearby areas. They can also be spread vegetatively through tubers, corms, rhizomes, stolons, or bulbs. Weeds compete with turfgrass for space, water, light, and nutrients. In addition to the direct damage caused by weeds, they also act as hosts for disease, nematodes, and insects and some weeds can cause allergic reactions and skin irritants.

Best Management Practices

- Select appropriate turfgrass species and cultivars adapted to prevalent environmental conditions.
- Use a proper turfgrass and nutrient management in combination with cultural practices.
- Properly identify weeds and understand their lifecycles.
- Select and use appropriate herbicides, if necessary, in line with IPM controls.
- Adopt or maintain cultural practices that protect turfgrass from environmental stresses such as shade, drought, and extreme temperatures.
- Manage turfgrass through use of fertilizers and chemicals, proper mowing height and frequency, proper soil aeration, and regulated traffic.
- Use weed-free materials for topdressing and establishment.

Additional reference for Texas turfgrass weeds:

https://aggieturf.tamu.edu/turfgrass-weeds/

Vertebrate Pests & Nuisance Wildlife

Vertebrate pest problems can often be solved by applying preventive controls such as sanitation, exclusion, and habitat modification. This may include addressing a habitat or an insect pest food source (i.e., armadillos or skunks looking for white grubs).

Examples of Texas Vertebrate Pests

- Jackrabbit
- Rodents
- Ground squirrel
- Armadillo
- Skunk
- Coyote
- Feral hog
- Alligator
- Snakes
- Vole

Best Management Practices

- Understand and follow federal, TPWD, and local permit requirements and regulations.
- Contact the Texas A&M AgriLife Extension Service – Animal Plant Health Inspection Service, Wildlife Services and TPWD with questions or for assistance on proper removal of species protected by federal or Texas state law before using control measures or relocating to another area.
- Observe migratory bird protection laws.
- Recognize the damage problem (i.e., burrowing, mounds, rooting, reduction in ground cover, erosion, girdled limbs, traces, etc.) and identify the species responsible.
- Understand the biology of the species relative to the problem; note time of year or seasons for population changes; damage may be more severe during population peaks.
- Determine management strategies and alternatives (habitat manipulation, trapping, fencing, population control, guard animals, etc.)
- Inform and educate staff and members on precautions to take with urban wildlife (i.e., coyotes, alligators)
  - https://tpwd.texas.gov/huntwild/wild/nuisance/coyote/
  - https://tpwd.texas.gov/huntwild/wild/species/alligator/safety/index.phtml
- Consult with a specialist authorized by the TPWD with an applicable nuisance control permit.

For additional information or assistance, contact the Texas A&M AgriLife Extension Service – Animal Plant Health Inspection Service, Wildlife Services per Chapter 825, Texas Health and Safety Code:

https://agrilife.org/txwildlifeservices/

https://agrilife.org/txwildlifeservices/who-to-contact/

Additional information on vertebrate pests and nuisance wildlife:

https://tpwd.texas.gov/huntwild/wild/nuisance/

https://aggie-horticulture.tamu.edu/citrus/l2312.htm

Controls

Turfgrass Selection & Cultural Controls

Selecting a pest-resistant plant species is central to IPM and can decrease the level of pesticide use. A species grown outside of its zone of adaptation is more prone to pest problems. Species should be managed under conditions similar to the intended use (for example, not exceeding mowing height limitations that a grass was bred for or selected for) and turfgrasses must be scientifically selected for the eco-region of the golf course. Reference the National Turfgrass Evaluation Program for help with cultivar selection: https://ntep.org/ and Texas turfgrasses: https://aggieturf.tamu.edu/texas-turfgrasses/.

Turfgrass Species Characteristics

Species	Mowing Height (inches)	Mowing Quality	Nutrient Needs	Pest Potential	Thatch Tendency	Recuperative Potential
Kentucky bluegrass	1-2.5	4	med-high	med-high	med-high	3-4
Roughstalk bluegrass	0.5	3	med	low-med	low-med	3
Supina bluegrass	0.2	3	high	low-med	med-high	3-4
Canada bluegrass	3-4	1	low	low	low	3
Annual bluegrass	0.3	3	high	high	med-high	3
Creeping bentgrass	0.25	3	high	high	high	3-4
Colonial bentgrass	0.25	3	low-med	med-high	med-high	1-2
Velvet bentgrass	0.2	3	low-med	med-high	med-high	1
Redtop	0.5-3	2	low	low	low-med	1
Creeping red fescue	1.5-2.5	1	low	low-med	med-high	1-2
Chewings fescue	1-2.5	1	low	low-med	med-high	1-2
Sheep fescue	2-3	1	low	low-med	low	1
Hard fescue	2-3	1	low	low-med	low	1
Tall fescue	1.5–3	3	med	low-med	low	1-2
Perennial ryegrass	1.5–2	2-3	med-high	med-high	low	3
Annual ryegrass	1.5–2	2-3	med-high	med-high	low	3
Zoysiagrass	.5-1	2	low-med	low	high	3-4

Mowing Quality and Recuperative Potential: 1 = Poor 2 = Fair 3 = Good 4 = Excellent

Source: http://cag.uconn.edu/documents/Turfgrass-IPM-manual-s.pdf

Best Management Practices

- Select the most suitable turfgrass for existing conditions and one that adheres to design specifications. Select shade-adapted turfgrasses for areas receiving partial sun or shaded areas.
- Minimize traffic in shaded areas to protect turfgrasses and trees from injury and soil compaction.
- Use proper cultural, mechanical, or physical methods to prevent problems (e.g., prepare site, choose correct turfgrass for Texas region; select resistant cultivars), reduce pest habitat, practice good sanitation, pruning, and dethatching.
- Pests can be minimized through proper irrigation, mowing (height, frequency, pattern), clipping management, topdressing, core aerification, and venting.
- Varying mowing pattern encourages vertical growth to reduce grain, increases tolerance from wear, and minimizes soil compaction.
- Reduce fertilizer applications and irrigation in shaded areas.
- Reduce pest and disease pressures by correcting dead spots and air-circulation issues through pruning and irrigation scheduling.
- Understand the ET of turfgrass on the course and use this to optimize irrigation.
- Mow when grass is dry to avoid spread of turfgrass diseases; maintain sharp cutting edges to avoid stress; keep equipment clean and/or sterilize equipment when pest infestations are present; properly manage grass clippings.

Reference common diseases by turfgrass species:

https://plantdiseasehandbook.tamu.edu/landscaping/lawn-turf/sorted-by-name-of-grass-turf/

Effect of various cultural practices on turfgrass diseases.

Cultural Practice	Disease	Response	References
Fertilization	Anthracnose	Weekly applications of nitrogen at 0.1 lb./1,000ft2 reduced disease severity.	Inguagiato et al., 2008
		Maintaining a foliar N concentration equal or greater than 3.4% reduced anthracnose severity.	Inguagiato and Guillard, 2016
	Brown patch	Brown patch was more severe in plots treated with nitrogen, but nitrogen did not affect fungicide performance.	Fidanza and Dernoeden, 1996
	Dollar spot	Dollar spot was less severe in plots treated with nitrogen.	Williams et al., 1996
	Pythium blight	Pythium blight severity increased with nitrogen application.	Moore et al., 1963
	Red thread	Disease was more severe in nitrogen-deficient turf.	Cahill et al., 1983
	Summer patch	Patch severity was reduced with application of ammonium sulfate compared with calcium nitrate.	Thompson et al., 1995
	Take-all patch	Acceptable levels of control were achieved in plots treated with ammonium chloride.	Dernoeden, 1987
Mowing	Anthracnose	Anthracnose severity was reduced with increased mowing height.	Inguagiato et al., 2009
	Brown patch	Clipping removal had no effect on disease.	Settle et al., 2001
	Dollar spot	Morning mowing reduced disease.	Ellram et al., 2007, Williams et al., 1996
		Clipping removal had no effect on disease.	Williams et al., 1996
	Pythium blight	Clipping removal had no effect on disease.	Settle et al., 2001
Irrigation	Anthracnose	Minimizing drought stress, while avoiding continuous high soil water content reduced disease severity.	Roberts et al., 2011
	Brown patch	Daily irrigation did not affect brown patch.	Settle et al., 2001
		Irrigation reduced brown patch severity.	Rowell, 1951
		Daily irrigation reduced brown patch severity on perennial ryegrass.	Jiang et al., 1998
	Pythium blight	Daily irrigation aggravated Pythium blight in some cases.	Settle et al., 2001
Other	Anthracnose	Light-frequent or heavy-infrequent sand topdressing resulted in lower anthracnose severity.	Inguagiato et al., 2012
		Lightweight rolling every other day reduced anthracnose.	Roberts et al., 2012
		Shallow verticutting did not affect anthracnose severity.	Inguagiato et al., 2008
	Dollar spot	Rolling to remove dew reduced disease.	Williams et al., 1996
		Dew displacement reduced disease.	Ellram et al., 2007
		Dew displacement improved efficacy of chlorothalonil.	McDonald et al., 2006
		Lightweight rolling daily reduced dollar spot.	Giordano et al., 2012.

Table adapted from A Practical Guide to Turfgrass Fungicides. Latin, 2011. American Phytopathological Society. St. Paul, MN.

Source: Connecticut Golf Industry Best Management Practices Guide, 2020

Biological Controls

The biological component of IPM involves the release and/or conservation of natural predators, such as parasites and pathogens, and other beneficial organisms. This can involve utilizing natural pest enemies such as ladybugs and releasing these near pest infestations. It can also involve modification of the course to support natural predators and beneficial organisms.

Understand the lifecycles of beneficials. When feasible, avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide a refuge for beneficial organisms. Targeted areas for biological controls should attract natural predators and protect them from pesticide applications. Plant insectary plants that provide pollen or nectar sources.

Minimizing impact to bees and beneficial arthropods is an important part of IPM. Consider pollinators before selecting and applying pesticides to prevent potential negative impacts.

Beneficial Insects in Texas

- Ladybugs
- Dragonflies
- Green lacewing
- Ox beetle

Best Management Practices

- Where possible, modify areas of the course to attract natural predators, provide habitat for them, and protect them from pesticide applications.
- Install flowering plants that can provide parasitoids with nectar, or sucking insects (aphids, mealybugs, or soft scales) with a honeydew source.
- Avoid applying pesticides to roughs, driving ranges, or other low-use areas to provide a refuge for beneficial organisms.
- When using pesticides, minimize injury and damage by following label directions.
- Avoid applying pesticides during bloom season when pollinators are active. If application is necessary, follow label information concerning the application of pesticides when plants may be in bloom.
- If flowering weeds are prevalent, control them before applying insecticides.
- Use the latest spray technologies (i.e., drift-reduction nozzles) to prevent off-site translocation.
- Use granular formulations of pesticides that are known to be less hazardous to bees.

Reference Pollinator Protection & Wildlife Habitat for additional BMPs on protecting pollinators.

Conventional Pesticides

IPM involves both prevention — keeping the pest from becoming a problem — and suppression — reducing the pest numbers or damage to an acceptable level. Pests will always be present on a golf course; it is not possible to completely eliminate them. A control strategy should be implemented that reduces pest numbers to an acceptable level while minimizing harm to non-targeted organisms. 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.

Key Factors for Pesticide Selection

- Effectiveness
- Method and frequency of application
- Potential toxicity to non-target species
- Cost
- Site characteristics
- Solubility
- Persistence
- Packaging

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. Always follow the directions on the label - these have been developed based on the chemistry, biological effects, and environmental fate of the pesticide. Note environmental hazards and groundwater advisories included on labels. Also note pesticide label "Use Restrictions" as to where a product may or may not be used – i.e., specific areas of the golf course, specific species and/or cultivars, specific soils, etc. Follow guidelines provided by the Fungicide Resistance Action Committee, Herbicide Resistance Action Committee, and Insecticide Resistance Action Committee.

Minimizing Pesticide Resistance

Pesticide resistance is a change in the sensitivity of a pest population to a pesticide, resulting in the failure of a correct application of the pesticide to control the pest. Pesticide mode of action (MOA) is the is the process of how pesticides control pests and site of action is the specific place where the pesticide works on a cellular level. Repeatedly relying on a single MOA selects for populations that are resistant to that specific MOA. Application of diverse IPM strategies for prevention and control, in combination with rotating or combining pesticide MOAs helps to prevent pesticide resistance.

Best Management Practices

- Always read the pesticide label, follow the recommended rates for application, timing, and equipment recommendations.
- Properly identify the pest which is present and its growth stage.
- Apply pesticides only when necessary; follow determined thresholds; practice IPM preventive measures and control strategies including proper cultural practices, mechanical, or biological controls.
- Check pesticide labels for the MOA and avoid using pesticides with the same MOA for a prolonged period of time.
- Use multiple MOAs and rotate pesticides with different MOAs for target pests.
- Understand the target site of action (SOA) which is a specific process that a pesticide disrupts (the location of inhibition); the more a SOA is relied upon, the greater the risk of resistance. Rotate SOA with different MOAs to reduce the risk of resistance.
- Mix and apply pesticides carefully and per the label instructions.
- Scout regularly to respond quickly to changes in pest populations and scout prior to application to determine correct timing when pests are most susceptible.
- Application of pesticides to pest populations that are beyond the optimal timing (i.e., large weeds, late instar insect larvae or disease in the epidemic phase) can speed the development of resistance.
- Monitor sites and results, clean equipment between sites.
- Maintain detailed records to confirm application history and to help plan for pesticide resistance management.
- Reference guidelines and tools provided by the Fungicide Resistance Action Committee, Herbicide Resistance Action Committee, Weed Society of America, and Insecticide Resistance Action Committee.

Additional information:

http://extension.msstate.edu/publications/publications/preventing-and-managing-herbicide-resistant-weeds-turfgrass

https://iwilltakeaction.com/

https://wssa.net/wssa/weed/resistance/

https://hracglobal.com/herbicide-resistance/overview

https://www.frac.info/fungicide-resistance-management/background

https://irac-online.org/about/resistance/management/

https://pesticidestewardship.org/

Pesticide Classification Hierarchy and Label

Pesticides contain active ingredients (the component in a commercial product that is primarily responsible for controlling the pest) that are identified on the product label. A numbering system assigns each pesticide to a mechanism of action (or SOA) group based on active ingredients. The EPA recommends that labels display the group number that identifies the mechanism of action for the active ingredient(s). In addition, pesticides include inert ingredients such as solvents, surfactants, and carriers. It is important to understand mode of action and mechanism of action compared to active ingredients to help develop strategies for pesticide resistance management. Both active and inert ingredients may be controlled or regulated by federal, state, and local laws.

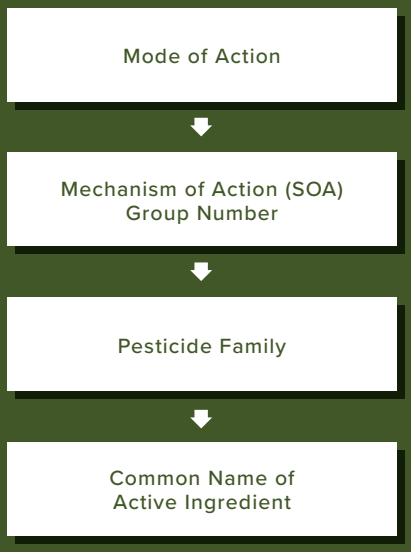
The goal of a mechanism of action numbering classification system is to help provide a tool to aid in pesticide selection. Labels also include resistance management guidelines for assistance.

Additional information:

https://emergence.fbn.com/agronomy/how-to-read-pesticide-label

https://slideplayer.com/slide/14388695/

Classification Hierarchy



Example of a Pesticide Label

Best Management Practices

- Train employees in proper pest identification and pesticide selection techniques. Always read the pesticide label, follow directions, and adhere to the use restrictions to determine whether a product is appropriate, how that product should be applied, and at what rates. The label is the law.
- Choose the product most appropriate for the problem or pest; ensure the turfgrass species/cultivar and pest are both on the label, and that the product is labelled for this particular use scenario.
- Use the rate specified by the pesticide product label. Do not mix more than the rate specified by the label, which should be only the quantity of pesticide needed; this also helps to avoid disposal problems, protects non-target organisms, and controls costs.
- Make note of any environmental hazards and groundwater advisories included on the label.
- Rotate pesticide and/or combine modes-of-action to reduce the likelihood of resistance.
- Spot-treat pests whenever appropriate.

Refer to Pesticide Management and Pollinator Protection and Wildlife Habitat for additional BMPs.

Reduced Risk Pesticides for Use on Golf Course Turfgrass

Fungicides	Herbicides	Insecticides
boscalid	penoxsulam	clothianidin *neonicotinoid
penthiopyrad	carfentrazone-ethyl	*chlorantraniliprole*
trifloxystrobin	mesotrione	*cyantraniliprole*
fludioxonil	bispyribac-sodium	fipronil
azoxystrobin		spinosad

Source: https://www.epa.gov/pesticide-registration/reduced-risk-and-organophosphate-alternative-decisions-conventional

The Environmental Protection Agency has identified alternatives to conventional pesticides.

Reduced Risk Pesticides

- Low impact on human health
- Lower toxicity to non-target organisms (birds, fish, plants)
- Low potential for groundwater contamination
- Low use rates
- Low pest resistance potential
- Compatibility with IPM practices

Biopesticides

- Derived from natural materials (e.g.; animals, plants, bacteria, certain minerals)
- Usually inherently less toxic than conventional
- Generally affect only target pest & closely related organisms
- Often effective in small quantities & decomposes quickly, resulting in lower exposures & pollution
- Compatibility with IPM practices

For more information:

https://www.epa.gov/pesticide-registration/conventional-reduced-risk-pesticide-program

https://www.epa.gov/ingredients-used-pesticide-products/what-are-biopesticides

03

PESTICIDE MANAGEMENT

Pesticides belong to numerous chemical classes that vary greatly in their toxicity and as such are highly regulated. When a pesticide application is deemed necessary, selection should be based on effectiveness, toxicity to non-target species, cost, site characteristics, its solubility and persistence in the environment, and label specifications. A product should not be used unless explicitly labelled for a given scenario. In Texas, the label is the law!

