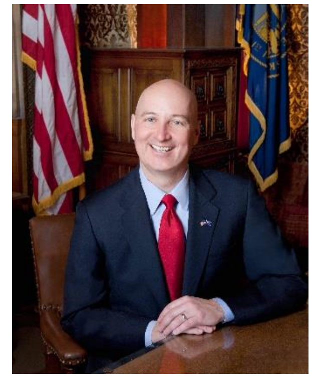
Best Management Practices for Nebraska Golf Courses

Nebraska Golf Course Superintendents Association

June 2018



STATE OF NEBRASKA

Pete Ricketts
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Friends:

I am pleased to support ***Best Management Practices for Nebraska Golf Courses***. This guidance document reflects the accumulation of the most recent advancements in turfgrass science and many years of collaboration with industry partners to achieve a science-based, environmentally friendly, and functional BMP. Superintendents throughout the state, University of Nebraska scientists, the Nebraska Golf Course Superintendents Association, and the State of Nebraska's agencies have all reviewed and contributed to this comprehensive effort. This document spans all facets of golf course operations, from design and planning of new golf courses, to renovation of existing golf courses, as well as normal and routine maintenance operations.

I applaud Nebraska's golf course superintendents for taking the time and effort to formulate and document best management practices that are tailored to Nebraska's needs and priorities. These voluntary guidelines will protect our environmental quality and conserve our precious water resources. By protecting our natural resources, preserving open space, and providing recreational opportunities, Nebraska's superintendents deserve recognition for their great stewardship of our natural resources. This work will help keep our state growing for years to come.

Sincerely,

Pete Ricketts
Governor

Table of Contents

Tables

Photo Credits

Acronyms

AST	above-ground storage tank
BMP	best management practice
Ca	calcium
CWA	Clean Water Act
DO	dissolved oxygen
DU	distribution uniformity
EPA	Environmental Protection Agency
ET	evapotranspiration
Fe	iron
FEMA	Federal Emergency Management Agency
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
FRAC	Fungicide Resistance Action Committee
GCSAA	Golf Course Superintendents Association of America
GWMA	Ground Water Management Area
HOC	height of cut
HRAC	Herbicide Resistance Action Committee
HVAC	heating, ventilation, and air conditioning
IBDU	isobutylidene diurea
IPM	integrated pest management
IRAC	Insecticide Resistance Action Committee
K	potassium
Mg	magnesium
mg/L	milligrams per liter
Mn	manganese
NDA	Nebraska Department of Agriculture
NDEQ	Nebraska Department of Environmental Quality
NeDNR	Nebraska Department of Natural Resources
NO_3-N	nitrate
NPA	Nebraska Pesticide Act
NPDES	National Pollution Discharge Elimination System
NRC	Nebraska Natural Resources Commission
NRD	Natural Resource District
NTEP	National Turfgrass Evaluation Program
PAW	plant available water
PPE	personal protective equipment
S	sulfur
SDS	Safety Data Sheet
SGN	size guide number
SWPPP	Stormwater Pollution Prevention Plan
TDS	total dissolved solids
TMDL	Total Maximum Daily Load
UNL	University of Nebraska-Lincoln
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGA	United States Golf Association
UST	underground storage tank
VFD	variable frequency drive
WIN	water-insoluble nitrogen
WIN-PST	Windows Pesticide Screening Tool
WSN	water-soluble nitrogen

Acknowledgements

The development of the *Best Management Practices for Nebraska Golf Courses* was made possible by superintendents in the state of Nebraska, scientists at the University of Nebraska, the Nebraska Golf Course Superintendents Association, and University of Nebraska-Lincoln turfgrass students. Representatives from each organization provided their time and expertise to develop and review drafts of best management practices specifically for the state of Nebraska designed to protect the state's natural resources.

Steering committee members for this effort have included the following;

- Bill Bieck CGCS, BMP Steering Committee Co-chair, Course Operations Manager, Heritage Hills Golf Course
- Steve Merkel CGCS, BMP Steering Committee Co-chair, Directory of Agronomy, Landscapes Unlimited
- Russ Cellar, CGCS, Assistant Superintendent Country Club of Lincoln
- Chad Giebelhaus, Superintendent, Crooked Creek Golf Club
- Eric McPherson CGCS, Superintendent, Omaha Country Club
- Ryan Krings, Superintendent, Country Club of Lincoln
- Katy Boggs, Executive Director, Nebraska Golf Course Superintendents Association
- Dr. Bill Kreuser, University of Nebraska-Lincoln
- Dr. Cole Thompson, formerly of the University of Nebraska-Lincoln

In addition, the following University of Nebraska-Lincoln personnel assisted in the development of this document: Clyde Ogg, Extension Educator; Dr. Jonathan Larson, Extension Entomologist; and Kim Todd, Associate Professor and Extension Landscape Specialist. Katy Boggs of the Nebraska Chapter of the Golf Course Superintendents Association of America not only servied on the committee, but also provided valuable leadership and assistance in initiating, organizing, and promoting this project. Last, we appreciate the photo contributions from superintendents across the state.

We would also like to thank the external reviewers of the draft final version of this document. The time and effort taken by individuals and agency representatives strengthened our document and ensured its accuracy. Reviewers included the following:

- Nebraska Department of Agriculture
- Nebraska Department of Environmental Quality
- Nebraska Department of Natural Resources
- Nebraska State Fire Marshal
- Nebraska
- Golf Course Builders Association of America
- Dr. Roch Gaussoin, University of Nebraska

- Jennifer Wemhoff, Groundwater Foundation
- Casey Crittenden CGCS, Holmes Golf Course

Funding and support for this project was provided by the Golf Course Superintendents Association of America (GCSAA), The Environmental Institute for Golf (EIFG) and the United States Golf Association (USGA). The GCSAA also provided a Best Management Practices template that served as source material for this project.

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 those 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

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

USGA provides governance for the game of golf, conducts the U.S. Open, U.S. Women's Open, U.S. Senior Open, 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.

1 INTRODUCTION

Nebraska's golf course superintendents are dedicated to protecting the state's natural resources. As a demonstration of this commitment, superintendents have partnered with University of Nebraska scientists to develop and document best management practices (BMPs) for golf course management. These research-based, voluntary guidelines have been developed specifically for Nebraska's 230 golf courses. When used alongside the state's pesticide and water quality and quantity regulations, the guidelines not only protect natural resources, they also afford the opportunity for superintendents to be recognized as environmental stewards by club members, the community at large, and state officials.

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

1.1 Best Management Practices

BMPs are methods or techniques found to be the most effective and practical means of achieving an objective, such as preventing water quality impacts or reducing pesticide usage. Because of the efforts aimed at protecting surface and groundwater quality, the majority of BMPs in this document relate to water quality. Because of limitations, such as budget, staff, clientele expectations, and management decisions, not all golf courses can achieve all of the best practices. However, planning for improvements over time and making small changes that meet the goals of BMPs can be achieved. For example, while a sophisticated washwater recycling system may be too expensive for many facilities, blowing clippings off mowers onto a grassed surface is easily achieved and markedly reduces the amount of nitrogen and phosphorus in clippings that end up in washwater.

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

1.2 Pollution Prevention

Best management practices reduce the potential for sedimentation, runoff, leaching, and drift -- the mechanisms that can transport these contaminants and impact water quality. For example, bare ground is much more likely to erode than turf. Therefore, following grow-in BMPs during course construction or renovation to quickly establish dense turf ground cover helps minimize erosion potential. Maintaining vegetated areas, such as filter strips and buffers, which slow down stormwater and any excess irrigation, allows infiltration and uptake and is another key BMP. Pesticide BMPs help superintendents follow state and federal regulations related to the storage, handling, transport, and use of pesticides, preventing point source pollution and minimizing the potential for nonpoint source pollution from these chemicals.

Understanding site characteristics is another key to preventing pollution. For example, some sites, such as valley slopes in eastern Nebraska, are more prone to runoff. The sandhills of central and western Nebraska are more prone to leaching due to sandy soils and shallower water tables. University of Nebraska-Lincoln (UNL) publishes a Nebraska Water Map that should be consulted by superintendents to understand where the high recharge potential (e.g. more prone to leaching) and high runoff potential areas of the state are located.

1.3 Water Conservation

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

1.4 Pollinators

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

1.5 Conclusion

This document was developed using the latest science-based information and sources. This resource is intended to be a living a document. The Nebraska BMP steering committee intends to review this information annually. Therefore, the latest version of this document will be posted on the Nebraska Golf Course Association website. As of the time of this publication, the information was the latest available. Some sources are updated regularly, and the reader should make an effort to identify the latest version. In addition, regulations may change and the reader should identify any changes since the publication date.

2 PLANNING, DESIGN, AND CONSTRUCTION

Building a new golf course or renovating an existing one requires careful protection of natural resources during all phases of planning, design, and construction. Implementing BMPs should result in an environmentally sustainable golf course that operates efficiently and cost effectively.

2.1 Regulatory Considerations

Regulations are in place at the local, state, and national levels that impact planning, design, and construction activities on Nebraska's golf courses. These laws are in place to protect and conserve the environment both during and after the construction process. Before beginning any golf course construction or renovation, consultation with the appropriate regulatory agencies is recommended. Communication between developers, designers, owners, the public, and regulatory agencies should occur early and often. In addition, if new wells must be installed, experts should be consulted for proper siting in the design plan and all setback and other regulatory requirements, as described in Chapter 5 of this document must be followed.

2.1.1 Stormwater Permits

The Environmental Protection Agency (EPA) protects streams, rivers and lakes from construction pollution under the Clean Water Act (CWA). The Nebraska Department of Environmental Quality (NDEQ) creates state-specific regulations. A National Pollutant Discharge Elimination System (NPDES) permit issued by NDEQ is required for any construction-related disturbance greater than one acre or projects that are part of a larger common plan of development. NPDES Permit Basics answers frequently asked questions related to this kind of permit. NDEQ can also be contacted for additional stormwater-related information at (402) 471-8330.

The development of a Stormwater Pollution Prevention Plan (SWPPP) that addresses erosion and sediment control during construction is a primary condition of stormwater construction NPDES permits. The SWPP must be kept on site and available for inspection. More information on SWPPPs can be found on the EPA's Developing a Stormwater Pollution Prevention Plan (SWPPP) web page. Regulatory requirements related to NPDES permits are also discussed in the NebGuide Stormwater Management: What Stormwater Management Is and Why it is Important. In larger cities, a Municipal Separate Storm Sewer System (MS4) permit may also be required.

2.1.2 Erosion and Sediment Control

The Erosion and Sediment Control Act (Sections 2-4601 to 2-4613) is the enabling legislation for Nebraska's Erosion and Sediment Control Program. The Nebraska Department of Natural Resources (NeDNR) and the 23 Natural Resource Districts (NRDs), has regulatory oversight of this program, which represents the state's commitment "to reduce erosion on Nebraska lands and to reduce sedimentation and other problems that result from that erosion." This state program guides erosion and sediment control programs of the 23 NRDs in the state, cities, and counties.

Links to regional erosion and sediment control programs for the NRDs can be found on the Natural Resources Commission (NRC) website.

2.1.3 Wetlands

Activities that impact wetlands are regulated under sections 404 and 401 of the federal CWA. The U.S. Army Corps of Engineers (USACE) regulates dredging and filling of waters in the United States under Section 404 of the CWA. The NDEQ Planning Unit administers the Section 401 Water Quality Certification Program of the CWA. Consultation with NDEQ and/or Nebraska's Game and Parks Commission during the design phase of any construction activities expected to impact wetlands will assist in understanding the permitting process.

2.1.4 Surface Water Usage

NeDNR is the state agency authorized to regulate surface water quantity and usage. All diversions of surface waters for irrigation, hydropower, industrial use, municipal use, domestic use, storage, and other uses require a state permit. Reporting requirements are identified in permits. Superintendents should ensure that required reports are submitted on time as required.

2.1.5 Floodplains

NeDNR delineates floodplains and provides technical assistance on floodplain management to local governments. Any construction activities within a floodplain should be identified, and local government should be consulted before any land disturbance in a floodplain.

2.1.6 Listed Species

Currently, 30 threatened and endangered species are protected by the Nebraska Nongame and Endangered Species Conservation Act. The Natural Heritage Program housed within the Nebraska Game and Parks Commission provides information on listed species and critical habitats and should be consulted prior to construction activities.

2.2 Overview

Proper planning is the first step to any construction or renovation project and minimizes expenses from unforeseen events and maximizes long-term success. Good planning also incorporates conservation of natural resources into the project. The design should allow for economic sustainability, while meeting the stakeholder needs. Once designed, construction must be carried out in a way that minimizes environmental impacts. Maintaining a construction progress report, as well as following regulations and coordinating with regulatory agencies as required, helps to ensure compliance. Table 2-1 summarizes the steps and best practices for each phase of the planning, design, and construction process. Topics of particular importance, such as wildlife habitat, erosion and sedimentation control, drainage, and grow-in, are then discussed in more detail.

Table 2-1. Best practices for golf course planning, design, and construction

Planning	
Step	**Description**
Assemble Team	The team should include, but not be limited to, a golf course architect, golf course superintendent, clubhouse architect, irrigation engineer, environmental engineer, energy analyst, economic consultant, civil engineer, soil scientist, golf course builder, and a legal team.
Define Objectives	Identify realistic goals, formulate a timeline, etc.
Conduct a Feasibility Study	Evaluate finances, environmental issues, water availability and sources, and energy, materials, and labor needs. Identify applicable government regulations.
Select Site	Site should meet project goals and expectations. Identify all strengths and weakness of each potential site. During site selection, any site constraints, such as the presence of listed species or valuable habitat, should be identified.
Design	
Retain a Project Manager/Superintendent	This person is responsible for integrating sustainable practices in the development, maintenance, and operation of the course.
Design the Course	Existing native landscapes should remain intact as much as possible. Should consider adding supplemental native vegetation to enhance existing vegetation alongside lengthy fairways and out-of-play areas. Nuisance, invasive, and exotic plants should be removed and replaced with native species adapted to the area.
	Greens: Should have plenty of sunlight and be well drained. Greens should be big enough to have several hole locations that can handle expected traffic. Root zone material should be selected with United States Golf Association (USGA) specifications in mind, as published in "A Guide to Constructing The USGA Putting Green." Native sands in western Nebraska may be suitable for use in "push-up" putting green construction. Physical testing of these sands by an accredited laboratory prior to use is recommended.
	Grass Selection: Species should be selected based on climate, environmental, and site conditions and species adaptability to those conditions, including disease resistance, drought tolerance, spring green-up, and traffic tolerance.
	Bunkers: The number, size of bunkers depends on considerations, such as the resources available for daily maintenance. For each bunker consider: • The need for drainage. • Entry/exit points and how these will affect wear-and-tear patterns. • The proper color, size and shape of bunker sands to meet needs. New bunker construction techniques can also be researched to see if they satisfy stakeholders' needs.