Best Management Practices

- Comply with all Federal, Environmental Protection Agency (EPA) and Texas State laws and regulations. Adhere to pesticide labels; the label is the law.
- Select the least toxic pesticide with the lowest exposure potential; visit the EIQ, Environmental. Impact Quotient for helpful information https://nysipm.cornell.edu/eiq/.
- Preventive programs outweigh curative programs and should be considered a staple of an IPM program.
- Use Reduced Risk Pesticides when appropriate.
- Know the emergency response procedure in case excessive exposure occurs.
- Follow all directions on pesticide's labelling.
- Properly calibrate application equipment.
- Always utilize Personal Protective Equipment (PPE) when required by the label.
- Ensure facilities for storing and handling are properly sited, designed, constructed, and operated.
- Maintain a designated area to mix, load, and clean sprayers with quality water.
- Use caution when mixing and understand what chemicals can be mixed together. Mix pesticides in a small container to check compatibility before mixing in spray tanks.
- Develop an emergency response plan including procedures to control, contain, collect, and store spilled materials.
- Create, within 30 days, and maintain for two years, a record for each application of a restricted use pesticide (RUP).
- Properly rinse all used pesticide containers to dispose of as non-hazardous solid waste.

Texas Regulation of Pesticides

Texas Department of Agriculture (TDA)

TDA is the state's lead agency in the regulation of pesticide use and application. TDA is responsible for licensing pesticide applicators, overseeing worker protection, registering pesticides, working to minimize unnecessary impacts, and protecting endangered and threatened species. Texas A&M AgriLife Extension Service and the private sector trains license candidates.

Texas Commission on Environmental Quality (TCEQ)

TCEQ is the lead agency for the regulation of waste discharges, including pesticide discharges, into waters of the state. Various divisions of the agency address many of the groundwater protection issues related to pesticides.

Texas Department of State Health Services (DSHS)

DSHS's General Sanitation Division tests and certifies government employees that apply pesticides.

Texas Groundwater Protection Committee (TGPC)

TGPC is a consortium of nine state agencies and the Texas Association of Groundwater Districts. The committee is charged with the state's preparation of the Pesticide Management Plans (PMPs).

Reference additional information:

https://www.texasagriculture.gov/RegulatoryPrograms/Pesticides.aspx

https://tgpc.texas.gov/pesticides/regulation-of-pesticides/

Pesticide use should be part of an overall pest management strategy that includes biological controls, cultural methods, pest monitoring, and other applicable practices, referred altogether as IPM.

Application, Storage & Transport, Emergency Response, Record-Keeping

Responsibilities of Pesticide Owners, Users, or Handlers

Whenever taking possession of a pesticide it is important to ensure that that both the pesticide labeling, and the guidance and regulations of the TDA are followed. Failure to do so can result in harm to human or animal health as well as contamination of land and water sources.

Federal law requires any person who applies or supervises the use of RUPs to be certified in accordance with EPA regulations and state, territorial, and tribal laws. Pesticide applicators must know how to apply RUPs properly and effectively. State, territorial, and tribal authorities certify applicators. To apply for certification, you must justify your eligibility, pay a fee and then pass an exam (or exams). Licensed commercial and noncommercial applicators in Texas are required to recertify annually by obtaining five continuing education credits; with one credit each from two of the following categories: laws and regulations, integrated pest management or drift minimization.

Information on training providers and the process to apply for certification:

https://www.texasagriculture.gov/RegulatoryPrograms/Pesticides/PesticideApplicatorInformation.aspx

Information on the Worker Protection Standard and Texas Hazard Communication Law (RTK), with required communications and education for safety and well-being of pesticide handlers and workers where pesticides are applied: https://www.texasagriculture.gov/RegulatoryPrograms/Pesticides/WorkerProtection/TexasWorkerProtectionLaw.aspx

https://agrilife.org/aes/worker-protection-standards-wps/

The TDA designates a pesticide as a State Limited Use (SLU) pesticide due to potential adverse effects on non-target sites. SLUs are regulated on the basis of containing an active ingredient which has been designated by the state.

List of SLU regulated ingredients on the TDA website:

https://www.texasagriculture.gov/RegulatoryPrograms/Pesticides/StateLimitedUsePesticide.aspx

SLUs have restrictions relating to purchase, use, and distribution. It is the joint responsibility of the person in control of the golf course and the applicator to ensure the application complies with regulations and that correct recordkeeping is maintained.

Texas Pesticide Classifications State Limited Use

The TDA refers to five classifications of pesticides:

1. General-Use pesticides can be purchased and used by the general public. They do not require a license for personal use on an individual's property or for distribution.
2. Restricted-Use pesticides will state "restricted-use" on the product label as required by the EPA.
3. State Limited Use pesticides contain certain active ingredients that have the potential to cause adverse effects to nontargeted vegetation.
4. Regulated Herbicides have additional restrictions in regulated counties to prevent a hazard to desirable vegetation caused by drift or an uncontrolled application.
5. Prohibited Pesticides. https://www.texasagriculture.gov/RegulatoryPrograms/Pesticides/ProhibitedPesticides.aspx

Additional information on Texas Pesticide Classifications: https://www.texasagriculture.gov/RegulatoryPrograms/Pesticides/AgriculturalApplicators/PesticideClassifications.aspx

Personal Protective Equipment (PPE) & Human Health Risk

Pesticides belong to numerous chemical classes that vary greatly in toxicity. Risk to human health associated with pesticide use depends on both pesticide toxicity and the level of exposure- i.e., the amount of product and length of time involved with any contact. The risk of a highly toxic pesticide may be very low if the exposure is sufficiently small. There are four pesticide signal words that help provide indicators for what level of risk is present when applying.

Pesticide Signal Words

Signal Word	Toxicity Level
Danger	Toxicity Category I
Warning	Toxicity Category II
Caution	Toxicity Category II
None required (or Caution as optional)	Toxicity Category IV

Source: www.epa.gov

PPE is used for protection against chemicals contacting the person loading, mixing, and spraying the chemical. It is important to read the label thoroughly and use the minimum required PPE listed on the pesticide label, users may always choose to use more PPE than required on the label.

Employees will need to wash clothes that may have pesticide residues on them; washing requires the use of hot water with clothes that are suspected to have pesticide residues. Run another empty load once the clothes are washed.

Best Management Practices

- Provide adequate PPE for all employees who work with pesticides (including equipment technicians who service pesticide application equipment).
- Ensure that PPE is sized appropriately for each person using it.
- Make certain that PPE is appropriate for the chemicals used.
- Ensure that PPE meets rigorous testing standards and is not just the least expensive.
- Store PPE where it is easily accessible but not in the pesticide storage area.
- Forbid employees who apply pesticides from wearing facility uniforms home where they may come into contact with children.
- Provide laundering facilities or uniform service for employee uniforms.
- The federal Occupational Safety and Health Administration (OSHA) requires employers to fit-test workers annually who must wear tight-fitting respirators.
- Where using respiratory protects ensure compliance with Occupational Safety and Health Administration (OSHA) 1910.134 Respiratory Protection Program.

Sprayer Calibration

Proper calibration of equipment is necessary to accurately and correctly apply any pesticide. Spray technicians must be experienced, licensed, and properly trained. Use an appropriately sized applicator for the size of area being treated. Minimize off-target movement by using properly configured application equipment. It's good practice to calibrate all application equipment at the beginning of each season (at a minimum) or after equipment modifications. Equipment should be checked daily when in use. Calibration of walk-behind applicators should be conducted for each person making the application to take into consideration their walking speed, etc. Always use recommended spray volumes for the targeted pest to maximize efficacy.

Common Turf Application Equipment

Equipment	Dry or Liquid	Use	Comments
Low Pressure Boom Sprayer	L	Large areas, Golf courses	Can cover large areas in short time.
Backpack/Hand Can	L	Spot Treatment	Durable, portable, easy to use. Difficult to keep the pressure up. Difficult to control uniform application.
Hand Gun	L	Small lawns and larger turf areas	Covers large area quickly. Very little maintenance needed.
Spreaders	D	Lawns and turf area	Can cover larger area more quickly with rotary than drop spreader.

Source: Adapted from Integrated Pest Management for Turf and Ornamentals, Edited by Anne R. Leslie (1994).

Environmental Fate and Transport

Pesticides, wherever they are applied, have the potential to interact with wildlife or migrate into surface and subsurface waters. A key environmental consideration concerns the runoff and leaching potential of a selected pesticide. Prior to application, it is important to consider the particular characteristics of each pesticide and site. Key issues include proximity to surface water; the water table and well-heads; soil type; prevailing winds; presence of endangered species and so on.

Environmental hazards related to a pesticide are listed on pesticide product labels. The “Environmental Hazards” are found under the general heading “Precautionary Statements,” which provides language advising the user of the potential hazards to the environment and off target organisms – found under three headings: general environmental hazards, non-target toxicity, and endangered species protection.

Best Management Practices

- Select pesticides that have a low drift, runoff, and leaching potential; understand pesticide sorption principles so that appropriate decisions can be made.
- Labels provide warnings about these potential risks with each product.
- Before applying a pesticide, evaluate the impact of site-specific characteristics (for example, proximity to surface water, water table, and well-heads; soil type; prevailing wind; etc.)
- Before applying pesticides, monitor wind conditions to ensure accurate target of intended application; establish a safe wind speed for application, i.e., 10 mph or less.
- Understand site characteristics that are prone to leaching losses (for example, sand-based putting greens, coarse-textured soils, shallow water tables).
- Select pesticides with reduced impact on pollinators.
- Select pesticides that, when applied according to the label, have no known effect on endangered species present at the facility.

For information on reducing risk from misapplication due to pesticide drift, reference: https://agrilifeextension.tamu.edu/solutions/flag-the-technology/

Pesticide Transportation, Storage, and Handling

It is important to carefully review and comply with storage information on pesticide labels as improper storage is a form of misuse. Pesticides are at their highest risk before dilution therefore it is especially important to take care of them during storage and transportation.

Key potential risks to human health and the environment are linked to spills, fire, and contaminated runoff.

Ideally pesticide storage facilities will be in a separate building at a distance from other structures. This is important to reduce contamination in the case of large accidental spills and to allow easy access to service vehicles in case of an emergency. Fire extinguishers suitable for chemical fires should be readily available. PPE should be kept off site but within easy access.

To minimize runoff and water contamination risks it is important to consider the immediate environment when selecting the site for a storage facility. Storage facilities should be at least 400 feet downhill from drinking water supplies; 200 feet from surface water and should not be placed within the 100-year floodplain.

Pesticide storage should always be locked and have signage indicating, Danger, Keep Out, Chemical Hazards, or similar. The local fire department should be informed about the storage unit, what it contains, and where it is located.

Best Management Practices

- Storage facilities should be a lockable concrete or metal building with sufficient access to allow fire department approach.
- Do not store pesticides near burning materials or hot work (welding, grinding), or in shop areas.
- Store, mix, and load pesticides away from sites that directly link to surface water or groundwater.
- Storage facility floors should be watertight and sealed with a chemical resistant paint. The 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 of storage facilities to allow the use of wheeled handcarts for moving material in and out of the storage area safely.
- Shelving and surfaces in the pesticide storage and transportation should never be wooden as wooden surfaces can absorb spilled pesticides. All shelving should be made of be made of sturdy plastic or reinforced metal, painted to avoid corrosion.
- 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 temperatures less than 40°F or greater than 100°F inside the pesticide storage facility.
- Do not transport pesticides in the passenger section of a vehicle and never leave pesticides unattended during transport.
- Place a spill containment kit in the storage area, in the mix/load area, and on the spray rig.

Pesticide Inventory & Storage

Pesticides degrade over time; do not store large quantities of pesticides for long periods - and only mix the amount planned for use. When bringing in new product, date the labels to be able to identify the oldest in inventory. Adopt the “first in–first out” principle, using the oldest products first to ensure that the product shelf life does not expire. Utilize computer software systems to record inventory and use. Safety Data Sheets (SDS) and copies of labels for all pesticides on hand should be kept in an easily identifiable location, outside the pesticide storage facility.

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.
- Ensure labels are on every package and container.
- 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 non-flammable.
- 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.
- Keep a separate notebook with copies of labels and SDS sheets outside of the storage area in an office.
- Consult inventory when planning and before making purchases.
- Maintain inventory copies off site for review in case of fire to help containment issues.

Pesticide Mixing/Washing

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

Handling open pesticide containers, measuring pesticide materials, or working with pesticide application equipment presents an exposure risk to the handlers and the environment. Applicators and handlers must put on label-required PPE prior to opening pesticide packages. Consider using closed systems when available.

Mixing is an important part of proper spraying application and it is important that the mixer know what they are spraying, and which chemicals can be mixed together. If uncertain, a jar test should be prepared to make sure the chemicals are compatible. A jar test is a simple method of using small samples of the mixture and mixing in a small jar. This will allow observation of the reaction and make sure a complete mixture can be achieved.

The specific mixing and sequence of mixing instructions on the label should be followed. No chemicals should be mixed without proper supervision. Management should always be involved in the selection and initial stages of mixing to avoid accidents. The most common accidents occur by staff misunderstanding the rates, distractions, and mixing of the wrong materials. Facilities should be ventilated and provide secondary containment of incidental spills due to normal mixing/loading practices, plus secondary containment in the event of large accidental spills.

Best Management Practices

- Loading pesticides and mixing them with water or oil diluents should be done over an impermeable (watertight) surface, so that spills can be collected and managed.
- The mixing station surface should offer easy cleaning and the recovery of spilled materials.
- Pump the sump dry and clean it at the end of each day.
- Liquids and sediments should be removed from the sump and properly managed and disposed of.
- Apply liquids and sediments from the sump the same as a pesticide, strictly following label instructions.
- Sweep up solid materials and use as intended.
- Rinsate may be applied as a pesticide (preferred) or stored for use as makeup water for the next compatible application. Caution: do not mix herbicide rinsate with other products.
- Collect wash water (from both inside and outside the application equipment) and use it as a pesticide in accordance with the label instructions.

Pesticide Container Disposal

Federal law (FIFRA) requires pesticide applicators to rinse all empty pesticide containers before taking other container disposal steps. Under the federal Resource Conservation and Recovery Act, or RCRA, a pesticide container is not empty until it has been properly rinsed. The improper disposal of a hazardous waste can result in fines and/or criminal penalties. Pesticide containers that have been properly rinsed can be handled and disposed of as non-hazardous solid waste.

Best Management Practices

- Refer to the label for disposal requirements.
- Rinse empty pesticide containers immediately after use 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 or crush empty and rinsed pesticide containers and dispose of according to the label.
- It is against the law to use empty pesticide containers for another function. Empty containers must be rendered unusable (i.e., punctured) and disposed of according to label directions. There are approved recyclers for plastic pesticide containers, refer to TCEQ: https://www.tceq.texas.gov/p2/hhw/about.html

Emergency Preparedness and Spill Response

Advance preparation on what to do when an accident occurs is essential to mitigate human health effects and environmental impact. An emergency response plan should be in place. The plan should include:

- Names and quantities of pesticides in inventory.
- Location of property, including a map and directions (to relay over phone in emergency).
- Names, addresses, and phone numbers of the designated spokesperson, superintendent, and key employees.
- Plan of facility showing pesticide storage locations, flammable materials, electrical service, water supply, fuel storage tanks, fire hydrants, storm drains, and nearby wetlands, ponds, or streams.
- Location of emergency equipment supplies.
- Procedures to control, contain, collect, and store spilled materials.
- Contact information for fire, police, hospital, pesticide bureau, spill clean-up firm, board of health, and facility owner.

Ensure that copies of the plan are located near the pesticide storage facility and the office and distributed to local police and fire departments. Maintain copies in English and any other language commonly used by employees.

Best Management Practices

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

Be Prepared for Emergencies

Be sure to always prominently post important telephone numbers, including:

- CHEMTREC, for emergency information on hazards or actions to take in the event of a spill
- Texas Commission on Environmental Quality (TCEQ) 1-800-832-8224 or (512) 239-2507
- TCEQ Small Business Assistance Program 1-800-447-2827
- Texas State Poison Control Center 1-800-764-7661 (1-800-POISON1)
- National Pesticide Information Center (http://npic.orst.edu/) 1-800-858-7378

Pesticide Record-Keeping

Pesticide applicators who have a private applicator license or certificate are required to maintain records of their applications of RUPs and state-limited-use pesticides under the Food, Agriculture, Conservation and Trade Act of 1990 and the Texas Pesticide Laws and Regulations.

Commercial and noncommercial license holders must keep records of all pesticide applications in Texas.

Records must contain:

1. Date and time of application
2. Person for whom application was made
3. Location of land
4. Product name
5. EPA registration number
6. Rate of product per unit
7. Amount applied per unit
8. Pest treated
9. Site treated
10. Total acres or volume of area treated
11. Wind direction and velocity and air temperature
12. Method or Type of Equipment Used to Make Application
13. Non licensed Applicator's name Working Under Licensee
14. FAA "N" number of aerial equipment; ID number of other application equipment
15. Applicator name and license number and/or person making the application
16. Spray permit number for regulated herbicides applied in a regulated county - spray permit not required for golf course applications
17. Documentation to verify training of persons working under the supervision of a licensed pesticide applicator

Best Management Practices

- Records must be maintained for two years.
- Records must be kept accessible and available for copying and must be maintained at the applicator's primary place of business as designated on the applicator's pesticide license.
- Records of application must be made available for inspection by TDA upon request.
- Keep a backup set of records in a safe, but separate storage area.
- Records do not have to be kept on TDA forms but must contain the required information.
- Use records to monitor pest control efforts and to plan future management actions.

There are several resources available to assist with record-keeping, examples include:

- GreenKeeper https://www.greenkeeperapp.com/marketing/
- Playbooks for Golf https://goplaybooks.com/coverage.html
- Sparks https://sparks2.com/
- PeRK https://cropwatch.unl.edu/unl-releases-perk-20-pesticide-recordkeeping-app

TDA Q527
7/15

Texas Department of Agriculture
Pesticide Applicator Record

COMMISSIONER SID MILLER

Business/Applicator Name _____ **Address** _____

Application Date	Time Started	Name of the person for whom the application was made	Location of Land Treated		Site Treated	Wind Direction	Wind Velocity	Air Temp

Product Trade Name	EPA Registration Number	Target Pest	Rate of Product Per Unit	Method or Type of Equipment Used To Make Application	FAA "N" Number for Aerial Application Equipment:

Is Application Applied in Regulated County: □ Yes □ No | **Regulated Herbicide Permit Number:**

Licensed Applicator's Name and License Number	Non-licensed Applicator's Name Working Under Licensee	Total Acres or Volume of Area Treated	Total Volume of Spray Mix, Dust, Granules or Other Materials Applied Per Unit

Documentation used to verify training of non-licensed applicator (Mark Applicable Box)
□ Direct Supervisor Affidavit □WPS Handler Card □Signed & Dated Label

Application Date	Time Started	Name of the person for whom the application was made	Location of Land Treated		Site Treated	Wind Direction	Wind Velocity	Air Temp

Product Trade Name	EPA Registration Number	Target Pest	Rate of Product Per Unit	Method or Type of Equipment Used To Make Application	FAA "N" Number for Aerial Application Equipment:

Is Application Applied in Regulated County: □ Yes □No | **Regulated Herbicide Permit Number:**

Licensed Applicator's Name and License Number	Non-licensed Applicator's Name Working Under Licensee	Total Acres or Volume of Area Treated	Total Volume of Spray Mix, Dust, Granules or Other Materials Applied Per Unit

Documentation used to verify training of non-licensed applicator (Mark Applicable Box)
□ Direct Supervisor Affidavit □WPS Handler Card □Signed & Dated Label

Pesticide recordkeeping requirements for state and federal restricted pesticides in Texas: https://www.texasagriculture.gov/Portals/0/Publications/PEST/pes_rkbroch.pdf

10

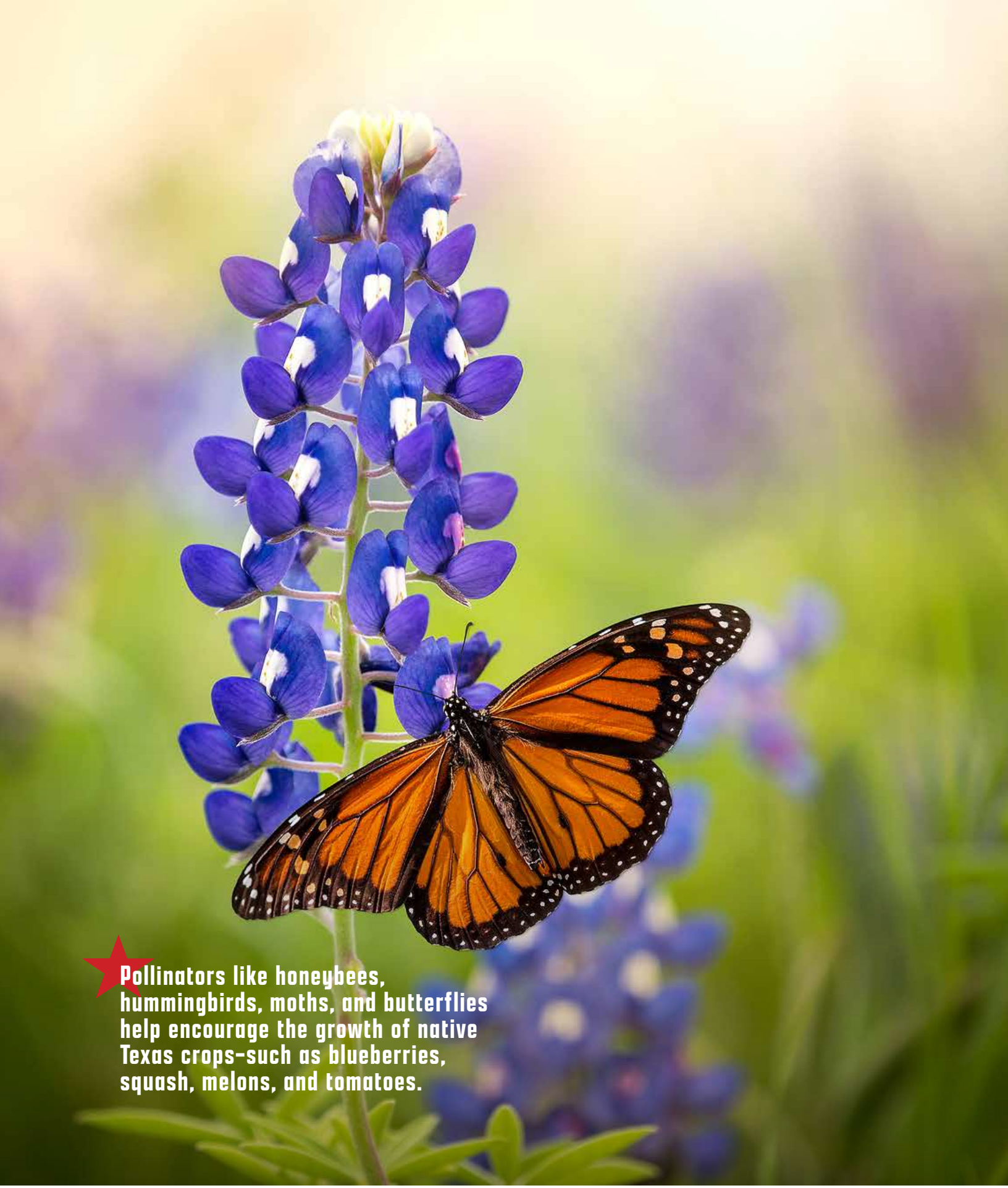
POLLINATOR PROTECTION & WILDLIFE HABITAT

Golf courses in Texas provide more than 136,000 acres of greenspace and bluespace for wildlife and pollinators to flourish.

With so many urban areas in the state and an increasing population, golf courses are integral to providing natural habitats, such as ponds, trees, and flowers, for pollinators and other wildlife.

Regulatory Considerations

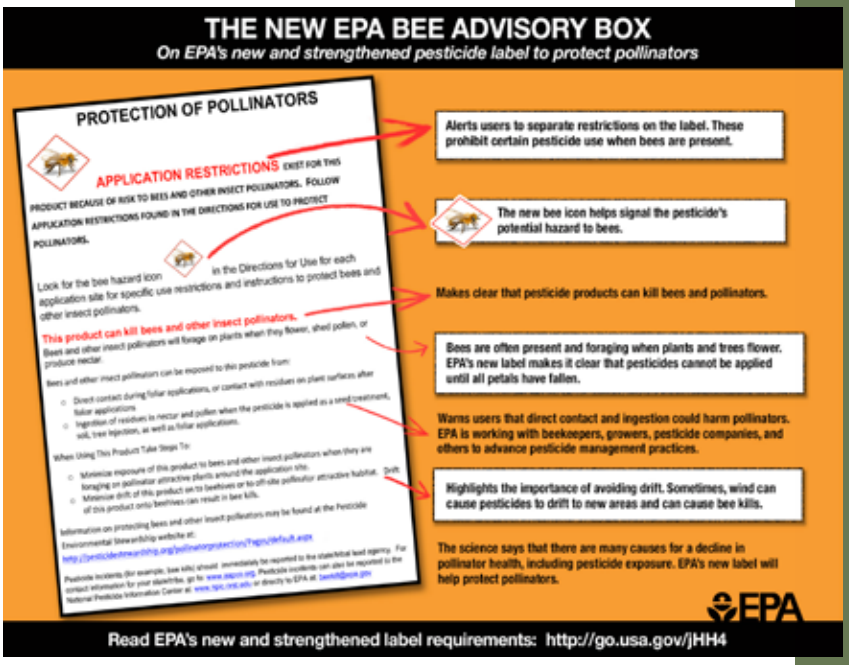
- Pollinator protection language is a label requirement found on pesticide labels and must be followed; it is the law!
- Pesticide applicators must be aware of honeybee toxicity groups and be able to understand precautionary statements
- Recordkeeping, as required by Texas law, should be maintained in order to refer to in the future and follow the best course of action with future applications if necessary, reference IPM BMPs section for additional information
- Applicators of pesticides should be mindful of applications and their effects on the target and any others that may be compromised
- Reference Texas Endangered and Threatened Species: https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/listed-species/
- Reference Texas Endangered, Threatened, and Special Concern Species by County: https://tpwd.texas.gov/gis/rtest/
- The Texas Apiary Inspection Service is a state agency to safeguard the apiary industry, which operates under the authority of Section 131 of the Texas Agricultural Code. The inspection service is administered under AgriLife Research, a part of the Texas A&M university system: https://txbeeinspection.tamu.edu/



Pollinators like honeybees, hummingbirds, moths, and butterflies help encourage the growth of native Texas crops–such as blueberries, squash, melons, and tomatoes.

Pollinator Protection

To reproduce and to grow more fruit, many flowering plants depend on pollination. The wind assists in spreading pollen, but insects and other animals play a larger role in this process. Population growth and increasing urban development can impact availability of natural habitats. Pollinators needs native plant habitats to thrive. If there is a significant decline in pollinators, it could place a financial burden on the state's agriculture industry. Honeybees alone pollinate Texas crops valued at more than $587 million each year. As more native plants are planted in Texas, more pollinators will survive, increasing the level of crops produced and helping the state's economy. Pollinators in Texas include bees, bats, hummingbirds, butterflies, beetles, and moths.



Best Management Practices

- Follow label instructions when applying pesticides to avoid application when plants are in bloom.
- Follow IPM BMPs.
- Consider lures, baits, and pheromones as an alternative to pesticides for pest management.
- Mow flowering plants before pesticide applications to remove blooms.
- Consider manual removal of weeds or spot treatment in pollinator habitat areas.
- Use the latest spray technologies such as drift-reduction nozzles to prevent off target application.
- Apply during times of little or no wind in order for more accurate placement of pesticide.
- Avoid applications during low temperatures and when dew or temperature inversion is forecasted.
- Plant flowers with varying characteristics like color, shapes, sizes, flowering times, and growth habits.
- Mow natural areas 1x per year late in season when plants are going dormant in order to control growth of woody ornamentals and other undesirable plants to minimize effects on pollinators.
- Limit use of granular pesticides that can be mistaken for pollen.
- Develop relations with local beekeepers and pollinator associations to become connected with local education events.
- Consider setting up hives within a natural area of the golf course that can be maintained by an interested staff member or person within the community.
- Attend workshops and online seminars to learn more about pollinators and steps to protect them.
- Invite local schools, garden clubs, master gardeners, etc. to visit the facility to demonstrate the steps taken to protect pollinators.

Texas Pollinator Plants

- Crape myrtle
- Texas redbud
- Live oak
- Coralbean
- Buttonbush
- Coralberry
- Red yucca
- Bee balm
- Texas lantana
- Butterfly milkweed
- Fennel
- Virginia creeper

Pollinator Habitat Protection and Enhancement

As the size of rural areas dwindle, pollinators accustomed to living in natural landscapes find it more difficult to survive. Golf courses can help mitigate these effects by including habitats for pollinators in non-play areas and protecting migratory corridors. It is important to pay attention to where pesticides are applied, making sure not to get it too close to these plants. Pollinators like diversity in plants, so it is best to mimic the plants found in natural areas. It's helpful to understand colors, odors, and variety of plants that encourage pollinators.

Other ways to encourage pollination include:

- Providing nectar sources with pollinator gardens
- Ensuring there are flowers blooming in every season
- Providing shelter, such as open patches of soil, old wood, branches, and leaves
- Protecting plants from cold weather
- Making sure plants are getting enough water

Examples of plants native to Texas:

https://www.wildflower.org/collections/collection.php?collection=Organization_1561

Additional pollinators information:

https://texasbeekeepers.org/about-5/

https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/texas_nature_trackers/monarch/#:~:text=The%20Monarch%20Butterfly,%26%20Other%20Insect%20Pollinators&text=Texas%20is%20an%20important%20state,the%20fall%20and%20the%20spring

https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/wildscapes/ecoregions/

https://www.syngenta.com/sustainability/operation-pollinator

Wildlife Habitats

Texas is home to more than 142 different species of animals. Nearly 100 plant and animal species in Texas are considered endangered, and many more are threatened or protected. This typically occurs due to loss of habitat when rural areas are turned into suburbs and cities. Some of the state's larger endangered species rely on large swaths of open land, but these expanses are declining. Golf course habitats featuring trees, flowers, lakes, ponds, and grasslands provide homes for many endangered species, including birds, fish, and foxes. Loss of habitat is the primary reason for a species becoming endangered. Some endangered animals in Texas include the ocelot, Houston toad, Kemps ridley sea turtle, and golden-cheeked warbler.

Best Management Practices

- Develop relations with Texas Parks and Wildlife
- Understand whether the property is an existing or potential habitat for endangered species
- Develop a management plan and objectives
- Retain existing vegetation when possible and plant native vegetation
- Use "xeriscape" landscaping and native drought tolerant plants where feasible
- Educate staff, members/guests, and community
- Use social media and local news outlets to educate golfers and the general public on steps taken to promote wildlife habitats
- Invite local schools, garden clubs, master gardeners, etc. to visit the facility to demonstrate the steps taken to promote habitats
- Participate in Texas Audubon https://tx.audubon.org/, or similar, bird counts or host bird-watching tours for guests
- Get involved with Audubon International https://audubonintenational.org/acsp-for-golf/

Texas golf courses host an abundance of wildlife species, providing habitats amongst designated wetlands, lakes, streams, ponds, grasslands, and native areas.

Examples of Texas Wildlife

Mammals

- Badger
- Black bear
- Bobcat
- Common Raccoon
- Coyote
- Desert Cottontail
- Eastern Red Bat
- Elk
- Gray Wolf
- Mountain Lion
- Ocelot
- Palo Duro Mouse
- River Otter
- Striped Skunk
- Texas Kangaroo Rat
- Virginia Opossum

Birds

- American Peregrine Falcon
- Bald Eagle
- Black-chinned Hummingbird
- Blue Jay
- Burrowing Owl
- Downy Woodpecker
- Eastern Bluebird
- Inca Dove
- Northern Cardinal
- Northern Mockingbird
- Pine Warbler
- Red-shouldered Hawk
- Whooping Crane

Amphibians

- Barred Tiger Salamander
- Houston Toad
- Southern Leopard Frog

Fish

- Blue Catfish
- Common Carp
- Fathead Minnow
- Green Sunfish
- Largemouth Bass
- Rainbow Trout
- Red Snapper
- Smallmouth Bass
- Spotted Seatrout
- Walleye
- White Bass
- Yellow Bass

Invertebrates

- Blue Crab
- Eastern Oyster
- Fiddler Crab
- Gulf Stone Crab

Reptiles

- American alligator
- Bullsnake
- Green Sea Turtle
- Loggerhead Sea Turtle
- Louisiana Pine Snake
- Northern Earless Lizard
- Red-eared Slider
- Southern Copperhead
- Texas Horned Lizard
- Texas Tortoise
- Timber Rattlesnake
- Western Cottonmouth

Reference for additional information: https://tpwd.texas.gov/huntwild/wild/species/

Texas golf courses provide the necessary living spaces for many different types of wildlife, from bats to alligators to bobcats. Ponds, lakes, streams, and designated wetlands allow for frogs, toads, turtles, and fish to survive, while native landscape and natural grasslands allow for birds and mammals to find shelter and food. Forested buffers along golf course streams and wetland areas provide sanctuaries for birds and other wildlife, while protecting water quality. When riparian buffers connect isolated blocks of habitat, they also serve as important travel corridors. Natural vegetation should be retained and enhanced through supplemental planting of native trees, shrubs, and grasses in non-play areas.

References for additional information:

https://ballotpedia.org/Endangered_species_in_Texas#Listed_species

https://tpwd.texas.gov/gis/rtest/

https://tpwd.texas.gov/education/hunter-education/online-course/wildlife-conservation/threatened-endangered-and-protected-animals

Education

Train the crew on identifying endangered species and educate members and guests through newsletters, meetings, and signage. Section off habitat areas so that nesting wildlife is left undisturbed. Plan and implement a public awareness program to increase landowner and land manager knowledge of wildlife needs.

External Certification Programs & Standards

Environmental management programs, health and wellness platforms, and environmentally-friendly building design can help courses protect the environment and promote community relations. These programs can help enhance natural areas and wildlife habitats that golf courses provide and improve efficiencies. Obtaining certifications and adhering to standards can enhance community, member/guest, employee, and civic relations.

Certifications and internationally-recognized frameworks that golf courses and clubs can pursue range from environmentally-focused programs to certifications related to health and wellness. Establish a communications plan to educate members/guests and the community.