Design Irrigation System	Hire a professional irrigation architect, if possible, to design the irrigation system. Keep in mind the different water needs of greens, tees, fairways, roughs, and native areas. Consider the topography, prevalent wind speeds, and wind direction when spacing the heads. Choose the most efficient type of irrigation system considering available resources. The “Irrigation” chapter of this document provides detailed information on irrigation-related BMPs.
Construction	
Select Qualified Contractors	Use only qualified contractors who are experienced in the special requirements of golf course construction. Members of the Golf Course Builders Association of America make great candidates.
Safeguard Environment	Follow all design phase plans and environmental laws. Soil stabilization techniques should be rigorously employed to maximize sediment control and minimize soil erosion. Temporary construction compounds and pathways should be built in a manner that reduces environmental impacts.
Install Irrigation System	Installation should consider the need to move equipment and bury pipe while maintaining the original soil surface grade to minimize the potential for erosion.
Establish Turfgrass	Turfgrass establishment methods and timing should allow for the most efficient progress of work, while optimizing resources and preventing erosion from bare soils before grass is established.

2.3 Planning and Design Considerations

2.3.1 Wetlands

The State of Nebraska has adopted the following federal definition of wetlands:

> *"Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas."* (USACE 1987)

Nebraska contains more acres of wetlands, marshes, lakes, rivers, streams, oxbows, wet meadows, fens, forested swamps, and seeps, than surrounding states. The wetlands are divided into four major categories and 14 subcategories, as described on the UNL web page Nebraska's Wetland Family. Conserving the state's wetlands protects water quality and biodiversity, while reducing flooding and soil erosion.

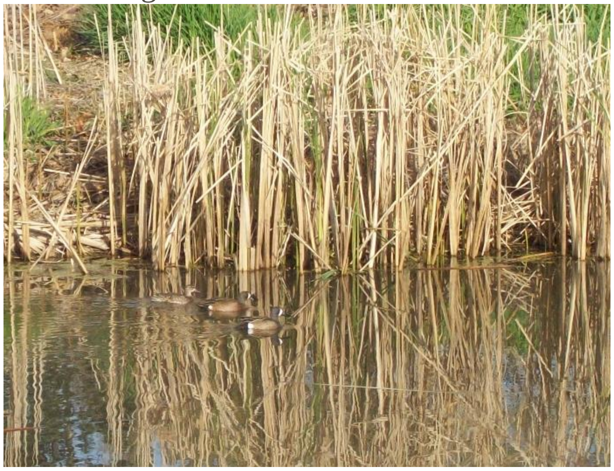

Figure 1. Wetland habitat at Holmes Golf Course. Credit: Casey Crittenden.

To protect this natural resource, wetlands should be identified in the field by qualified wetland specialists during the design phase and before the permitting process is initiated. Course design should minimize any impact to wetlands and streams tied to activities such as filling, dredging, flooding, crossings, or converting areas from one habitat type to another. In addition, natural buffers should be retained around wetlands (as with other waterbodies) to protect water quality and provide habitat (Figure 1).

In some instances, wetlands and streams can be improved or restored during golf course construction. For example, a highly degraded stream or wetland can sometimes be reshaped, rehabilitated, or replaced entirely to meet project goals and improve ecological function. Qualified environmental consultants can evaluate the overall benefit of stream enhancement or restoration and assist with permitting issues, which my include a federal 404 permit and/or state 401 certification.

2.3.2 Floodplains

Golf course development is often compatible with floodplains, particularly when compared with other uses such as residential or commercial development. Minimizing encroachment into floodplains to the extent possible is prudent. Any substantial disturbance to a floodplain, including clearing and grading, generally requires an engineering analysis to demonstrate minimal impact on the base flood elevation in accordance with local ordinances. Depending on the complexity of the encroachment, this analysis may be as simple as a comparison of cut and fill quantities within the floodplain or as complex as a detailed floodplain model of the entire watershed. A complex analysis may require a Federal Emergency Management Agency (FEMA) review along with potential revision to the floodplain mapping.

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

2.3.3 Stormwater Management

The movement of water across the land surface (i.e. runoff) from either precipitation or irrigation that does not infiltrate into the ground is the conveying force behind nonpoint source pollution. In this section, stormwater management refers to the management of runoff from precipitation but applies to irrigation runoff as well. Stormwater management is the control and use of stormwater runoff and includes planning for runoff, maintaining stormwater systems, and regulating the collection, storage, and movement of stormwater. This section describes the approach to stormwater management that should be incorporated into the design of new courses or renovations of existing courses. For more information on specific stormwater structural and non-structural controls and their role in protecting water quality, see the “Surface Water Management” chapter of this document.

Managing stormwater on a golf course is more than preventing the flooding of facilities and play areas. In addition to controlling the amount and rate of water leaving the course, stormwater management also involves storing irrigation water, controlling erosion and sedimentation, removing potential runoff contaminants and preventing them from reaching surface water, protecting groundwater and wellheads, and addressing aesthetic and playability concerns. To add to the complexity of managing stormwater runoff, not all stormwater runoff that ends up on a golf course originates there. Some may be from adjoining lands, including residential or commercial developments. Therefore, planning on how stormwater runoff will be managed and preventing impacts from the runoff is integral to every phase of planning, design, and construction. When stormwater management is done well, streams, rivers, and lakes are cleaner; flood risks are reduced, costs tied to flood damage decrease, and community quality of life increases.

Several key elements help to effectively manage stormwater runoff include:

- Keeping stormwater close to where it falls.
- Slowing down stormwater runoff.
- Allowing stormwater to infiltrate into the soil.

These key elements must be considered and incorporated into the design. Stormwater management is best accomplished by a “treatment train” approach in which water is conveyed from one treatment to another by conveyances that themselves contribute to the treatment. These treatments include source controls, structural controls, and non-structural controls.

Source controls are the first car of the BMP treatment train. They help prevent the generation of stormwater runoff or the introduction of pollutants into stormwater runoff. The most effective method of stormwater treatment is to prevent or preclude the possibility of movement of sediment, nutrients, or pesticides in runoff. For example, during construction or redesign, strict adherence to erosion and sedimentation controls helps to prevent, or at least minimize, the possibility for sediment and nutrients to impact water quality through runoff (Figure 2). Once a course is built, the implementation of BMPs is the most effective method of preventing negative impacts from golf course management activities.

Figure 2. Erosion and sediment control during construction helps to protect water quality from runoff during construction at Oak Hills Country Club. Photo Credit: Dan Maddox.