Reference GCSAA Environmental Institute of Golf for more information: https://www.eifg.org/

External Certifications and Frameworks

Audubon International Cooperative Sanctuary, Signature, and Sustainable Communities Programs
https://www.audubonintenational.org/

US Green Building Council Leadership in Energy and Environmental Design (LEED)
https://new.usgbc.org/leed

Global Reporting Initiative GRI Standards
https://www.globalreporting.org/standards/

Blue Zones Project
https://www.bluezonesproject.com/

B Corp Certification
https://bcorporation.net/certification

Sustainable Development Goals
https://sustainabledevelopment.un.org/sdgs

11

MAINTENANCE OPERATIONS

Maintenance operations facilities include areas for employee training, equipment maintenance, and storage of all maintenance items including chemicals, fertilizers, and fuel. Key protocols must be put in place to minimize environmental impact and promote the health and safety of staff and customers.

Regulatory Considerations

Early engagement amongst developers, designers, community groups, and permitting agencies is essential to constructing a golf maintenance and storage facility. Local and regional regulations may be in place by municipality or county. Consult the proper regulatory officials to determine requirements.

It is important to ensure proper handling and storage of pesticides and petroleum-based products to reduce human, environmental, and economic risks including the potential for serious injury to operators or bystanders, environmental contamination, fines, and cleanup costs. Resources for state regulations are noted in each subsection.

Labor regulations and guidance pertain to wages, work hours, licenses, safety training, and more. Every employer shall post in a conspicuous place upon its premises, a workplace poster regarding federal and state laws. Requirements may be found at: https://www.twc.texas.gov/businesses/posters-workplace

Additional resources:

Texas' statewide recycling program, governed by the TQEC: https://www.tceq.texas.gov/p2/recycle

The Texas Workforce Commission enforces regulations on wages, hour requirements, and licenses: https://www.twc.texas.gov/equal-opportunity-law

Texas Civil Rights and Discrimination: https://www.twc.texas.gov/partners/civil-rights-discrimination

OSHA training: https://www.osha.gov/training/outreach

GCSAA labor guidance: https://www.gcsaa.org/advocacy/compliance/labor

Department of Labor youth and labor: https://www.dol.gov/general/topic/youthlabor

Good golf course maintenance operations and facilities help create a safe, productive and enjoyable environment for employees, as well as golfers and onsite visitors.

Texas Emergency Contact Numbers

Poison Control Center: 1-800-222-1222 (National)

State of Texas Spill-Reporting Hotline and the SERC:
1-800-832-8224—24 hours a day.
https://www.tceq.texas.gov/response/serc.html

TCEQ Regional Office, Monday-Friday, 8:00 a.m.–5:00 p.m.
https://www.tceq.texas.gov/agency/directory/region/reglist.html

Maintenance Facility

Maintenance facilities accommodate needs such as office, lunch or break rooms for staff, equipment and supplies storage, and mechanics areas. All areas should be properly ventilated and well-lit. Numerous activities should be considered to help contribute to water, energy, and cost reductions:

- Restrict water flow to the maximum necessary for adequate use
- Use automatic shutoffs on faucets
- Install 1.5-gallon tanks on toilets
- Use motion detectors to turn on lights when staff is preseny

Administrative and Managerial Offices, Employee Break Room and Training Area

Maintenance facilities should include an employee lunch/break room, which can also serve as a professional training area for technical education. The area should be clean, organized, and promote a relaxed atmosphere. The size of the lunchroom will be determined by the size of the golf course operation and number of maintenance crew employees; this area should be developed alongside the administrative and managerial offices with desks, computers, files, phones, and storage. Important items to include:

- Ample tables/chairs for dining and training
- One or two microwave ovens (reduces time for meal preparation)
- One adequate-sized (energy saver) refrigerator
- Drinking water with dispenser, coffeemaker, refreshment vending machine
- Kitchen area with sink, water, sufficient cabinet area
- Adequate space including light, easy-to-clean colors/walls
- Organized food and utensil storage with labeled containers and easy-to-access shelves
- Erasable or electronic communication board
- Air conditioned and insulated, with overhead fans for air flow

Employee Restroom/Locker Room/Shower

Design restrooms to promote superior personal hygiene. They should be easy to clean with adequate space/amenities to service several employees simultaneously. The locker room should be adjacent to restrooms and incorporate full-length lockers with at least one shower. Use a semi-gloss, high quality paint for ease of cleaning. Use a dry deck type material on portions of the floor to prevent slippage and spread of bacteria. These rooms should be insulated and air conditioned.

Mechanics Workshop and Office

The mechanics workshop should be designed with enough space to facilitate servicing and repair of equipment. To minimize the risk of injuries, install an assortment of lifts (beam supported, flush floor mounted, and portable) which should be used to assist with moving equipment. Floor space requirements can be reduced through installing grease and oil dispensers in an overhead lube center, supported by compressed air connected to bulk drums. Inflammable materials should be kept in fire resistant storage and a sink and hand dryer should be available for staff use.

Large work benches provide ease for working at waist level and can decrease risk of back injury. These benches can also incorporate underneath storage for space optimization. An air-conditioned office with desk, computer, files, phone, and storage should be adjoining.

Storage Areas

Chemical and Fertilizer Storage

Due to their potentially hazardous nature pesticides should be stored inside an IPM Control Center. This is a lockable concrete or metal building designed for storage of pesticides which should be located away from other buildings, especially fertilizer and fuel storage facilities.

A separate fertilizer storage structure should be large enough to allow a small forklift to deliver fertilizer by pallet. If the building is constructed of metal this should be protected from degradation by fertilizer (such as adding painted plywood around the walls). A dehumidifier can be a useful addition to a fertilizer tool in order to help protect fertilizer from water absorption.

Best Management Practices

- Place appropriate warning signs within and outside of storage buildings.
- Store PPE away from pesticide storage in an easily accessible area.
- Follow all PPE statements on pesticide labels.
- Develop an emergency response plan and educate personnel regarding emergency procedures on a regular basis.
- Individuals conducting emergency chemical cleanups should be properly trained under requirements of the Occupational Safety and Health Administration (OSHA).
- Detailed records of current pesticide inventory should be maintained in the storage facility.
- SDS for chemicals stored onsite should be readily accessible and stored separately from the storage room.
- Follow a “first in, first out” principle to rotate products into use and ensure products do not expire. Do not store large quantities of pesticides or chemicals for long periods.
- Store chemicals in original containers; never store in containers that might be mistaken as packaging for food or drink.

For more information refer to the Pesticide Management Section for additional BMPs.

Soil Storage

Soil storage and fertilizer storage areas should be near to each other. Deliveries may be deposited outside storage bins and pushed into the bin with a front-end loader. Soil storage areas should have roof coverings to prevent wind from dispersing seeds into top dressing and to prevent rain or moisture from reaching the soil.

Block walls that separate sand, topdressing, and rock should be filled solid with concrete. Ceiling fans can help reduce moisture retention.

Equipment Maintenance & Storage

Equipment storage and maintenance facilities should be designed to prevent accidental discharge of chemicals, fuels, or contaminated wash water from reaching water sources. The proper storage and preventive maintenance of equipment also extends the useful life of machines and reduces repairs. The equipment maintenance and storage areas provide an excellent location for the shop compressor, eliminating the loud running sound in a personnel work area.

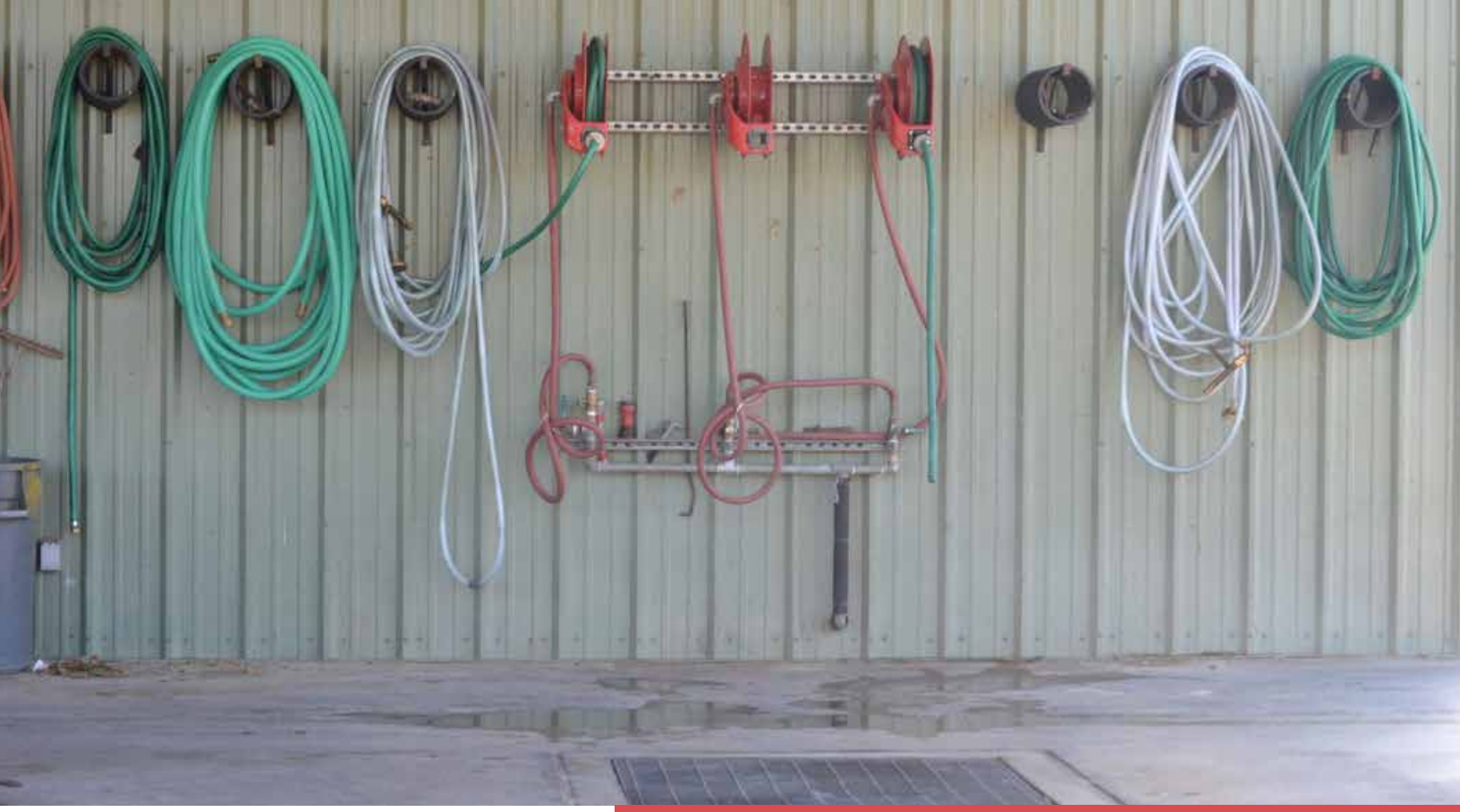
Developing a list of necessary equipment to properly maintain the golf course, with information including the size of the equipment is important to determine space requirements. Each piece of equipment should have a designated spot, delineated by colored lines, with its name or number indicated, and consistently parked in the same spot daily. It helps to identify if a leak (oil, hydraulics, etc.) develops when equipment is parked in a designated location and increases accountability for optimal operating conditions.

Good facility logistics planning and management will minimize unnecessary shuffling of equipment when one piece needs to be brought in or out. Overhead doors located on both sides of the equipment storage area allow for ease when moving equipment and improve air flow. Overhead fans in the equipment storage area facilitate also air flow and help reduce moisture.

Waste oil from equipment should be collected and stored in a container set on containment. If stored outside, there should be a roof over the container and a valve in the bottom to release rainwater.

Best Management Practices

- Store and maintain equipment in a covered area with a sealed impervious surface to limit risk of fluid leaks and facilitate early detection of small leaks that may require repair.
- 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 to prevent discharge into 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 materials onsite, in a different location that is easily accessible in case of an emergency.
- Keep basins of solvent baths covered to reduce emissions of volatile organic compounds.
- When possible, replace solvent baths with recirculating aqueous washing units. Soap and water or other aqueous cleaners are often as effective as solvent-based products and present a lower risk to the environment.
- Always use appropriate PPE when working with solvents.
- Never allow solvents or degreasers to drain onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.
- Collect used solvents and degreasers in containers clearly marked with contents and date.
- Blow off equipment with compressed air to reduce damage to hydraulic seals.



Equipment Washing

A clean, enclosed, watertight area should be dedicated for washing down equipment. Closed loop water recycling systems with a proven track record should be utilized. Captured wash water may be pumped into a rinsate storage tank for use in the next application and used as a dilute pesticide per label instructions. Equipment washing guidelines should be established to help prevent potential for residues (such as pesticides, oil, and grass clippings) from reaching surface waters, groundwater, drainage pipes, or storm sewers.

When washing mowers, it is important to address grass clippings so that these do not enter the wash water recycling system. Blow clippings off mowers using compressed air, to be collected and composted or disposed of in a designated debris area.

For equipment with possible pesticide residue, BMPs should be followed to ensure that wash water does not become a pollution source.

Best Management Practices

- Before washing use compressed air to blow off grass clippings from equipment.
- Wash equipment on a water-resistant surface (concrete or asphalt pad) that collects the wash water. Once collected material dries, dispose properly.
- Only use the amount of water required - wash equipment with a bucket of water and a rag; use spring-loaded spray nozzles; and minimize unnecessary rinsing.
- Minimize use of detergents and use only those which are biodegradable, non-phosphate.
- Consider a closed-loop wash water recycling system.
- Do not discharge wash water to surface water, groundwater, or susceptible/leachable soils either directly or indirectly through ditches, storm drains, or canals; never discharge to a septic tank.
- Never discharge wastewater to a sanitary sewer system without written approval from the appropriate entity.
- Washing areas for equipment not contaminated with pesticide residues should drain into oil/water separators before draining into sanitary sewers or holding tanks.
- Do not wash pesticide-application equipment on pads with oil/water separators. Do not wash near wells, surface water, or storm drains.
- Do not wash equipment on a pesticide mixing and loading pad; keep grass clippings and debris from becoming contaminated with pesticides.
- Solvents and degreasers should be used over a basin that collects used material.

Texas Waste Management Regulatory Resources

Waste Management Requirements and Permits including Dredge or Fill Material: https://www.tceq.texas.gov/permitting/waste_permits

Industrial and Hazardous Waste: https://www.tceq.texas.gov/permitting/registration/ihw/Am_I_Regulated.html

https://www.tceq.texas.gov/assets/public/comm_exec/pubs/rg/rg-086.pdf

Composting and mulching guidance: https://www.tceq.texas.gov/p2/composting.html

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.

Waste Handling

Proper waste management is important for the health and safety of the public, in addition to conserving natural resources within the state of Texas. Current statewide recycling efforts include around 23 percent of waste being diverted from Texas landfills annually. TAC Title 30 §328.13 sets a recycling goal of 40 percent of municipal solid waste for the state. Waste reductions through recycling and composting result in reduced energy use and pollution. A golf course maintenance facility generates a variety of waste materials including fluorescent or LED lights, glass containers, plastic, tires, metal, paper products, solvents, chemical containers, batteries, used oils, used or contaminated fuel, paints, aluminum cans, and wood. A proper recycling and waste removal program should be deployed to maintain health and safety, plus reduce waste to landfills.

Recycling: Paper, Plastic, Aluminum, Glass, and More

Paper, cardboard, #1 and #2 plastics, aluminum, and glass should be recycled. Containers for recycling aluminum cans and plastic bottles should be placed in convenient locations on the golf course. Texas law requires television and computer-equipment manufacturers to offer recycling opportunities to consumers for these electronics. Options under the Texas Computer Recycling and TV Recycling programs for recycling electronics: https://www.tceq.texas.gov/p2/recycle/electronics/manufacturer-list.html

The waste disposal area should be located away from normal employee activity, but close enough to be utilized properly. Proper access for waste pick-up vehicles should be incorporated into the design and location.

Reference additional information:

https://www.tceq.texas.gov/p2/recycle

https://www.tceq.texas.gov/assets/public/comm_exec/pubs/gi/gi-288.pdf

https://texreg.sos.state.tx.us/public/readtac$ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=328&rl=6

Best Management Practices

- Measure waste levels and implement source reduction practices to reduce the amount of waste generated in the first place.
- Separate and label designated areas for recyclables and waste.
- Educate staff and guests on items which may be recycled; identify ways to increase recycling efforts, including proper signage and communications.
- Operate equipment properly, adhering to preventive maintenance and manufacturer guidelines to avoid need for repair and prolong lifecycle, minimizing replacement needs.
- Source environmentally preferred products when possible.
- Reduce waste by only purchasing materials in a quantity that can be used prior to the expiration date or within six to 12 months of purchase.
- Label containers for the purpose of storing oils, solvents, degreasers, and fuels.
- Never dispose of waste down storm drains.
- 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.
- Properly manage used batteries and fluorescent bulbs as Universal Waste and recycle as soon as feasible.
- Recycle used tires.
- Consult an expert in composting for optimal design and processes.
- Utilize DNR guidelines for hazardous waste disposal and collection services.
- Local laws and regulations related to disposal of hazardous waste products may vary; become familiar with local laws related to disposal/recycling of these materials.

Pesticide Containers

Under the federal Resource Conservation and Recovery Act, or RCRA, a pesticide container is not empty until it has been properly rinsed. Unless properly rinsed empty a pesticide container us therefore classified as hazardous waste. Federal law (FIFRA) requires pesticide applicators to rinse all empty pesticide containers before taking other container disposal steps. The improper disposal of a hazardous waste can result in fines and/or criminal penalties. Pesticide containers that have been properly rinsed can be handled and disposed of as nonhazardous solid waste.

Resource for recycling empty, clean plastic pesticide containers: http://www.usagrecycling.com/

Reference the "Pesticide Management" section for additional BMPs for waste generated from pesticide activities.

Used Oil, Antifreeze, and Lead-Acid Batteries

Collect used oil, oil filters, and antifreeze in separate marked containers and recycle them. Oil filters should be drained (puncturing and crushed) and transported to a place that recycles used oil or to a hazardous waste collection site. Antifreeze must be recycled or disposed of as a hazardous waste using commercial collection services. Do not mix used oil with used antifreeze or sludge from used solvents.

Used-acid from lead-acid storage batteries is hazardous waste. They must be disposed of as hazardous waste, unless the acid is contained within a battery being recycled. Make sure caps are in place to contain the acid and store batteries on an impenetrable surface, under cover if possible. Used lead-acid batteries must be recycled to be exempt from hazardous waste regulations. Refer to TAC Title 30 §328.13 for additional state information regarding disposal.

Solvents and Degreasers

EPA and FDEP can deem a "small quantity generator" of hazardous waste based on disposal of as little as 25 gallons per month of used solvents, triggering regulatory reporting requirements. This is because, over time, routine discharge of small amounts of solvents can create environmental and liability consequences, due to accumulation of contaminants in soil or ground water. As much as is possible, replace solvent baths with recirculating aqueous washing units (which resemble heavy-duty dishwashers). Soap and water or other aqueous cleaners may be as effective as solvent-based ones.

Composting

Composting can reduce the amount of grass clippings and debris, such as leaves, or routine, healthy landscape trimmings that would normally go to a landfill. Composted materials can be used effectively to improve the soil for topdressing, non-putting surface areas, and donated or sold to offsite vendors.

In addition, the clubhouse food and beverage department may engage in food waste composting. Additional information on composting in Texas: https://www.tceq.texas.gov/p2/composting.html

Best Management Practices

- Use compressed air to blow off equipment instead of washing with water to minimize wear to hydraulic seals and lead to fewer oil leaks.
- Solvents and degreasers are generally toxic and highly flammable and should be stored in lockable metal cabinets in an area away from ignition sources, provided with adequate ventilation.
- Never store solvents or degreasers with pesticides or fertilizers, or in areas where smoking is allowed.
- Keep basins or cans of solvent covered to reduce emissions of volatile organic compounds and fire hazards.
- Follow OSHA signage requirements.
- Ensure all personnel wear adequate PPE, especially eye protection, when working with solvents.
- Never allow solvents to drain onto pavement or soil, or discharge into waterbodies, wetlands, storm drains, sewers, or septic systems.
- Most solvents can be filtered and reused so should be used over a collection basin or pad that collects all used material.
- Keep an inventory of solvents stored and the SDS for each on premise, but not in the solvent storage area.
- Emergency response equipment recommended by the solvent manufacturer should be kept in an easily accessible place near the storage area, but not inside the area itself.
- Store collected material in marked containers until it can be recycled or legally disposed of. Solvent disposal organizations provide solvent washbasins that drain into recovery drums and pickup service to recycle or properly dispose of drum contents.
- Collect used solvents and degreasers, place them into containers marked with contents and date, prior to pick up. Never mix used oil or other liquid material with used solvents. Use only FDEP-approved, licensed contractors.

Fuel Facilities

Fueling facilities should be designed, constructed, maintained and monitored to local or state codes. Check codes for regulations on storage tanks; aboveground storage tanks (AST) are the preferred storage method because it is easier to monitor for leakage. An underground storage tank (UST) must have leak detection monitoring for compliance. Leaks or spills must be contained or cleaned up immediately.

Proper fueling sites have impervious surfaces, spill containment and recovery facilities, located away from surface waters and water wells. Floor drains should be eliminated or removed unless they drain to containment storage tanks or pits.

Title 40, Section 112 of the Code of Federal Regulations (CFR) requires a Spill Prevention Control and Countermeasure (SPCC) plan for facilities with total aboveground petroleum product storage (i.e., new oil, used oil and fuel) capacity in excess of 1,320 gallons. SPCC plans can help minimize the potential for a petroleum leak or spill to occur and mitigate environmental impacts. SPCC regulations generally require secondary containment for filling and dispensing operations; alternatives are allowed if secondary containment is impractical.

Best Management Practices

- Locate fuel storage tanks above ground, on impervious surfaces under roofed areas, when possible.
- Areas should be equipped with spill containment and recovery facilities.
- Keep a log of fuel added and discharged.
- Visually inspect the tank for leaks and document in an inspection log.
- Place automatic shut off valves away from the tanks in case of emergency.
- Post “No Smoking” signs near the fueling facility.
- Properly and clearly label fuel storage tanks.

Fuel Storage Requirements and Regulations

Federal: EPA
https://www.epa.gov/oil-spills-prevention-and-preparedness-regulations/overview-spill-prevention-control-and

Texas: TCEQ
https://www.tceq.texas.gov/permitting/registration/pst/Am_I_Regulated.html

Having a positive, engaging culture helps reduce turnover, drives motivation, and improves productivity.

Labor & Staffing

Golf courses in Texas drive economic impact through workforce development and job creation. Texas golf course maintenance departments provide full-time and seasonal work for a diverse workforce across the state, collaborating with local municipalities, school systems, workforce development boards, and community programs to hire talented, dedicated staff.

To ensure a continuous, quality labor supply it is important to engage with state educational institutions. This can be done in a number of ways including supporting scholarships for local college students or hosting field trips for elementary, junior high, and high schools to explore golf courses from a science, math, biology, and learning perspective. These engagements begin to develop future generations of golf maintenance professionals. Superintendents frequently hire students from local schools and universities for full-time or part-time employment and internships.

Labor supply is influenced by demographic, economic, technological, educational, and societal factors. BMPs provide strategies for overcoming labor shortages and minimizing training and recruiting costs, plus lowering turnover and associated expenses. As part of the overall effort, it is crucial to create a culture of inclusiveness, teamwork, education, and professional development.

It is essential to maintain compliance with all equal rights labor standards and civil rights. Educate staff and encourage awareness of state and federal laws regarding key issues such as minimum wage regulations. OSHA training and safety practices should be kept up-to-date; accessible operating standards should be available; and proper workplace injury reports, along with clearly documented worker's compensation programs should be in place.

Best Management Practices

- Adhere to federal and state hiring regulations and requirements
- Provide ongoing OSHA and safety training, post required signage
- Communicate written operating standards in multiple languages and through various formats
- Educate on PPE and proper safety precautions when operating equipment or handling chemicals
- Understand current golf maintenance labor data, including expenses, retention, and turnover rate
- Develop relationships within the community through a variety of school and government-based programs to diversify workforce
- Utilize multiple recruiting methods and pipelines to integrate diversity and inclusion into hiring practices
- Sponsor events, host meetings with key community influencers including school administration, chambers of commerce, parents
- Utilize the Work in Texas site to post positions: https://www.workintexas.com/vosnet/Default.aspx
- Understand and explore H2B process for seasonal employees
- Create a statewide Apprenticeship program with unified standards that can be adopted at the facility level; where students may take courses related to the profession as a way of enhancing what is being learned on the job
- Develop relations with the local school systems, vocational schools, community colleges, and universities; provide continuing education opportunities
- Build relationships with post-secondary institutions to offer continued education and training through certificate programs, 2- and 4-year programs and masters programs

Recruiting Resources

There are several ways to improve the efficiency of recruitment processes, while increasing inclusivity and quality of candidates. Use a structured approach throughout recruitment – from advertising, through interviewing, all the way to onboarding. Encourage potential applicants who have faced barriers to employment and actively work to recruit appropriate candidates. Vocational rehabilitation and veteran-based programs are two widely available sources of diverse candidate pools, as are JobCorps and ex-offender programs.

Identify potential employee candidates using:

- Chamber of Commerce
- Ex-Offender programs
- H-2B
- Public workforce systems
- Retirees
- School systems
- Staffing agencies
- Veteran-based programs
- Vocational rehabilitation

Understanding Golf Course Labor Data

Understanding local data around workplace culture, barriers, and operational data is important when developing a recruitment and labor management plan. Conduct an operational audit through a third party or input data from monthly tracking systems including digital job boards, GPS tracking systems, time studies, and other performance metrics such as engagement surveys. Once annual data is entered, it should be designated as the baseline year to measure against in subsequent years.

Public Workforce Systems: Local Workforce Development (LWD) Boards

A Workforce Development Board is a group of community leaders appointed by local elected officials and charged with planning and oversight responsibilities for workforce programs and services in their area. In Texas, there are 28 LWDs which help employers recruit, develop on-the-job training and financial reimbursement programs, and provide access to job fairs and job seekers.

Additional information:

https://www.twc.texas.gov/partners/workforce-development-boards-websites

Vocational Rehabilitation

The Texas Vocational Rehabilitation Services supports people with disabilities to prepare for, obtain and advance in meaningful employment. This no cost program provides additional talent pipelines to recruit qualified workers, build diversity, connect golf courses to experts on the American Disabilities Act, and to access workforce planning resources.

Additional information:

https://www.twc.texas.gov/programs/vocational-rehabilitation-program-overview

https://aapd.com

https://abilityjobfair.org

https://disabilityin.org

Veteran Programs

The Texas Workforce Commission and Texas Veterans Commission serve to encourage employers to build a workplace support system for veterans, hire and retain more veterans, and connect to veterans in the community and their families. These organizations maintain a list of employers with written veteran hiring policies or initiatives, this provides awareness to encourage applicants and recognition. The HIRE Vets Medallion Award may be applied for to show commitment to veteran hiring, retention, and professional development.

Additional information:

https://www.twc.texas.gov/businesses/hiring-veterans

https://www.tvc.texas.gov/employment/employers/

School Systems

Reaching out to guidance counselors, work-study, and co-op coordinators is an effective method to reach students. Volunteering for career awareness programs as early as kindergarten will help build relations. Also connect with career and technical education programs or centers.

Additional information:

https://tea.texas.gov/academics/college-career-and-military-prep/career-and-technical-education

Chambers of Commerce

There are 510 Chambers of Commerce in the state of Texas. These organizations provide exceptional networking opportunities for golf course superintendents to share employment opportunities, participate in outreach events, and conduct meet-and-greets. These organizations can provide opportunities to meet with influencers in the community, civic organizations (Rotary, Kiwanis, Lions), and industry-centric conferences as well.

Additional information:

https://www.tcce.org/

The H2B Temporary Workers Program & Process

The H-2B temporary non-agricultural program allows U.S. employers who meet specific regulatory requirements to bring foreign nonimmigrant workers to the U.S. to fill temporary nonagricultural jobs. Before requesting H-2B classification from the U.S. Citizenship and Immigration Services (USCIS), the employer must apply for and receive a temporary labor certification for H-2B workers from the U.S. Department of Labor (DOL).

Step 1

Employer Obtains a Prevailing Wage Determination (PWD) from the National Prevailing Wage Center (NPWC) using the *Application for Prevailing Wage Determination* (ETA Form 9141) PWD may also be submitted by mail to the following address:

U.S. Department of Labor
Employment and Training Administration
Office of Foreign Labor Certification
National Prevailing Wage Center
1341 G Street, NW- Suite 201
Washington, DC 20005- 3105
ATTN: PWD Request

Step 2:

Employer Conducts Pre-Filing Recruitment: File a job order no more than 120 calendar days prior to the employer's date of need with the State Workforce Agency (SWA) serving the area of intended employment. The job order must be open and available for recruitment purposes for a minimum of 10 days. The list of SWA contacts can be found here.

Publish two print advertisements for the position(s), one of which must be on a Sunday. Advertisements must be placed during the period of time the job order is active. Job order and print advertising must contain:

- Employer's name and contact information to allow applications to send resumes
- Geographic area of employment to allow applicants to be aware of travel requirements and where applicant will likely have to reside to perform the services or labor
- If transportation to the worksite is provided by the employer, the advertising must say so
- Description of job opportunity including duties to apprise applicants of services or labor to be performed and the duration of the job opportunity
- Work hours and days, expected start and end dates of employment, and whether or not overtime will be available
- Wage offer or offers in the event of multiple wage offers
- Disclose the position is temporary, and the total number of job openings the employer intends to fill

Step 3:

Employer submits an application and provides the following documentation to the Chicago National Processing Center (NPC):

- Completed ETA Form 9142B, https://www.dol.gov/sites/dolgov/files/ETA/oflc/pdfs/ETA_Form_9142B.pdf - Application for Temporary Employment Certification
- Completed ETA Form 9142 - Appendix B https://www.dol.gov/sites/dolgov/files/ETA/oflc/pdfs/ETA_Form_9142B_APPENDIX.pdf
- Completed recruitment report
- Any applicable supporting documentation (documentation substantiating temporary need is recommended)

Electronic Filing:

Employers may submit the H-2B application electronically via the Department's iCERT Portal System. Read the H-2B iCert Quick Start Guide and H-2B iCERT User Manual before completing and submitting an H-2B application. The online help provides step-by-step instructions for completing and submitting the H-2B application electronically. For resources and information, visit: http://www.foreignlaborcert.doleta.gov/h2ah2b_icert_rollout.cfm

Mail Filing:

Mail the application package to the Chicago NPC at:
U.S. Department of Labor
Employment and Training Administration
Office of Foreign Labor Certification
Chicago National Processing Center
11 West Quincy Court
Chicago, IL 60604- 2105
ATTN: H-2B Program Unit

Additional H2B information:

https://www.uscis.gov/working-in-the-united-states/temporary-workers/h-2b-temporary-non-agricultural-workers#H2-B%20Program%20Process

https://www.foreignlaborcert.doleta.gov/h-2b.cfm

Source: Wisconsin Golf Course Best Management Practices Guide, 2020

Apprenticeships

Another way to broaden the profile of applicants and find the best candidate is to consider providing apprenticeship opportunities. Under apprenticeships employees are provided with instruction and on-the-job training. The training is much more customizable than traditional tertiary education systems and can be tailored to fit employer needs.

High school juniors and seniors can bring new talent to a golf course team through one or two-year youth apprenticeships. During these apprenticeships, students complete relevant courses aligned to enhance what is being learned on the job. Through these programs young people can develop skills and start on the path toward becoming credentialed workers, or work toward college credit programs.

Additional information: https://www.twc.texas.gov/programs/apprenticeship-program-overview

Continued Education

Connect with local institutions and community colleges to learn about services and potential collaboration for workforce development. There may be grant programs available. Be flexible and help employees with on-the-job training, whether through internal or external programs. The following post-secondary institutions offer turfgrass, landscape, or horticulture programs:

Western Texas College
6200 College Avenue
Snyder, TX 79549
https://www.wtc.edu/

Texas Tech University
Texas Tech Plaza
1901 University Avenue, Suite 513
Lubbock, Texas 79410-5095
http://www.depts.ttu.edu

North Central Texas College
1525 West California Street
Gainesville, TX 76240
https://www.nctc.edu/

Texas A&M University
2474 TAMU
College Station, TX 77843
https://soilcrop.tamu.edu/

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LANDSCAPE

Landscape (non-play) areas on a golf course provide enhanced course aesthetics, wildlife habitat, noise abatement, natural cooling, and freeze protection.

An ecological landscaping approach when used in golf course design aims to enrich the local area through developing attractive, healthy, and practical landscapes with a strong emphasis on conservation. Ecological landscapers aim to reduce water consumption, protect biodiversity, and adhere to IPM principles.

Regulatory Considerations

The TDA publishes a list of noxious and invasive plant species that have serious potential to cause economical or ecological harm in Texas. This list is required per Texas Agriculture Code Subchapter D, Sec. 71.151; administration of this statute is per TAC §19.300.

Additional information:

https://www.texasagriculture.gov/RegulatoryPrograms/PlantQuality/NoxiousandInvasivePlants.aspx

Species Selection and Size Considerations

The fundamental principle for the environmentally sound management of landscapes is “right plant, right place.” From an ecological perspective the ‘right plant’ is one which is native to the area. This is because these plants have adapted over thousands of years to the climate, pests, and soil culture of the area. Native plants are more tolerant to drought and stress, requiring less water or maintenance, than non-native varieties. When determining species selection, maintain as close to a natural ecosystem as practical, while meeting the needs of the golf course.

Texas Native Plants

Trees

Texas Mountain Laurel
Desert Willow
Mexican Redbud
Eastern Red Cedar
Pecan
Escarpment Live Oak
Cedar Elm
Bur Oak
Bald Cypress
Gum Bumelia
Western Soapberry
Texas Ash
Texas Red Oak
Mesquite
Lacey Oak
Anaqua
Escarpment Black Cherry
Chinquapin Oak
Carolina Cherry Laurel
Bigtooth Magpie
Texas Redbud
Texas Pistache
Yaupon Holly
Texas Persimmon
Eve’s Necklace
American Smoke Tree

Grasses

Arizona Cottontop
Big Bluestem
Brownseed Paspalum
Buffalograss
Cane Bluestem
Mesquite
Eastern Gamagrass
Fall Witchgrass
Hairy Grama
Hooded Windmillgrass
Red Grama
Red Lovegrass
Bristlegrass
Rough Tridens
Seacoast Bluestem
Shortspike Windmillgrass
Sideoats Grama
Silver Bluestem
Tanglehead
Texas Grama
Texas Panicum
Texasgrass
Thin Paspalum
Tobosagrass
Vine Mesquite
Whiplash Pappusgrass
Yellow Indiangrass

Shrubs

Agarito
Allthorn Goatbush
Brasil
Catclaw Acacia
Chittimwood
Coma
Coyotillo
Desert Yaupon
Elbowbush
Ephedra
False Mesquite
Guayacan
Heart-Leaf Hibiscus
Knife-Leaf Condalia
Lime Prickly-Ash
Littleleaf Sumac
Lotebush
Mexican Olive
Peachbush
Sweet-Stem
Tenaza
Texas Ebony
Texas Kidneywood
Texas Lantana
Texas Mountain Laurel
Texas Persimmon
Tornillo
Yaupon

Flowering plants (Forbs)

Awnless Bush Sunflower
Bearded Dalea
Blackfoot Daisy
Bristleleaf Dogweed
Brown-Eyed Susan
Bundleflower
Common Sunflower
Cowpen Daisy
Dayflowers
Groundcherries
Hooker’s Plantain
Indian Blanket
Low Menodora
Partridge Pea
Pigeonberry
Plains Lazy Daisy
Prairie Clover
Queen’s Delight
Rio Grande Clammyweed
Ruellia
Scarlet Pea
Wild Petunia
Woolly Croton
Woolly Globemallow

Sources: https://www.austintexas.gov/sites/default/files/files/Watershed/growgreen/2_8_12_native_tree_growing_guide_for_central_texas.pdf

https://www.ckwri.tamuk.edu/research-programs/south-texas-natives/native-plant-list

Additional reference for Texas native landscape plants:

https://www.wildflower.org/

https://www.nativelanddesign.com/blog/the-best-native-plants-to-include-in-your-texas-sustainable-landscape

Texas has a wide range of native plants which can create ecological diversity on the course while providing a desirable aesthetic and playability experience. When selecting plants, it is important to know the ultimate growth size and rate in order to plan appropriately for pruning, maintenance, and debris removal, including associated expenses.