The next car in the treatment system is often structural controls, which are design and engineering features of the course created to remove, filter, retain, or reroute potential contaminants carried in surface runoff. Examples of structural BMPs include retention basins and infiltration basins that address water quality, water recharge, and stream channel protection. Properly designed golf courses can capture rain and runoff in structural controls such as water hazards and stormwater ponds, providing a source of water for irrigation. The depth to groundwater and soil structure should be taken into account when incorporating retention and infiltration basins to avoid any potential issues with leaching of potential contaminants in runoff to groundwater. Though most golf courses plan their lakes and water hazards to be a part of the stormwater control and treatment system, natural waters of the state cannot be considered treatment systems and must be protected.

Non-structural controls often mimic natural hydrology (e.g. constructed wetlands), hold stormwater (e.g. constructed wetlands and wet retention basins), and filter stormwater via vegetative practices (e.g. filter strips and grassed swales) (Figure 3). The treatment train approach combines these non-structural controls with structural controls, as in the following example: Stormwater can be directed across vegetated filter strips, through a swale, and into a retention pond, then out through another swale to a constructed wetland system.

Figure 3. Native grass buffer next to wetland protects water quality at The Players Club in Omaha. Photo credit: Steve Merkel.

Reducing the amount of stormwater to be treated, especially in and around the clubhouse and other structures, should also be incorporated into the design. For example, wherever impervious surfaces exist (buildings, parking lots, cart paths, etc.), opportunities should be identified to slow down the movement of water and allow for infiltration. For example, in paved areas, depressions within landscaped islands can catch, filter, and infiltrate water instead of letting it run off. When hard rains occur, an elevated stormwater drain inlet allows the island to hold the treatment volume and settle out sediments, while allowing the overflow to drain away.

Maximizing the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass, allows stormwater to infiltrate into the soil as opposed to running off. Crushed stone and other permeable products are available for cart paths or parking lots (Figure 4). Runoff from gutters and roof drains should flow into permeable areas. Rain gardens near these areas can be incorporated into the landscape design, as discussed in the "Landscape" chapter of this document.

Figure 4. Crushed stone cart path at Ashland Golf Club. Photo credit: Steve Merkel.

2.3.4 Drainage

Adequate drainage is necessary for healthy turfgrass. The drainage system should be part of the stormwater management approach, incorporating the containment and treatment features described above. Subsurface drainage directs stormwater and can reduce runoff and leaching. Subsurface drainage is also installed to control a water table or to interrupt subsurface seepage or flow. Wherever possible, direct this drainage into vegetative areas for biological filtration or into infiltration basins to help control the potential loss of nutrients and pesticides from the golf course.

Drainage is only as good as the system's integrity. Damaged, improperly installed, or poorly maintained drainage systems negatively impact play and increase risks to water quality. The drainage system should be routinely inspected to ensure proper function. Roots and animal activity can easily clog drains and prevent proper functioning.

2.3.5 Listed Species

Thirty species of plants, birds, mammals, fish, insects, reptiles, and mussels are currently listed as Nebraska Endangered or Threatened species. Prior to beginning construction activities, the Nebraska Natural Heritage Program housed within the Nebraska Game and Parks Commission should be consulted for the presence or habitat of any of these species on the site.

2.3.6 Habitat Conservation

In addition to adhering to regulations that protect listed species, maintaining habitat to the extent possible during all phases of planning, design, and construction helps maintain biodiversity. Natural habitats provide food and shelter for numerous species, including mammals, birds, fish, amphibians, reptiles, insects, and native plants (Figure 5).

Figure 5. Wildlife at Heritage Hills Golf Course. Photo Credit: Bill Bieck.

In urban and suburban environments, a golf course may provide the best habitat for many species. A number of golf course management activities can maintain and enhance habitat. For example, retaining natural buffer areas around wetlands and watercourses preserves habitat while protecting water quality for aquatic species. Planting native species provides food for animals and insects. Retaining dead trees to serve as nesting areas and providing nest boxes for birds, bees, and bats also enhances habitat quality. Removing exotic and invasive species improves habitat as well. The Nebraska Invasive Species Program provides lists of invasive species by eco-region. The "Pollinator Protection" and "Landscape" chapters of this document provide additional recommendations and BMPs for enhancing habitat on the golf course.

2.4 Turfgrass Establishment

2.4.1 Species Selection

Nebraska's climate is generally favorable to cool season grasses, with the exception of the warm season buffalograss, a native of the Great Plains. When selecting species and cultivar, site specific characteristics, such as desired use, site and microclimate conditions, disease resistance, drought tolerance, and spring transition traits, should be considered.

Numerous new turfgrass cultivars continue to be developed and released by turfgrass breeders. To evaluate different species and identify cultivars that perform well in this region, extensive trials are conducted under the National Turfgrass Evaluation Program (NTEP). Results of NTEP trials conducted and evaluated by UNL are available on the NTEP website.

Buffalograss (*Buchloe dactyloides*), a native grass to the plains region of the United States, is often used as a low-maintenance turfgrass in Nebraska. It forms a dense sod that establishes quickly through stolons, has good color, and has exceptional drought, heat, and cold tolerance -- qualities that can benefit the golf industry by reducing management inputs and costs. These inputs, such as reduced nitrogen requirements, are significantly less than those used to manage most other turf species, such as Kentucky bluegrass. Although buffalograss requires minimal inputs once established, it takes longer to establish than cool season grasses and requires a higher level of maintenance during establishment to ensure an adequate stand. In addition to proper fertilization, weed control during the first year is essential to ensure adequate establishment because high weed pressure at this time can greatly reduce quality and density for several years. Newer buffalograss cultivars developed at UNL are superior to common buffalograss for turfgrass quality, uniformity, production characteristics, and canopy density.

For more information on buffalograss research, establishment, and management, see the following:

- Establishing Buffalograss Turf in Nebraska, UNL
- Management of Buffalograss Turf in Nebraska, UNL
- The Next Generation of Buffalograss Cultivars, UNL

2.4.2 Seedbed Preparation

Proper seedbed site preparation can help avoid long-term problems, such as weed encroachment, diseases, and drought susceptibility. Debris should be removed that could hinder root growth and limit access to water and nutrients. Any drainage issues should be corrected through grading and installation of drainage technologies.

Sodding

Most grasses can be sodded during any time of the year. Sod should be topdressed to fill in the gaps between the pieces to speed establishment and create a smoother surface. During dry weather (summer or winter), light and frequent irrigation is required until the sod takes root. Check for rooting by lightly pulling the corner of the sod. Irrigation frequency can be reduced when the sod cannot be pulled from the soil surface.

Seeding

Cool-season turfgrass species (bluegrass, fescues, ryegrass, and bentgrass) should be seeded in late summer. This timing is ideal because soils are warm, nights are cool, and disease and weed pressure are reduced. A drop-type spreader should be used to ensure uniform seed dispersal. Lightly raking the soil or using specialized “slit seeders” improves seed-to-soil contact (Figure 6). Warm-season species like buffalograss and zoysiagrass should be seeded in mid-spring to late spring. All species can also be dormant seeded in late fall through the winter. Cool-season species can be seeded in the spring, especially following winterkill. For any spring seeding, pre-emergence herbicides vastly improve the success of grow-in. Without a pre-emergence herbicide, spring seeding success is significantly reduced because of the intense summer annual weed pressure across Nebraska. Herbicide labels should be reviewed to ensure that the product is labeled for use during establishment.

Figure 6. Fairway seeding at Omaha Country Club. Photo Credit: Eric McPherson.