It is also important to understand the potential damage caused by a variety of non-native species which have been introduced to Texas. Non-native species can cause harm to the environment or human health, with some species exhibiting aggressive growth habits which out-compete and displace native species. These are referred to as invasive species.

Texas' most problematic invasive species include:

- Saltcedar: an evergreen shrub which alters soil salinity and reduces the flow of water bodies
- Hydrilla: an aquatic plant which depletes water oxygen levels and blocks sunlight
- Giant Salvinia: an aquatic fern which forms dense mats on the surface of water
- Red Imported Fire Ant: can kill small children and livestock
- Nutria: beaver-like rodent which carry diseases and nematodes
- Channeled Applesnail: difficult to identify, primarily a risk to rice crops
- Feral Hogs: elusive, can cause severe physical damage to landscapes, turfgrass, and are dangerous to approach

Additional information on invasive species:

https://www.texasinvasives.org/

https://www.texasagriculture.gov/RegulatoryPrograms/PlantQuality/NoxiousandInvasivePlants.aspx

https://tpwd.texas.gov/huntwild/wild/species/exotic/prohibited_aquatic.phtml#plant

TDA List of Noxious and Invasive Plants for Texas

Common Name	Botanical Name
Noxious plants	
alligatorweed	*Alternanthera philoxeroides*
balloonvine	*Cardiospermum halicacabum*
Brazilian peppertree	*Schinus terebinthifolius*
broomrape	*Orobanche ramosa*
camelthorn	*Alhagi camelorum*
Chinese tallow tree	*Triadica sebifera*
Eurasian watermilfoil	*Myriophyllum spicatum*
giant duckweed	*Spirodela oligorrhiza*
giant reed	*Arundo donax*
hedge bindweed	*Calystegia sepium*
hydrilla	*Hydrilla verticillata*
itchgrass	*Rottboellia cochinchinensis*
Japanese dodder	*Cuscuta japonica*
kudzu	*Pueraria montana* var. *lobata*
lagarosiphon	*Lagarosiphon major*
paperbark	*Melaleuca quinquenervia*
purple loosestrife	*Lythrum salicaria*
rooted waterhyacinth	*Eichhornia azurea*
saltcedar	*Tamarix* spp.
salvinia	*Salvinia* spp.
serrated tussock	*Nassella trichotoma*
torpedograss	*Panicum repens*
tropical soda apple	*Solanum viarum*
water spinach	*Ipomoea aquatica*
waterhyacinth	*Eichhornia crassipes*
waterlettuce	*Pistia stratiotes*
Invasive plants	
chinaberry	*Melia azedarach*
Chinese tallow tree	*Triadica sebifera*
Japanese climbing fern	*Lygodium japonicum*
kudzu	*Pueraria montana* var. *lobata*
saltcedar	*Tamarix* spp.
tropical soda apple	*Solanum viarum*

Source: https://texreg.sos.state.tx.us/fids/201300604-1.html

Soil testing should be completed before planting new areas to ensure that the soil is naturally compatible with the chosen flora, including proper pH, nutrient levels, drainage, shade, etc.

Soil amendments, when properly selected and applied, can improve the soil's physical and chemical properties. This can increase the soil's water-holding capacity and reduce leaching of fertilizers. Amendments may be organic or inorganic; however, soil microorganisms rapidly decompose organic amendments such as peat or compost.

Landscape areas should be fundamentally designed to facilitate rapid plant establishment to conserve water and lower nutritional input requirements once mature. Maintain or enhance as much natural vegetation as possible within landscape design, with 50 to 70 percent of non-play areas in natural cover. Out of play areas, or those which are not critical to course design, provide an opportunity to remove non-native plants and replace them with native ones that require little to no maintenance once established. This may include the supplemental planting of native trees, shrubs, and herbaceous vegetation to provide wildlife habitat in non-play areas and along water sources to support fish and other water-dependent species. By leaving dead trees (snags) near waterbodies where they do not pose a hazard, a well-developed understory (brush and young trees), and native grasses, the amount of work needed to prepare a course is reduced while habitat for wildlife survival is maintained.

Best Management Practices

- Follow federal, state, and local regulations regarding invasive species, nutrient and pesticide management.
- Select plants as close to a natural ecosystem as practical, while meeting the needs of the golf course. Native plants have adapted specifically to the soil, microclimate, rainfall, light patterns, insects and other pests, and endemic nutrient levels over many years.
- Select trees, plants, and grass species to attract birds seeking wild fruits, herbs, seeds, and insects.
- Know the ultimate sizes and growth rates of trees, shrubs, and ground covers.
- Use plants that are adapted for the site based on the United States Department of Agriculture (USDA) cold-hardiness map: https://plants.usda.gov/hardiness.html
- Choose the most stress-tolerant species or cultivar for a particular area, those which can manage periodic dry/wet conditions.

Texas Wildscapes: Landscaping for Wildlife

Incorporating native plants, colors, scents, groupings and structures (food, water, and cover) can help provide habitats to attract desired wildlife, including birds and butterflies.

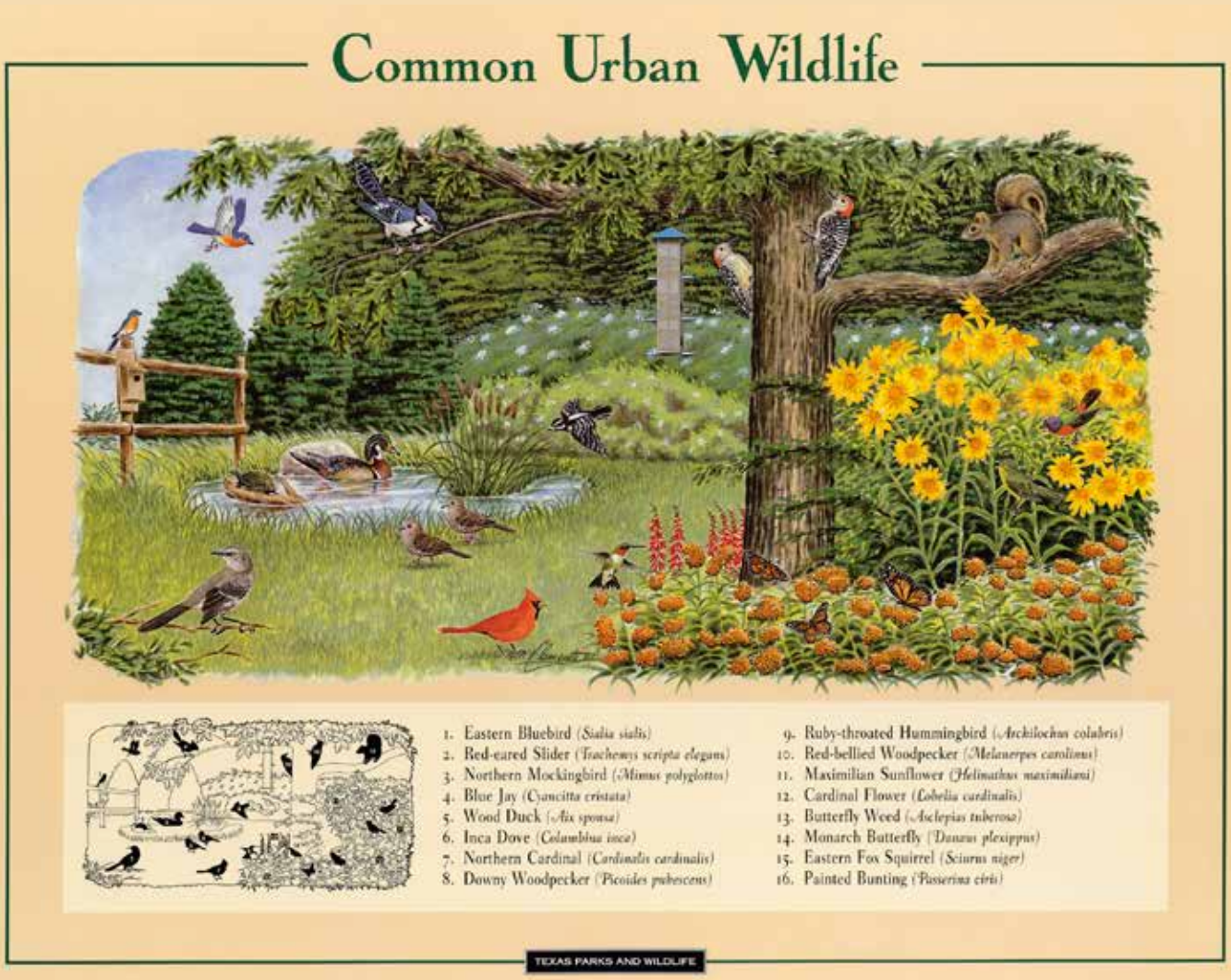
For specific Wildscape habitat and wildlife combination examples, and to apply for Wildscape certification visit:

https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/wildscapes/

Design and Function

It is important to consider both aesthetics and environmental impact for landscape design. Where possible, design should aim to increase native diversity and support growth of pollinators including hummingbirds, bees, and butterflies. This can be achieved through including a variety of nectar-providing plants of different heights in aesthetic gardens, window boxes, and container gardens. Section off habitat areas so that nesting wildlife is left undisturbed. Garden plants, shrubbery, ground covers, or native plants may provide a pleasing a view and also provide useful food, cover, or other environmental benefits to wildlife; they may also require less maintenance.

It is important for landowners and managers to have a good understanding of how to create, maintain, and protect habitats for wildlife diversity. Train crew members to identify endangered species and educate club members and guests through newsletters, meetings, and signage. There are several state tools and incentives designed to promote wildlife habitat, plus benefit rare and at-risk species through support to landowners. It is of particular importance to promote biodiversity and protect wildlife habitat using effective landscape practices in urban areas where wildlife has limited access to sources of food and shelter.



Source: https://tpwd.texas.gov/education/resources/s.posters

When integrating turfgrass areas into the landscape around the clubhouse, entries, and other areas, design for ease of maintenance and keep in mind that turfgrasses grow best in sunny areas. Xeriscape landscaping and drought resistant native plants should be used wherever practical and particularly around buildings and parking areas. Xeriscaping is a landscaping style which minimizes the need for irrigation, reduces water consumption, and decreases fertilizer needs. Trees and shrubs can affect sunlight access as well as moderating temperature. Planted alongside streams this temperature moderation, through shade, lowers water temperature in summer and increases it in winter. In areas where turfgrass is prioritized, however, it is important to consider the effect that tree canopy and other design features may have on the health and function of the turfgrass.

Additional information regarding state programs to support wildlife diversity and land stewardship:

https://tpwd.texas.gov/huntwild/wild/wildlife_diversity/nongame/listed-species/landowner-tools.phtml

Best Management Practices

- Forested buffers should contain a mixture of fast- and slow-growing native plants to provide a diverse habitat for wildlife.
- Use forested buffers to:
  - Trap and remove upland sources of sediments, nutrients, and chemicals.
  - Protect fish and wildlife by supplying food, cover, and shade.
  - Maintain a healthy riparian ecosystem and stable stream channel.
- Leave dead tree snags whenever possible (i.e., at a safe distance from playing surfaces) for nesting and food source to wildlife.
- Use turfgrass as a landscape element where needed.
- Use xeriscaping and drought resistant native plants to minimize irrigation needs.
- Incorporate diversity into the plant palette, with a variety of shapes, scents, colors, and species to attract pollinators.

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

Planting Methods

Ecological landscaping approaches to planting should be utilized, using drought-tolerant plants with a root system substantial enough to keep them alive with little or no supplemental irrigation and grouping plants based on irrigation requirements.

Weed growth can be prevented through application of organic mulches in gardens and aesthetic areas. The mulches increase the moisture-holding capacity of plantings and are decomposed by soil microorganisms, strengthening tilth condition. Mulches should, however, be kept 2-3 inches away from plants to prevent excess dampness which can cause fungal growth.

Compaction or excessive mulch buildup should also be avoided as this can be problematic, causing water to shed away from the root zone and encourage overwatering. This is particularly important to monitor when annual re-mulching is performed.

Best Management Practices

- Plants should be grouped together based on irrigation demand.
- Irrigation systems and plant palette should be appropriate for site conditions, bearing in mind that, in some cases, soil improvement can enhance water-use efficiency.
- Minimize the percentage of landscaped area in irrigated high-water-use hydrozones. Local government ordinances should address the percentage of irrigated landscaped area that may be included in high-water-use hydrozones. These high water-use limits should not apply to landscaped areas requiring large amounts of turfgrass for their primary functions (for example, ball fields and playgrounds).
- Pruning and fertilizing will benefit landscape plants while they are becoming established.
- Use appropriate soil amendments to improve the soil's physical and chemical properties, increase its water-holding capacity, and reduce leaching of fertilizers.
- For information about developing a BMP for pollinators or establishing pollinator friendly gardens, please reference the Pollinator BMP section.

Trees

Most golf courses in America use trees for both aesthetic and practical uses, making them an important and significant component of course design. Trees can offer beauty to the landscape, with a strategy for golf holes by indicating the line of play, either through, around or over existing trees. Native trees should be planted wherever possible as they have adapted to local conditions climate over thousands of years and are better able to withstand extreme weather events. Native trees are largely more resistant to pests, require less watering and provide more appropriate habitat for native wildlife.

The correct placement and selection of species are paramount to having a successful tree program. Through the support of an experienced tree professional the golf course design and maintenance strategy can be complemented, allowing decades long tree life with minimal pest problems.

Best Management Practices

- Hire an arborist or tree specialist to aid in developing a planting plan and establish a tree care program.
- A tree inventory should be developed, outlining tree species; map of location; age; condition; life expectancy; monetary value.
- Annual evaluation of tree condition should be conducted to support decision-making regarding removals, pruning, thinning, fertility, pest control requirements.
- Regular inspection throughout the year is important, to establish pruning requirements. Most trees should be pruned during cool seasons of the year. This is essential for safety purposes, and the health of the tree by removing dead, poorly attached, or overcrowded branches.
- For safety purposes use staff or an arborist for small scale pruning, pest management, and some tree removal. Use an outside professional tree service to handle large scale spray applications and removals that require climbing and bucket work.
- Use paint to improve the appearance of a wound when in a highly visible location.
- Tree canopy can be raised from the ground to improve air movement and light for better turfgrass growth. Dense canopies can be crown thinned to increase light penetration and wind resistance.
- Root pruning can be done with a trencher, vibratory plow, backhoe, or cutting saw to reduce competition for water between the turfgrass versus trees.

Examples of Native Trees & Benefits

- Gum Bumelia: flowering with edible berries; highly adaptable to soil types; drought resistant.
- Chinkapin Oak: attractive, light-colored bark, suited to limestone soils.
- Eve's Necklace: flowering; appreciates light, wet soils.

Additional information on Texas native trees, benefits, and care:

https://www.austintexas.gov/sites/default/files/files/Watershed/growgreen/2_8_12_native_tree_growing_guide_for_central_texas.pdf

13

ENERGY

Energy conservation is an important focus area in the state of Texas. The Lone Star State is home to more than 70 energy providers, from natural gas to electricity to renewable energy. Texas takes pride in producing the most energy in the nation, with 27 key refineries in the state. The Texas State Energy Conservation Office (SECO) sponsors several programs to encourage using energy efficiently, especially relying more on renewable energy and less on sources that emit carbon dioxide into the earth's atmosphere. Cities like Austin and Houston are aiming to produce no greenhouse gases by the year 2050, and many other cities are choosing to follow their lead.

In the GCSAA Golf Course Environmental Profile, Phase II, Vol. V (GCSAA 2017), it is estimated that turfgrass maintenance accounts for 47 percent of energy use at a golf facility; this total is comprised of clubhouses, swimming pools, tennis courts, and various other operations. This study notes six major energy sources for golf course use: electricity, gasoline, diesel, natural gas, propane, and heating oil. Texas golf courses use all of these sources.

Texas golf courses can set the pace for other industries in the state when they work toward achieving energy reductions from these six sources. By aiming to lower emissions and conserving energy, golf courses promote cleaner air,

Texas superintendents can help the state achieve its energy goals through reducing energy use by adhering to BMPs and using cleaner forms of energy when available.

Texas Energy Conservation Resources, Incentives, Rebates

The following resources provide information on Texas conservation (i.e., alternative fuel) programs, incentives, and rebates for conserving and using cleaner forms of energy, including federal and state tax credits, municipal energy programs, and other incentives:

https://comptroller.texas.gov/programs/seco/#skip-scroll

https://www.cleanenergyauthority.com/solar-rebates-and-incentives/texas

http://www.texasishot.org/energy-efficiency-rebates/

Best Management Practices

- Measure annual energy use for electricity, natural gas, gasoline, and diesel; propane, and heating oil input data from monthly utility statements, utilizing 2 years of data
- Set baseline year to track improvements and future reductions; determine carbon footprint when practicable
- Analyze data to identify efficiencies, prioritize reduction targets and set attainable goals; monitor metrics regularly to confirm compliance
- Share data to ensure success and to identify other areas that need improvement
- Prioritize opportunities and establish steps to implement initiatives, identify resources, projected energy and cost savings; incorporate all stakeholders to increase ownership
- Establish and communicate position statement and energy policy; relate to guests, members, community
- Audit and replace lighting and irrigation component use to identify efficiency opportunities
- Ensure efficient operation and maintenance of pump station, irrigation pumps, controls, components; utilize manufacturer data to fine tune specifications and optimize conservation.
- Incorporate energy efficiency and conservation measures into location, design, construction; collaborate with stakeholders to prioritize energy conservation
- Explore onsite solar and electric vehicle charging stations when practicable; stay up-to-date with Texas legislation on renewables and energy efficiencies: https://www.puc.texas.gov/agency/rulesnlaws/subrules/electric/Electric.aspx
- Communicate with utility provider, insurance company, regulatory officials
- Adhere to state regulations, use guidelines from U.S. Green Building Council (LEED certification program)
- Educate, train, motivate employees on energy efficiency practices
- Identify opportunities for product rebates and incentives

Data Analysis

To efficiently manage a golf course, superintendents need to understand energy consumption and its impact on the individual course. Conduct an energy audit through a third party or input data from monthly utility bills, receipts, and statements into a spreadsheet. Once annual data is entered, it should be designated as the baseline year to measure against in subsequent years. When practicable, conduct a carbon footprint analysis using total energy consumption to determine emissions. Golf courses also help sequester carbon, which is a factor that helps offset golf course emissions. Plants on a course assimilate carbon from the atmosphere during photosynthesis, some of which is eventually stabilized in the soil, in the form of soil organic matter. The net difference between carbon emissions and carbon sequestration on a golf course reflects the overall carbon footprint. Consult an expert to assist further in calculating and understanding impacts.

Because the pump station uses the most energy of a golf course facility, track its energy usage separately by pump station, if possible. Installing properly-working meters and gauges to measure energy used throughout the course is helpful. Segregate this data on meters by area–such as maintenance buildings, clubhouse, tennis facilities, pools, or additional amenities–for optimal monitoring and control.

Analyzing Data & Setting Energy Reduction Goals

Look at consumption metrics by month, area, day of week, and time of day. Factors to consider during analysis year-over-year, by month, or quarterly include:

- Electricity utilization during peak hours 7 a.m. to 4 p.m.
- Unusually high temperatures creating increased HVAC usage - summer season between June and September
- Periods of drought causing increased irrigation
- Seasonality resulting in switches between energy sources
- Alterations to landscape or building renovations
- Faulty or damaged equipment

Understand how faulty equipment, leaks, or peak utilization creates trends or spikes. Track these trends to prepare responsiveness to potential repairs.

When analyzing data, consider equipment maintenance and how it impacts energy use. Determine what energy is being used by different types of equipment and evaluate efficiency, costs, maintenance, and replacement costs. To better support future purchases, administer a regular inventory of equipment and log its date of operation, total energy uses, operational hours, and any further issues.

Superintendents can determine annual goals for energy based on the quantity of energy used in the last year and what your golf course has chosen to prioritize. These goals for energy conservation could encompass initiatives related to infrastructure, equipment, behavior, processes, and agronomic practices. Aim for SMART goals which are Specific, Measurable, Attainable, Relevant, and Timely. Sharing goals with employees at monthly meetings and posting them in a clearly visible area is also helpful.

Energy Use Conversion Factor

To understand aggregate energy used on a golf course for electricity, natural gas, gasoline, diesel, propane, and heating oil, a conversion factor to BTU for each energy input may be used. (reference chart footnote 12 GCSAA 2017* US Department of Energy)

Energy Use Intensity

Energy use intensity, or EUI, expresses a building's energy use as a function of its size or other characteristics. It's calculated by dividing the total energy consumed by the building in one year (measured in kBtu or GJ) by the total gross floor area of the building. A low EUI signifies good energy performance. EUI helps to benchmark and gauge the effect of renovations and expansion within clubhouses or other built environments. Example benchmarks and conversion data may be found at www.energystar.gov.

Monitoring, Tracking, and Communication

Keeping organized when tracking energy use is a must. Creating a spreadsheet detailing units of measurement, energy used by day, month, meter or department, rates, weather, and energy conversion factors can help indicate which goals are being met and which ones need more attention. There are tools and software services available for tracking, such as Energy Star. If feasible, particularly at resort facilities, consider energy management software which can provide robust data and controls, incorporating intelligent building automation systems and monitoring. Calculate savings achieved through energy reductions to track progress and support energy efficient capital investments.

It is best to analyze data weekly or monthly to note progress toward goals and understand any inefficiencies or issues. Establishing parameters for performance can optimize energy conservation with irrigation pumps. Discuss results with employees on a regular basis; this can be done by posting signage displaying monthly progress to goal attainment. Consider encouraging teamwork and innovation through benchmarking performance between departments, or versus similar-sized facilities.

Behavior

An energy management plan (EMP) creates structure and accountability in order to move priorities forward. It aligns stakeholders around common goals and displays a continuous improvement process centered around the concept of “Plan-Do-Check-Act” which incorporates a roadmap, implementation, monitoring, and adjustments. EMPs and BMPs often share goals. For example, an effective preventive maintenance program that improves equipment efficiency and reliability will benefit energy conservation efforts. On the other hand, EMPs can improve lifespan of equipment and reduce emissions.

Various sources can provide recommendations for energy efficiency opportunities - these can include staff, consultants, or energy providers. Engage employees responsible for a specific job or task, managers, and departments influential in decision-making or processes. Effective engagement of stakeholders will drive efficiencies, reduce bottlenecks, and positively impact departments.

What to Include in EMP: Prioritizing, Determining Steps, Assigning Tasks

Analyze and decide on the top three to five energy conservation opportunities in order to target specific goals. Areas like infrastructure updates, equipment replacement, behavioral changes, and agronomic practices or processes are examples of priority initiatives. Evaluate benefits, in addition to short-term and long-term costs in regard to priority initiatives, factoring in the source of energy (electricity, fuel, etc.)

Establish steps to implement by identifying:

- Resources needed (capital expenses, acquiring products/systems, communications, etc.)
- Departments involved
- Projected energy reductions
- Estimated cost savings
- Timeframe

Accountability and teamwork can be maximized when all task owners have priorities aligned.

Implementation

Tie EMP progress to overall energy reduction goals. Communication and engagement should happen on several levels.

- Engage energy management team weekly and/or monthly to review progress
- Engage leadership team regularly to provide updates to support investment decisions and show progress
- Communicate with all staff regularly, including updates to employees within stakeholders' departments
- Share EMP conservation highlights and achievements with members and guests

Policy and Performance Guidelines

Commit to following set energy conservation standards to highlight behavioral changes that employees and guests should follow. Emphasizing the importance of conserving energy will aid in this operation. All facilities should have a conservation plan; for example, the turfgrass department should include goals around irrigation systems, pump stations, landscaping, and the broader framework of the operation.

Behavioral Practices: Lighting, HVAC, Irrigation/Water, and Equipment

Perform a breakdown of energy usage by area. Typically, heating, ventilating, air conditioning (HVAC) comprises 40 to 50 percent of total electricity usage for a building (e.g., clubhouse). Lighting consumes about 20 percent of this total, and other miscellaneous equipment uses another 20 percent. Hot water can greatly increase the total energy, so only use it for showers, hand-washing, and restaurant operations.

By simply adhering to preventive maintenance schedules and keeping mechanical systems clean, HVAC efficiency can improve by 10 to 20 percent and lower electricity costs.

Because the pump station is the largest user of energy during the summer months, ensure it is properly engineered and maintained at regular intervals. Monitor for any signs of abnormal flow, increased pressure, or substantial gallon variances from the central computer. Power consumption can be minimized, and pipes can be better protected, through using variable frequency drives (VFD). Power surges will happen due to demand, so engineer the system to allow a variance and continue operating. The actual field heads should be audited at least once per year to show discrepancies and to fine-tune efficiency.

Schedule irrigation during off peak hours and, when feasible, use newer systems of remote monitoring pumps and flow to identify problems before they escalate.

Energy Management Tip!

Create a checklist of energy reduction behavioral best management practices for the clubhouse, golf maintenance facility, and other buildings on property. This can be used as a self-audit and guide toward continuous improvement. Example checklist on the next page.

Golf Club Energy Reduction Best Management Practices Behavioral Checklist

Lighting	Y/N	HVAC	Y/N	Irrigation/Water	Y/N	Equipment	Y/N
Conduct a lighting audit		Clean & change air filters regularly		Maintain plumbing fixtures/ piping to avoid losses		Check electricity meters at least once per month	
Arrange interior space to optimize natural light & comfort zones		Utilize ceiling fans		Run irrigation early in the morning or late at night		Operate machines according to manufacturers' recommendations for energy efficiency	
Initiate 'lights off' employee awareness campaign		Ensure HVAC units have proper ventilation		Repair leaks		Avoid automatically turning on kitchen equipment when arriving in morning	
Display reminders & visual management signage		Turn off air/set heating at minimum in unoccupied rooms		Check insulation on hot water pipes to reduce heat losses		Consider temperature of kitchen rooms when installing or relocating refrigerators/freezers	
Code light switches (labels or color) to switch on only those needed		Close exterior doors when not in use		Check laundry room equipment regularly for leaks		Turn off food & beverage equipment when not in use	
Reduce general lighting during daytime				Water less area, apply hand watering		Do not exceed oven preheating times	
Turn exterior lighting on only at night; utilize timekeepers				Evaluate cleaning practices (dry vs. wet washing)		Open refrigerators & freezers only when necessary	
Train staff & invite guests/ members to get involved						Defrost refrigerators & clean door seals monthly	
Maintain routine preventive maintenance on lighting equipment						Fill dishwashers & washing machines to maximum capacity	
Turn off lights in unoccupied rooms						Use low temperature wash cycles & avoid overloading dryers	
Limit pool lighting that is not required for safety						Conduct regular PM on equipment, vehicles	
						Run washer/dryer during off peak hours	
						Do not leave televisions on standby	
						Switch off equipment (copiers, computers, printers, coffee) when not in use	
						Charge golf carts & equipment during off-peak hours (evening/early a.m.)	
						Encourage car sharing; designate EV parking & charging stations	
						Source products locally to reduce logistics/transportation fuel consumption	
						Log equipment use including hours operated, length of use, patterns to determine efficiencies (e.g., shift to off-peak hours, minimize use per week, etc.)	

Source: Radius Sports Group, LLC. 2019

Equipment and Materials Efficiencies

Evaluate new technologies, products, or upgrades that improve efficiencies through meetings with suppliers. Examine fuel types, level of energy required, and use of alternative energy or fuels. Shifting to hybrid mowers and electric golf carts helps reduce fuel consumption and lowers greenhouse gas emissions.

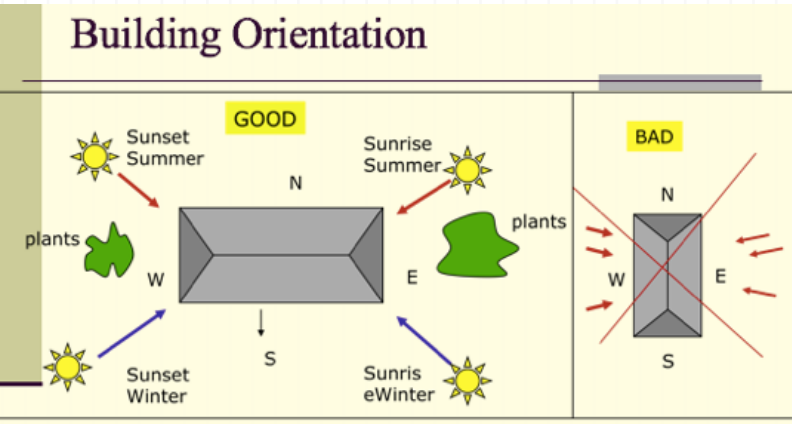
For new equipment purchases throughout the club, consider programs like Energy Star or the EPA's WaterSense program for product labeling to identify products with high energy efficiency.

Energy Management Tip!

Create a checklist of energy reduction product selection best management practices for the clubhouse, golf maintenance facility, and other buildings. Example checklist on the next page.

Design

Early in the design phase, include partners to help ensure that the completed golf course and its facilities will adhere to energy conservation plans. Communicate goals with architects and contractors for incorporating into the design and build out. Consider renovations or new construction that can provide an opportunity to integrate energy saving efficiencies into the plans. Investment determinations should be focused on integrating energy conservation measures.



Source: Energy for Sustainability, Randolph & Masters, 2008.

Energy Considerations During Design

- Building location
- Building orientation
- Course slope
- Vegetation
- Materials used (e.g., thermal conductivity, best material for cooling, etc.)
- Lifecycle assessment on materials
- Technology/smart building automation
- Monitoring systems
- Programmable scheduling and controls

The use of locally-sourced materials is encouraged for saving construction costs and resources, especially in regard to heavy and bulky materials. This plays an important role in lowering the carbon footprint, for it reduces embodied energy (energy used in the extraction, production, transportation and construction of a building material.) Use resources like the US Green Building Council and the American Society of Heating, Refrigerating, and Air-Conditioning Engineers, or ASHRAE for details on the LEED framework and certification for highly energy efficient buildings and for energy efficiency standards and guidelines, respectively.

Golf Club Energy Reduction Best Management Practices
Product Selection Checklist

Lighting	Y/N	HVAC	Y/N	Irrigation/Water	Y/N	Equipment	Y/N
Install LED lighting and/or retrofit devices		Install energy-efficient air conditioning/chiller equipment		Install shower flow restriction devices to reduce water usage		Choose programmable thermostats	
Replace less efficient T12s with low-wattage T8 & T5 lamps with electronic ballasts		Install HVAC fans & pumps with variable frequency drives (VFDs) that control pump speeds		Install insulation on water heater tanks and pipe		Install onsite photovoltaic solar panels for onsite electricty generation	
Replace incandescent bulbs with CFLs which use less energy & last longer		Install window film to reduce air/heat loss		Install energy efficient water-heating equipment		Install National Electrical Manufacturers Association's (NEMA) premium efficiency-rated pump motors	
Replace fluorescent light exit signs with LEDs		Maximize envelope efficiency; choose high performance insulation systems		Install aerators to reduce demand for hot water		Install solar/geothermal pumps for pools	
Install induction lighting in hard-to-reach places & public facilities		Add insulation for windows & doors, such as weather stripping & thresholds		Install water-saving devices (flow regulators, water flow sensors, self-closing taps, low-flush toilets)		Select a well-engineered pump station with variable frequency drives (VFDs) to minimize water & energy use	
Install pulse-start metal halide & high-pressure sodium lamps in spaces with prolonged use & high ceilings		Utilize energy management systems		Install prescriptive irrigation systems to manage use & detect leaks		Select hybrid equipment including fairway mowers	
Add occupancy sensors or programmable timers		Decrease daytime thermostat setting		Audit irrigation system		Choose electric or battery-powered golf carts	
Install light tubes & natural light maximizers		Install a night setback system to lower room temperature at night		Install localized devices (micro- sprinklers, drip irrigation) for plants & ornamentals		Choose Energy Star rated equipment for clubhouse operations	
		Install an economizer to use outdoor air for cooling		Incorporate native plants to reduce water & energy use			
		Install a timer on supply air fans		Install rooftop solar thermal panels for water heating			
		Install double-glazed windows		Incorporate drought resistant, salt tolerant turf (e.g., paspalum) to lower irrigation needs			
		Shade windows from sun to limit HVAC needs (awnings, automatic louvres, curtains, blinds, screens, heat reflecting sheets, trees)					
		Incorporate a green roof with vegetation or cool roof (white or cool colored)					

Source: Radius Sports Group, LLC. 2019

Texas Solar Site Considerations

Location (roof or ground mounted), area, orientation and tilt, shading

- Preferred orientation allows for south facing
- Roof tilt degree equal to the latitude device is located at
- Clear access to the sun for most of the day unobstructed by trees
- Adequate space on roof or property
- A roof in good condition

Onsite Solar Electricity Generation

Consider installing solar panels for onsite electricity, as many golf courses are finding this beneficial to operations. It is important to understand the long-term effects of turning to solar energy in regard to employee and community well-being, so evaluate costs and benefits with these impacts in mind.

Education

Foster education and motivation amongst employees to adhere to conservation standards through lunch and learn sessions, tips, quizzes, and challenges. Encouraging participation in these efforts will further drive energy efficiencies. Continuous education may be completed through email, signage, and stakeholder meetings.

Celebrate successes year-round. Dedicate a small portion of weekly meetings to noting progress and new goals to achieve and include stakeholders and guests in suggesting new ways to foster improvement.