During grow-in and establishment, more water is required than for established stands. Until the sod begins to root down or the seedlings start to establish, water should be applied lightly and frequently. The goal is to keep the surface moist until germination. Irrigation frequency should then be reduced, though the amount of water applied should be slightly increased until the first mowing. Turfgrasses with relatively large seeds (i.e. tall fescue, perennial ryegrass, fine fescue, buffalograss) generally need fewer irrigation events during establishment than finer-textured seeds (i.e. Kentucky bluegrass, creeping bentgrass).

2.4.3 Erosion and Sediment Control

The loss of topsoil from a site can be a problem for numerous reasons. Soil carried by wind and water transports contaminants with it. For example, erosion can enrich surface waters, where phosphorus, and to a lesser extent nitrogen, can cause eutrophication. When sediments and soils enter water, they can also increase turbidity, which can have harmful effects on aquatic plants and animals. Therefore, control measures should be documented in an erosion and sediment control plan, put in place prior to any soil disturbance, and properly maintained.

2.4.4 Nutritional Needs

In phosphorus-deficient soils, phosphorous should be applied to the soil before seeding or sodding at a rate ranging from 0.5 to 1.5 lbs P_2O_5 per 1,000 square feet (22 to 65 lbs P_2O_5 per acre). A follow-up application of phosphorus fertilizer may be required four to eight weeks after seedling germination or sodding. A second application is justified if the turf has symptoms of phosphorus deficiency (such as purple-blue color, thin canopy, poor nitrogen response). Soils with a pH greater than 7.5 are also at greatest risk of phosphorus deficiency during establishment. Therefore, higher rates and a second application of phosphorus fertilizer are recommended for high pH soils.

Nitrogen management is essential during establishment. For highly maintained turf stands or turf growing on sand or sand-based soils, soluble sources of N fertilizer should be applied every 7 to 14 days. Fertilizer applications should continue until the turf canopy has achieved 100% cover. Single application rates should not exceed 0.5 lbs of nitrogen per 1,000 square feet. Slow-release nitrogen sources can also benefit establishment regardless of soil type. Higher nitrogen application rates may be used with products containing more slow-release nitrogen. Fertilizers with 50% quick-release and 50% slow-release nitrogen provide uniform nitrogen release for a period of 6 to 10 weeks, depending on the formulation.

Micronutrient fertilizers can also be beneficial during establishment, especially on sandy or high pH soils. Nutrients such as iron and manganese can sometimes be limiting in these soil conditions. The recommendations found in soil test results are for established turfgrass; for establishing a new stand, these recommendations are not as beneficial. Instead, deficiencies can be diagnosed through small applications of fertilizer to a section of the turf. Lack of a response indicates that nutrient is not limiting and an application to the entire area is not warranted.

2.4.5 Mowing

For a majority of turfgrass areas, mowing should begin as soon as the turf height reaches the desired mowing height for that area. An exception may be putting greens. While some managers will start mowing to standard putting green heights immediately (0.15” or less), most managers start mowing at 0.4” and slowly reduce the height of cut as the stand matures. Regular mowing promotes new tiller formation and stimulates the transition from juvenile to mature plants.

2.4.6 Grow-In

Turfgrass establishment is a unique phase in turfgrass growth and can require greater quantities of water and nutrients than established turfgrass. To this end, the establishment phase should be considered carefully to minimize environmental risk. For example, caution should be exercised when applying nutrients during establishment because of the increased susceptibility of bare soil to nutrient loss via leaching and runoff. Nurse crops (such as oats) can be used to protect areas from erosion, especially on slow-to-establish warm season native areas.

Figure 7. Hydro mulching at Indian Creek Golf Course. Photo Credit: Jim Nedrow.

Of the three options for establishing turf -- seeding, sodding, and plugging -- the first two are currently the most-used methods in Nebraska. Hydro seeding and hydro mulching also help prevent erosion and speed establishment (Figure 7).

2.5 External Programs

Golf courses can gain valuable recognition for their environmental education and certification efforts. Examples of external designations include Audubon International’s Cooperative Sanctuary Program and the Groundwater Foundation’s Groundwater Guradian Green Site program (Figure 8). The Groundwater Foundation was founded in Nebraska and is headquartered in Lincoln.

Figure 8. Heritage Hills Golf Course is a Groundwater Guardian Green Site. Photo Credit: Bill Bieck.

2.6 Planning, Design, and Construction Best Management Practices

Planning and Design

- ❖ Maintain appropriate silt fencing during construction to prevent erosion and sedimentation in accordance with the SWPPP.
- ❖ Establish a low- to no-maintenance level within a 75-foot buffer along wetlands.
- ❖ Establish and maintain a 100-foot riparian buffer around wetlands, springs, and channel.

Floodplains

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

Stormwater Management

- ❖ Use a treatment train approach to stormwater management and incorporate it into the course design and renovation plans.
- ❖ Install vegetated swales and slight berms where appropriate around water edges, including irrigation storage ponds, to slow water and allow infiltration.
- ❖ Eliminate or minimize directly connected impervious areas.
- ❖ Use depressed landscape islands in parking lots to catch, filter, and infiltrate water, instead of letting it run off.
- ❖ Use elevated stormwater drain inlets in parking lots for hard rains that can hold the treatment volume and settle out sediments, while allowing the overflow to drain away.
- ❖ Maximize the use of pervious pavements, such as brick or concrete pavers separated by sand and planted with grass. Consider using crushed stone or other permeable products cart paths or parking lots.
- ❖ Ensure runoff from gutters and roof drains flows onto permeable areas, allowing the water to infiltrate near the point of generation.

Drainage

- ❖ Evaluate the watershed size to understand drainage needs and appropriate pipe sizing.
- ❖ Ensure that no discharges from pipes go directly to surface water.
- ❖ When constructing drainage systems, pay close attention to engineering details such as subsoil preparation and the placement of gravel, slopes, and backfilling.
- ❖ Discharge internal golf course drains through pretreatment zones and/or vegetative buffers to help remove nutrients and sediments. Do not discharge directly into an open waterbody.
- ❖ The drainage system should be routinely inspected to ensure proper function.

Listed Species

- ❖ Identify any listed species and critical habitat that may be present on the site and preserve habitat, as well as feeding and nesting areas.

Habitat Conservation

- Identify the different types of habitat specific to the site.
- Identify habitat requirements (food, water, cover, space) for wildlife species.
- Identify and preserve regional wildlife and migration corridors by avoiding or minimizing crossings. Design unavoidable crossings to accommodate wildlife movement.
- Design and locate cart paths to minimize environmental impacts. Construct the paths with permeable materials, if possible.
- Remove nuisance and exotic/invasive plants and replace them with native species that are adapted to a particular site.
- Maintain clearance between the ground and the lowest portion of any fences or walls to allow wildlife to pass, except in areas where feral animals need to be excluded.
- Retain dead tree snags for nesting and feeding sites, provided they pose no danger to people or property.
- Construct and place birdhouses, bat houses, bee boxes, etc. in out-of-play areas.
- Plant pollinator gardens around the clubhouse and out-of-play areas.
- Retain riparian buffers along waterways to protect water quality and provide food, nesting sites, and cover for wildlife.

Turfgrass Establishment

- Select cultivars that are adapted to the desired use, taking note of disease resistance, spring transition and green up, drought tolerance, and other traits such as shade and wear tolerance.
- Ensure erosion and sediment control devices are in place and properly maintained.
- Use mulch (e.g. hydromulch, loose straw from a clean source, strawmats) for soil stabilization.
- Prepare seed/sod bed to maximize success.
- Fill gaps in sod seams with soil or sand to provide a uniform surface.
- Use selective pre-emergence herbicides to reduce weed cmopetitions and improve the chance of success with seeding establishment during the spring.
- Apply a fertilizer containing phosphorus at seeding. An additional application should be applied if turf displays symptoms of phosphorus deficiency.
- Nitrogen and sufficient water are essential during establishment. Light and frequent applications of nutrients are most desirable, unless a slow-release nitrogen source is applied.
- Mow turf to the desired mowing height as soon as practical to promote density and maturation. Never remove more than one-third of the turf leaf at mowing.

3 IRRIGATION

The supplemental use of water in turfgrass management encourages healthy turfgrass and landscape plant health. BMPs related to irrigation conserve and protect water resources. Conservation and efficiency-related efforts consider the strategic use of course and irrigation design, computerized and data-integrated scheduling, and alternative water quality/supply options that maximize plant health and reduce the potential for negative impacts on natural resources.

Irrigation BMPs may also provide an economic, regulatory compliance, and environmental stewardship advantage to those who integrate them into an irrigation management plan. BMPs are not intended to increase labor or place an undue burden on the owner/superintendent. If applied appropriately, irrigation-related BMPs can help stabilize labor costs, extend equipment life, reduce repairs, and limit overall personal and public liability while protecting and conserving natural resources.

3.1 Regulatory Considerations

Nebraska’s 23 NRDs manage the use of groundwater in the state. Most NRDs require a permit prior drilling a new well. Some NRDs require water use reports and flow meters on wells. The NRDs also have the authority to enforce drilling moratoriums and allocate and restrict irrigation usage within their districts. For more information, see NRD Groundwater Quantity Regulations Across Nebraska. NeDNR is the entity responsible for the registration of groundwater wells and also monitors surface water usage.

During times of extended drought, groundwater use restrictions may be issued by the NRDs while NeDNR can restrict surface water usage. Superintendents should be aware of water use restrictions and be prepared with a drought management plan.

The “Surface Water Management” and “Groundwater Management” chapters of this document provide additional information on regulatory policies and agencies that regulate the use and protection of Nebraska’s water resources.

3.2 Irrigation Water Supply

3.2.1 Irrigation Water Sources

Golf course designers and managers should identify and use alternative water supply sources to conserve freshwater drinking supplies whenever possible. The routine use of potable water is not a preferred practice; therefore, municipal drinking water should be considered only when no alternatives exist.

3.2.2 Irrigation Water Quality

Irrigation water should be assessed to determine its suitability for irrigation and for plant growth. Non-potable water irrigation sources (such as retention ponds and recycled water) should be regularly tested to ensure that the quality is within acceptable parameters for irrigation. The assessment should identify the chemical characteristics of the water and address possible issues with soil salinity and plant health caused by poor water quality.

For more information, on irrigation water quality specifically for turfgrass, see:

- Irrigation Water Quality Guidelines for Turfgrass Sites, Penn State University.
- Understanding Water Quality and Guidelines to Management, USGA Green Section.

3.2.3 Irrigation Water Requirements

An adequate water supply is essential for any planned or proposed golf course irrigation system. Water requirement analyses can be conducted to understand irrigation needs. A seasonal bulk water requirement analysis verifies the suitability of a water source and irrigation system to supply irrigation water under normal conditions. Because of the potential for drought, a maximum seasonal bulk water requirement analysis should be conducted as a worst-case scenario and calculated to not account for rainfall. For more information on calculating water requirements and example calculations, see Chapter 3 of "Environmental Best Management Practices for Virginia's Golf Courses."

It is essential that all delivery systems install and maintain accurate metering devices. Being able to measure water use allows baselines to be established and progress in water conservation efforts to be tracked. Installation of water meters will become more critical as more regulatory and compliance obligations are imposed on users of water for irrigation.

3.3 Irrigation System Design

3.3.1 Site Assessment

A site assessment of the entire facility should be conducted prior to developing a system design. The site assessment should include site-specific features, such as water sources; soil types (see the Web Soil Survey for identifying site specific soil types), soil physical properties (Table 3-1); microclimates; slopes; sun, wind and shade exposures; and a seasonal and bulk water requirement analysis. In addition, the site assessment should evaluate the impact of design elements, such as design features and concepts, planned or existing turfgrass varieties, and planned or existing drainage systems. The system design should include a general irrigation schedule with recommendations and instructions on modifying the schedule to meet these site-specific needs.

3.3.2 Design

A well-designed irrigation system should operate at peak efficiency and be designed and installed to optimize water use efficiency, focusing on water placement and distribution. The design should maximize water use, reduce operational cost, conserve supply, and protect water resources. Where feasible, variable frequency drive (VFD) pumps and/or pump station should be used. These systems only expend enough energy to meet the demands of the irrigation pump(s). VFD systems reduce water hammer to fitting, pipe, and sprinklers when systems are pressurized. Detailed BMPs for irrigation system design are published by the Irrigation Association in 2014 Landscape Irrigation Best Management Practices.

The irrigation system design should meet the site-specific needs identified by the water quantity analyses and the site assessment. The system's capacity to deliver water should not exceed the infiltration of the soils on site, as that will lead to runoff. Though the design of an irrigation system is complex, some of the most important design decisions that influence the efficiency and effectiveness of water usage include those related to sprinkler and piping placement, sprinkler coverage and spacing, and communication options.

Figure 9. VFD pumping station at Heritage Hills Golf Course. Photo Credit: Bill Bieck.

Multi-row sprinkler systems provide the most efficient use of water and can respond to specific moisture requirements of selected areas. Newer designs with multiple nozzle configurations provide increased flexibility and improved distribution uniformity. Single row systems do not uniformly distribute water and increases the risk of runoff. Double-row systems offer an improved efficiency over single-row coverage, although manual watering or other types of supplemental watering may be needed outside the fairway area and into the extended rough. Sprinkler layouts can be specific to each area. For example, part-circle sprinklers can be arranged to avoid overspray of impervious surfaces, to apply water only to the green surface, or in heavy traffic areas. Manual quick-coupler valves can be an important conservation element and should be installed near greens, tees, and bunkers so these can be hand-watered during severe droughts. Irrigation systems strive to provide uniform water distribution and to achieve distribution uniformity (DU)

Figure 10. Irrigation satellite station at Holmes Golf Course. Photo Credit: Casey Crittenden.

values near 80%. After installation, nozzles and irrigation head runtimes should be optimized to maintain uniform soil moisture distribution. That can be easily monitored with a soil moisture probe.

For precise irrigation control, courses should consider using advanced irrigation control systems that can schedule each green, tee, and fairway separately and allow course managers to make adjustments for differences in microclimates and root zones (Figure 10). Weather stations that calculate and automatically program water replacement schedules also provide opportunities for more precise irrigation, as do soil moisture sensors placed in multiple locations. Additional features may include rain stop safety switches that either shut down the system in the event of rain or adjust schedules based on the amount of precipitation.

3.4 Irrigation System Installation

To ensure maximum efficiency, the irrigation system must be installed per the design and specifications. The installer must ensure that there is qualified supervision of the installation process and that a qualified irrigation specialist inspects and approves the system installation.