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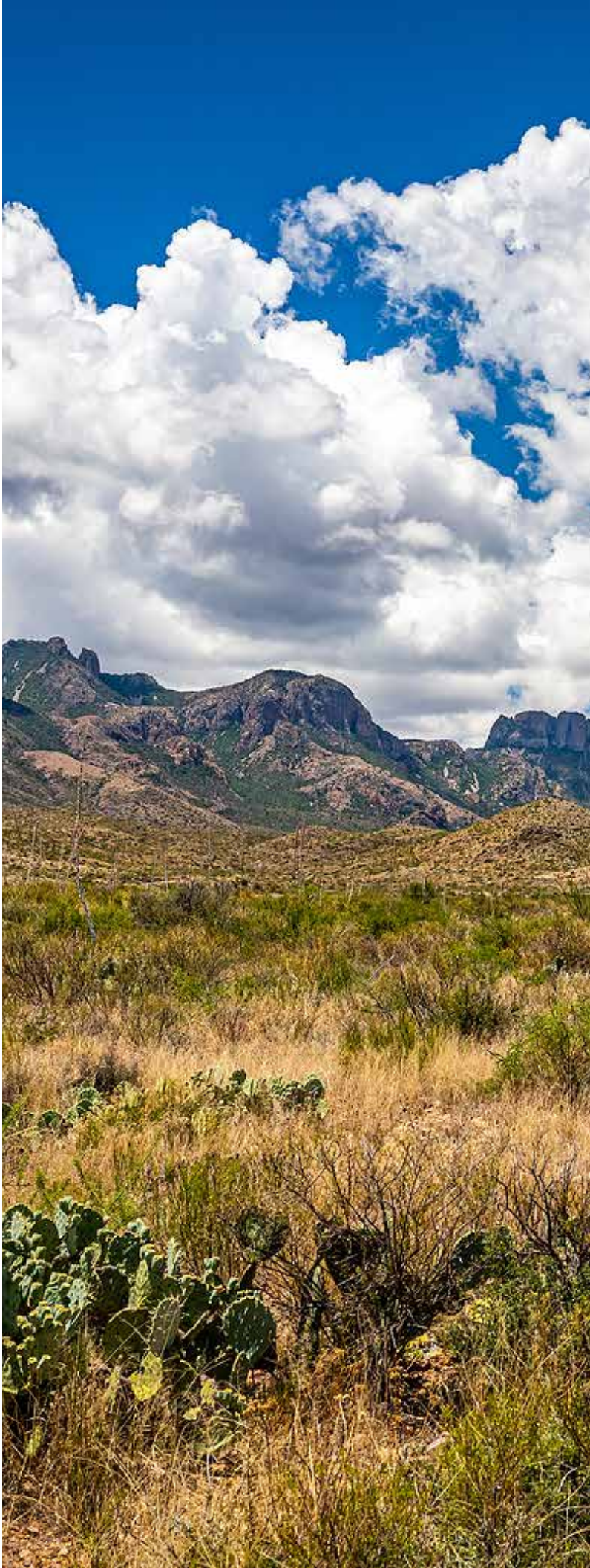

GLOSSARY

Aerification
Core aerification involves removal of small (0.25- 0.75-inch diameter) cores or plugs from the soil profile. Other forms of aerification and cultivation include solid tine aerification, air-injection, sand-injection, water-injection, slicing, drill-and-fill, and fraise mowing.

Apron
The fairway area close to and in front of the putting green, adjoining the putting green
collar. This area is normally mowed at fairway height, but sometimes is mowed slightly closer.

Aquifer
A saturated bed, formation, or group of formations which yields water in sufficient quantity to be economically useful.

Benchmarking
Comparing or assessing to a standard or point of reference, such as to evaluate energy efficiency.

Best Management Practices
Methods or techniques found to be the most effective and practical means of achieving an objective, such as preventing water quality impacts or reducing pesticide usage.

Biological Control
The use of living organisms, such as bacteria, to reduce populations of pests.

Calibrate
To determine or mark the graduation of, or to determine and control the amount of material delivered by a sprayer or spreader on a given area or in a given time.

Collar
An area of turf adjoining the putting green that is mowed at an intermediate height between the fairway and the green.

Compaction
The reduction in the number and size of airspaces caused by compression, most often the result of traffic. Compaction prevents adequate water and air penetration and reduces turfgrass root growth.

Coring
The removal of a core from a turfgrass area with a soil probe or hollow metal tines, usually to provide aeration.

Corrective Maintenance
Corrective maintenance (CM) is simply the act of fixing what is broken (e.g., cleaning a clogged orifice or a complete renovation of an irrigation system). As opposed to preventative maintenance.

Cultivar
A term used to distinguish cultivated varieties of plants from the naturally occurring
varieties.

Cultivation
A mechanical procedure such as spiking, grooving or core removal on established turf without destroying its sod characteristics.

Dethatching
The procedure of removing an excessive thatch accumulation either mechanically, by practices such as vertical mowing, or biologically, such as by topdressing with soil.

Disease
A disturbance in normal functioning and growth, usually caused by pathogenic fungi, bacteria, or viruses.

Dissipation
Relates to the reduction in concentration over time of a pesticide or other compound which has been applied to plants, soil, water, etc. This may be due to a number of factors including dilution and degradation.

Distribution Uniformity
A measurement of how evenly water is applied across turf during irrigation.

Drainage
The rapid removal of water by surface contouring (swales or ditches) or the installation of subsurface tile.

Drift
The physical movement of pesticide droplets or particles through the air at the time of pesticide application or soon thereafter from the target site to any non- or off-target site.

Endangered, Threatened or Listed Species
Species that have been identified as being in danger of extinction now or are likely to become endangered within in the foreseeable future.

Environmental Fate and Transport
The movement and distribution of chemicals in the environment.

Erosion
The wearing away of the land by running water, wind or other geological agents.

Evapotranspiration
The combination of soil evaporation and transpiration from a plant; total water loss from plant and soil.

Fairway
No precise definition exists in the Rules of Golf for fairway. It is deemed to be an area between the tee and putting green included in the term “through the green.”

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)
The basic U.S. system for the regulation of pesticides to protect applicators, consumers, and the environment. Under FIFRA, the USEPA sets the minimum standards concerning the distribution, use, and disposal of pesticides and their containers.

Fertigation
The application of fertilizer through an irrigation system.

Fertilizer
A nutrient applied to plants to assist growth.

Foliar fertilizers
Soluble plant nutrients applied to the leaf and capable of being absorbed through leaves.

Fumigant
A liquid or solid substance that forms vapors that destroy pathogens, insects, or other pests. Fumigants are usually used in soils or closed structures.

Fungicide
A chemical that kills or inhibits the growth of fungi.

Fungus
A form of life distinct from plants that, lacking chlorophyll and being incapable of manufacturing its own food, lives off dead or living plant and animal matter.

GDD
Growing degree day.

Germination
The beginning of growth in a seed, plant bud or joint.

Grain
As applied to putting greens, the tendency for grass leaves to lie down in one direction and interfere with the natural roll of the ball.

Growing degree days
Growing degree days (GDDs) are heat units used to estimate the development of plants and pests during the growing season. This method is more reliable at predicting insect development than calendar days.

Ground covers
Plants used to provide a low-maintenance, vegetative cover that is not necessarily turf.

Habitat
The natural home or environment of an animal, plant, or other organism.

Herbaceous
Nonwoody plants.

Herbicide
A chemical used to kill weeds or herbaceous growth.

Humus
A dark, well-decomposed material formed from decayed vegetable or animal matter in
the soil.

Hydroseeding
A technique for applying seed, mulch and fertilizer in a water slurry over a seedbed.

Infiltrate
To filter into, the penetration of water through soils.

Inorganic fertilizer
Plant nutrients derived from mineral rather than organic sources.

Insecticide
A chemical used to destroy insects.

Integrated Pest Management
Integrated Pest Management (IPM) is an ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices, and use of resistant varieties. Pesticides are used only after monitoring indicates they are needed according to established guidelines, and treatments are made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and nontarget organisms, and the environment.

Internode
The portion of a stem between the nodes or joints.

Invasive Plants
Plants that are not native to an environment, and once introduced, they establish, quickly reproduce and spread, and cause harm to the environment, economy, or human health.

IPM
Integrated Pest Management.

Lip
An abutment of sod raised 3 to 4 inches above the sand level of a bunker. It faces the putting green and prevents a player from putting out.

Lime
Materials containing calcium and magnesium used to neutralize soil acidity and to supply calcium and magnesium as plant nutrients. Lime materials include limestone, shell, marl, slag and gypsum.

Localized dry spot
A dry area of sod and soil that resists water as normally applied; caused by various factors such as heavy thatch, soil or fungal organisms.

Leaching
The downward movement of a chemical or nutrient (e.g., pesticide or nitrogen from fertilizer) through the soil and potentially into groundwater.

Littoral Zone
Shallow areas within the near shore area of a lake or pond. Littoral shelves provide emergent aquatic vegetation the appropriate water depth.

Micronutrient
An element needed in small amounts for turfgrass growth.

Minimum Risk Pesticides
Certain “minimum risk pesticides” pose little to no risk to human health or the environment. Because of this, the USEPA has exempted them from the requirement that they be registered under the Federal Insecticide, Fungicide, and Rodenticide Act.

Mulch
A material such as wood chips, straw, netting, or burlap spread over seeded or stolonized areas to protect them from erosion, moisture loss, and temperature extremes and to enhance germination and growth.

Native grasses
Grasses that are indigenous or that occur naturally in a particular region.

Native plants
A plant that is a part of the balance of nature that has developed over hundreds or thousands of years in a particular region or ecosystem (USDA).

Nematicide
A substance used to destroy nematodes.

Nematode
A small, round worm, usually microscopic and colorless, that lives free in moist soil, water or decaying or living organic matter. Parasitic forms puncture plant tissues and live by sucking the juice of the plant.

Neonicotinoids
A class of neuroactive insecticides chemically similar to nicotine that are absorbed by plants and can be present in pollen and nectar, resulting in potential adverse effects to bees.

Node
The joint of a grass stem from which leaves and buds arise.

NPDES
Created in 1972 by the Clean Water Act, the National Pollutant Discharge Elimination System (NPDES) permit program is authorized to state governments by USEPA to address water pollution by regulating point sources that discharge pollutants, such as pesticides, to Waters of the United States (WOTUS).

Nutrients, plant
The elements taken in by the plant, essential to its growth and function.

Organic matter
Decomposed aterial derived from plant or animal sources. An important component of topsoil often added to topdressing soil mixtures to give added water-holding capacity and exchange capacity to the soil.

Organic soil
A general term used in reference to any soil that is at least 20 percent organic matter.

Overseed
To sow seed over an area that is sparsely covered or to plant cool-season grasses into dormant warm-season turfgrass swards for a temporary, green winter cover.

Pathogen
An organism causing disease.

Peat
Unconsolidated soil material consisting largely of undecomposed or only slightly decomposed organic matter accumulated under conditions of excess moisture.

Permeability
A measure of the ease with which air, roots and water penetrate the soil.

Pest Threshold
The pest threshold is the point at which the damage caused by the pest is equal to or greater than whatever threshold you establish. This may be an economic, aesthetic and/or operational threshold.

Pesticide Resistance
The repeated use of herbicides, insecticides, and fungicides with the same mode of action that can result in the selection of insensitive pest.

Pesticide Signal Word
Wording on the pesticide label that describe the short-term toxicity of the product. From least-to-most toxic: “Caution”, “Warning”, and “Danger”.

pH
A measure of the acidity or alkalinity of a material or solution.

Phytotoxic
Harmful to plants.

Plant growth regulator
In turfgrass, a chemical used to slow vegetative growth.

Point Source
Any single identifiable source of pollution from which pollutants are discharged, such as a pipe, ditch, ship or factory smokestack.

Pollinators
Pollinators include native bees, honeybees, butterflies, birds, and bats.

Postemergence
A term used to refer to herbicide treatment made after weed seedlings have emerged from the soil.

Preemergence
A term used to refer to herbicide treatments made before weed seedlings emerge from the soil.

Profile, soil
A cross-section of soil that shows the layers or horizons lying above the unweathered parent material.

Preventative Maintenance
Preventative maintenance (PM) is maintenance that is performed on equipment to prevent it from breaking or malfunctioning in the future. As opposed to corrective maintenance (CM).

Reclaimed Water (Recycled or Effluent Water)
Water which, as a result of treatment of waste, is suitable for a direct beneficial use or a controlled use that would not otherwise occur and is therefore, considered a valuable resource.

Renovation
Turf improvement carried out by replanting into existing live and/or dead vegetation.

Residual Toxicity
Residual Toxicity (RT) time is that period of time after completing a pesticide application until there is minimal toxic effect to bees.

Resiliency
The capability of the turf to spring back when balls, shoes or other objects strike the surface, thus providing a cushioning effect.

Restricted Use Pesticide (RUPs)
Federally restricted use pesticides are pesticides that are not available to the general public and have the potential to cause unreasonable adverse effects to the environment and injury to applicators or bystanders without additional restrictions.

Rhizome
An underground, root-like stem; underground creeping stem.

Runoff
Water flow along the ground's surface that can pick up contaminants, such as fertilizers and pesticides. Runoff occurs when the soil is saturated, compacted, high in clay particles, or has lost soil structure (large pores).

Saline soils
Soils in which there is a heavy accumulation of salts.

Sand Applications
Topdressing the playing surface with sand following core aerification and heavy vertical mowing to aid in recovery of turf.

Scalping
Cutting into or below the crown of the grass plant while mowing. Continued scalping will weaken or kill the turf.

SDS
Safety Data Sheet (formally referred to as a Material Safety Datasheet or MSDS).

Section 404 Permit
Permit required by the US Army Corps of Engineers when dredge and fill are proposed in a Water of the United States (WOTUS).

Sedimentation
The transport of soil particles (sediment) in runoff that are deposited into surfacewaters.

Seed bed
An area of soil prepared for seeding.

Seedling
A plant grown from seed; usually refers to a young plant.

Selective herbicide
One that can be applied to a mixed stand of turfgrass and weeds that will selectively kill certain weeds without injuring the turfgrasses.

Sodic Water
Water high in salts, including sodium, that can adversely impact turf quality and have long-term impacts to soil and its ability to sustain a viable root zone.

SPCC Program
A Spill Prevention Control and Countermeasures (SPCC) plan helps facilities prevent, control, and provide adequate countermeasures to the discharge of petroleum, animal, and vegetable-derived oils.

Species
An established classification into which similar individuals in the plant or animal kingdom are placed. A species is described as a morphologically distinctive and genetically isolated natural population.

Spray drift
The movement of small spray particles away from the target area.

Sprigging
The planting of stolons (runners), rhizomes or vegetative segments of plants.

Sterilize
To treat soil chemically or by heat to kill disease organisms, weed seeds and insects.

Stolons
Creeping stems or runners aboveground that may produce roots and new stems and become independent plants.

Stormwater
Water that originates from precipitation events. Stormwater may soak into the ground or, when faced with impervious surfaces, result in runoff.

Stormwater Pollution Prevention Plan (SWPPP)
A SWPP is a plan developed to demonstrate sediment and erosion control. SWPPPs include identifying potential pollution sources that may impact stormwater discharge and listing measures that will be taken to reduce or eliminate erosion and sediment movement.

Striping
A pattern left on turfgrass, usually a fairway or green, using lightweight mowing equipment. Its main purpose is a pleasing appearance. Patterns are the result of light reflected from blades of grass lying in different directions because they have been mowed in different directions.

Subsoil
That part of the soil profile below plow depth, usually considered unsatisfactory for plant growth.

Surfacewater
Surfacewater is are water bodies that reside on the surface of the Earth, such as lakes, reservoirs, and ponds. It is distinct from groundwater.

Surfactant
An agent that reduces the surface tension of liquids on plant materials or in the soil. Wetting agents are common examples.

Susceptible
Lacking an inherent ability to resist. Turf may be susceptible to diseases, insect damage or weed encroachment.

Thatch
A tightly intermingled layer of dead and decaying roots, stolons, shoots and stems that develops between the green vegetation and soil surface.

TMDL
The Total Maximum Daily Load (TMDL) is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. TMDLs are established for water bodies on the 303(d) list.

Tolerance
The ability of a plant to withstand the effects of adverse conditions, chemicals or parasites.

Topsoil
A general term applied to the top natural layer of soil.

Topdressing
The act of adding a material to a turfgrass surface to enhance its quality and appearance such as a fertilizer spread thinly on the surface of soil or a lawn. A prepared mixture usually containing sand and organic matter used for leveling and smoothing the playing surface. It aids in controlling thatch and in maintaining biological balance. Topdressing is also used to cover stolons or sprigs in vegetative planting.

Total Dissolved Solids (TDS)
Total dissolved solids (TDS) is a measure of the dissolved combined content of all inorganic and organic substances present in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended form.

Toxicity
The degree to which a chemical can cause adverse effects in an organism, considering the dose, route of exposure, and duration of exposure.

Transpiration
The movement of water vapor out of a plant through leaf openings.

USACE
The United States Army Corp of Engineers is a U.S. federal agency under the Department of Defense made up of civilians and military that review Section 404 permits.

Variable Frequency Drive (VFD) pumping systems
An adjustable-speed drive that controls pump motor's speed to deliver only what the operation needs to function at optimal efficiency.

Variety
In classification, a subdivision of species. Differing from the remainder of the species in one or more recognizable and heritable characteristics.

Vertical Cutting (Verticutting)
The thinning of turfgrass grasses by blades or wire tines, which cut perpendicular to the soil surface.

Water Solubility
The tendency of a chemical to dissolve in water. Chemicals with high water solubility may be more inclined to be mobile if they come into contact with water.

Weeds
Plants out of place; undesirable or unwanted plants.

Winterization
Preparation of an irrigation system to protect the system and reduce equipment failures resulting from freezing.

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Lone Star Chapter
GCSAA

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