Figure 11. Irrigation installation at Omaha Country Club. Photo Credit: Eric McPherson.

3.5 Irrigation System Maintenance and Performance

A properly working irrigation system is critical to insure optimum operation. System checks and routine maintenance should be done for pumps, valves, programs, fittings, and sprinklers. A schedule of inspections and a plan for record keeping should be completed. Use of photography is especially helpful in recording installations/repairs of underground systems (Figure 12). The publication 2014 Landscape Irrigation Best Management Practices can be consulted for devising a schedule and a plan for record keeping. To ensure that it is performing as intended, an irrigation system should be calibrated regularly by conducting periodic irrigation audits, such as catch-can tests and an annual irrigation audit, to check actual water delivery and nozzle efficiency. Nozzles can wear over time. This will change irrigation output and distribution. Nozzles should be replaced, depending on the manufacturer's recommendation, to ensure proper function.

Figure 12. Irrigation repair at Holmes. Photo Credit: Casey Crittenden.

While routine inspection and audits can be performed by the golf course superintendent, a professional irrigation consultant is required for a detailed irrigation audit, which should be conducted according to the Irrigation Audit Guidelines published by the Irrigation Association. Ideally, this professional audit should be conducted at least once every 5 years.

3.5.1 Seasonal Maintenance

Winterizing protects irrigation system pipes from damage due to water expanding and rupturing the pipe walls and fittings. Most Nebraska golf courses need to drain or used compressed air to remove water from lateral and mainlines pipes when temperatures drop below freezing. Many facilities operate an independent irrigation system below the "frost-line", allowing the facility to apply water during cold periods to dormant turf in an effort to prevent winter desiccation and winter kill, as described in the "Irrigation Scheduling" section of this chapter (Section 3.6.5).

3.6 Irrigation Management Decisions

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 -- not on a calendar-based schedule. Therefore, irrigation scheduling must consider soil infiltration and percolation rates as well as plant water requirements into account to prevent excess water use that could lead to leaching and runoff.

3.6.1 Soil Infiltration Rate and Plant Available Water

The rate of infiltration depends on soil textures. Sandy soils, with their higher porosity, have greater infiltration rates than silty or clay soils. Plant available water (PAW) represents the amount of water (expressed in inches) available per inch of soil depth that a plant can access for transpiration. A soil moisture probe indicates the total volumetric water content, which is greater than the PAW for a soil. The PAW can be estimated with a soil moisture meter by subtracting the current soil moisture content by the moisture content when the turf wilts. Plant available soil moisture and infiltration rates are provided in Table 3-1.

3.6.2 Root Zone Depth

The depth of effective turf rooting should be determined with a soil probe or spade. Golf greens and tees have the majority of roots in the top several inches of soil, while fairways and roughs will typically have deeper roots. Exact root depths depend on grass species and time of year. The soil infiltration rate and root zone depth should be used together to estimate the amount of water that needs to be available to the root system to avoid wilting. The rooting depth is multiplied by the PAW to estimate the total amount of water available to the turf.

Table 3-1. Available soil moisture and infiltration rates for common soil textures [1,2]

Soil Texture	Soil Type	Typical plant-available moisture per foot of soil depth (inches)	Infiltration rate (inches h^{-1})
Light, sandy	Coarse sand Fine sand	0.7 0.9	Fast (0.5 – 3)
Medium, loamy	Fine sandy loam Sil loam, loam	1.5 1.9	Moderate (0.25 – 0.5)
Heavy, clay	Clay loam, Silty clay loam Clay	2.1 2.0	Slow (0.1 – 0.25)

3.6.3 Evapotranspiration

Evapotranspiration (ET) describes the water lost through soil evaporation and plant transpiration and is influenced by the climatic conditions on any given day, in addition to day length and solar intensity. For example, hot, windy days with low relative humidity have higher rates of ET than cooler, calm days with low relative humidity.

Potential ET can be calculated and should be used to help determine irrigation needs. Sources of potential ET data include onsite weather stations and automated weather data network maps based on climate data produced daily by the High Plains Regional Climate Center.

3.6.4 Soil Moisture

Annual rainfall varies greatly in Nebraska, with averages from 13" in the panhandle to 36" in the southeast. Rainfall may even vary from location to location on a course. Therefore, the proper use of rain gauges, rain shut-off devices, soil moisture sensors, and other irrigation management devices should be incorporated into the site's irrigation schedule. Monitoring of soil moisture, in addition to calculating ET rates and visual observations of turf, assists in meeting turf water needs while conserving water resources (Figure 13).

Date	Rain	High Target	Low Target	2017 readings
A1 AM		20	15	21.6
A2 AM		20	15	20.9
A3 AM		20	15	21.8
A4 AM		20	15	21.2
A5 AM	0.25	20	15	20.3
A6 AM		20	15	18.9
A7 AM		20	15	19.2
T1 AM		19.75	14.75	19.4
T2 AM	0.12	19.25	14.25	23
T3 AM		18.75	13.75	16.8
T4 AM		18.25	13.25	16.3
T5 AM		17.75	12.75	15.8

Figure 13. Soil moisture readings. Photo Credit: Jim Nedrow.

[1] Source: Adapted from Emmons, R.D. 2000. Turfgrass science and management, 3rd ed. Delmar Publishers, Albany, NY and published in Drought Effects on Turf in the Landscape, UNL.
[2] Depth penetrated by 1" of water can vary depending upon a number of different soil factors. Therefore, this information is not included in the table.

3.6.5 Irrigation Scheduling


Figure 14. Hand watering at Country Club of Lincoln. Photo Credit: Russ Cellar.

Proper irrigation can sustain plant energy reserves, increase root mass and depth, and reduce thatch accumulation. Irrigation should be applied as necessary to prevent wilt without oversaturating the soil/root zone and without compromising playing conditions. Soils do not need to be wetted below the root zone depth, as this could potentially lead to leaching, especially in shallow soils.

The goal of successful irrigation management is to limit excessive soil moisture while preventing wilt. Golf managers strive to precisely apply water so plant-available water is only slightly greater than predicted ET (Figure 14). For many highly maintained turf areas, like greens, small amounts of water are applied every night to replace what was lost the prior day. Soil moisture probes can help further improve irrigation precision. These technologies can guide irrigation head run times and identify locations that might benefit from additional handwatering.

During periods of sufficient natural precipitation, stress pre-conditioning with deficit irrigation can improve tolerance to future drought, heat, and cold stress. Deficit irrigation is the practice of limiting irrigation to slowly deplete soil PAW until the soil moisture approaches wilt points. Examples of how this strategy can be utilized in Nebraska include the following:

- Western Nebraska: buffalograss health can be maintained at 40% to 50% ET and Kentucky bluegrass at 70% to 80% ET.
- Central Nebraska: 65% to 75% ET can maintain Kentucky bluegrass, tall fescue, and buffalograss.
- Eastern Nebraska: 60% to 70% ET can suffice to support Kentucky bluegrass, tall fescue and buffalograss.

Nebraska experiences harsh and cold winters coupled with strong wind velocities that may require the application of irrigation water during turf dormancy (Figure 15). During the summer, the crowns are 80-85% water by weight. After fall cold-acclimation, crown moisture values typically range from 50 to 60% water by weight. This dramatically increases the plants cold tolerance. When crown moisture values drop below 50% in winter, certain grass species, like creeping bentgrass, annual bluegrass, and perennial ryegrass, can suffer from desiccation stress. The lower the water weight, the greater the risk of plant death when temperatures drop well below freezing.

Figure 15. Handwatering at Pioneer Golf Course during the 2017/2018 winter to prevent dessication. Photo Credit: Casey Crittenden.

Turf growing on sandy soils and having excessive thatch are more likely to have issues with winter desiccation. Therefore, lightly irrigating high value turf on dry sunny days when the air temperatures are well above freezing is recommended to rehydrate plant crowns back to a survivable level and restore moisture at the surface. Other cultural practices such as sand topdressing, turfgrass covers, snow fences, and desiccants may also help prevent desiccation/winter injury.

Computerized systems provide many advantages, including allowing a superintendent to remotely cancel the program if the course has received adequate rainfall. Time clock-controlled irrigation systems preceded computer-controlled systems, and many are still in use today. Electric/mechanical time clocks cannot automatically adjust for changing ET rates. Therefore, frequent adjustment is necessary to compensate for the needs of individual turfgrass areas.

3.7 Drought Planning

Many of the BMPs discussed in this chapter result in more efficient water usage, such as improving the efficiency of irrigation systems and deficit irrigation. Turfgrass selection can also reduce irrigation requirements. The increased availability of improved turfgrass species and varieties provides an excellent opportunity to select the most well-adapted turf to site conditions, as discussed in the "Cultural Practices" chapter. If selected for drought tolerance, some turfgrass varieties require less water to survive and maintain playability. For example, buffalograss has a relatively deep root system, low ET rates, and the ability to tolerate and recover from drought.

Extended droughts can occur in Nebraska, and superintendents should be prepared for possible water use restrictions imposed by NRDs or public water suppliers. For example, Lincoln's Water Management Plan specifies three phases of water use restrictions that include restrictions on golf courses in Phases 2 and 3. A written drought management plan also provides a valuable tool for communicating conservation efforts with regulatory agencies and the general public.

3.8 Irrigation Best Management Practices

Irrigation Water Supply

- Identify appropriate water supply sources that meet seasonal and bulk water allocations for grow-in and routine maintenance needs.
- Use alternative water supplies/sources that are appropriate and sufficiently available to supplement water needs.
- Reclaimed, effluent, and other non-potable water supply mains must have a thorough cross-connection and backflow prevention device in place and operating correctly.
- Post signs in accordance with local utility and state requirements when reclaimed water is in use.
- Use salt-tolerant varieties of turf and plants to mitigate saline conditions resulting from an alternative water source, if necessary.
- Assess the irrigation water quality.
- Account for the nutrients in irrigation water when making fertilizer calculations.
- Monitor irrigation water regularly for dissolved salt content.
- Conduct a seasonal bulk water requirement analysis and a maximum bulk water requirement analysis.
- Design and/or maintain a system to meet a site's peak water requirements under normal conditions. Be flexible enough to adapt to various water demands and local restrictions.
- Install and maintain accurate metering systems.

Irrigation System Design

- Conduct a thorough site assessment prior to designing the irrigation system.
- Develop a written, site-specific Irrigation Management Plan.
- Seek assistance from irrigation professionals, such as from Certified Golf Course Irrigation System designers and WaterSense-certified irrigation consultants, and follow established BMPs related to system design.
- Sprinkler placement should avoid interfering with the playability of the hole.
- Irrigation pipes should be installed away from the green surface to avoid substantial increases in repairs and damages should pipe failures occur.
- Update multi-head control systems with single-head control systems to conserve water and to enhance efficiency.
- Manual quick-coupler valves should be installed for site specific irrigation so these can be hand-watered during severe droughts.

- Install part-circle heads along lakes, ponds, wetlands margins, native areas, and tree trunks.
- Use part-circle or adjustable heads to avoid overspray of impervious areas such as roadways, sidewalks, and parking areas.
- Incorporate multiple nozzle configurations to add flexibility and enhance efficiency/distribution.
- When possible, use precise irrigation control technologies.

Irrigation System Installation

- The designer must approve any design changes before construction.
- Prior to construction, all underground cables, pipes, and other obstacles must be identified and their locations flagged.
- Only qualified specialists should install the irrigation system.
- Construction and materials must meet existing standards and criteria.
- Construction must be consistent with the design.
- Installers must provide an accurate and comprehensive As-Built map.

Irrigation System Maintenance and Performance

- Visual inspections should be conducted to identify necessary repairs or corrective actions, which should be completed before further evaluation of system performance.
- Pressure and flow should be evaluated to determine that the correct nozzles are being used and that the heads are performing according to the manufacturer’s specifications.
- Pressure and flow rates should be checked (ideally annually) at each head to determine the average precipitation rates.
- Catch-can tests should be run to determine the uniformity of coverage and to accurately determine irrigation run times.
- Catch-can testing should be conducted on the entire golf course to ensure that the system is operating at its highest efficiency.
- Conduct an irrigation audit annually to facilitate a high-quality maintenance and scheduling program for the irrigation system.
- Inspect for water distribution interferences, such as trees and other obstructions.
- Inspect for broken and misaligned heads.
- Check that the rain sensor is present and functioning.
- Inspect the backflow device to determine that it is in place and in good repair.
- Examine turf quality and plant health for indications of irrigation malfunction or a need for scheduling adjustments.
- At least every five years, conduct a professional irrigation audit that follows established guidelines.
- Record any modifications to the As-Builts, including head and nozzle choices.
- Use photography to record and document any major underground installations/repairs.
- Flush and drain above-ground irrigation system components that could hold water as part of winter preparation.

- Remove water from all conveyances and supply and distribution devices that may freeze. Use compressed air or open the drain valves at the lowest point on the system.
- Change filters, screens, and housing; remove drain plugs and ensure any water is removed from the system. Secure systems and close and lock covers/compartment doors to protect the system from vandalism and from animals seeking refuge.
- Drain any above-ground pump casings that may have "trapped" water.
- Record metering data before closing the system.
- Secure or lock any remote irrigation components, including satellites.
- Perform pump and engine servicing/repair before winterizing.
- Recharge irrigation system in the spring with water and inspect for malfunctions.
- Review efficiency of above-ground electric motors annually.
- Licensed professionals should routinely inspect the well housing routinely inspect well housing.

Irrigation Management Decisions

- Evaluate root zone depth on the course and do not irrigate beyond this depth.
- Monitor potential ET and calculate plant available water to improve irrigation precision.
- Utilize soil moisture technologies and techniques consistently.
- Use soil moisture sensors to assist in scheduling or to create on-demand irrigation schedules.
- Use multiple soil moisture sensors to reflect soil moisture levels.
- Place soil moisture sensors in a representative location within the irrigation zone.
- Use predictive models to estimate soil moisture and the best time to irrigate.
- Use a journal to record the "indicator zones" that should be more closely monitored.
- Calibrate older clock-control station timing devices periodically, and at least seasonally.
- Install control devices to allow for maximum system scheduling flexibility.
- Base plant water needs should be determined by ET rates, recent rainfall, recent temperature extremes, and soil moisture.
- Avoid use of a global setting; make adjustments to watering times per head.
- Adjust irrigation run times based on current local meteorological data.
- Use a computed daily ET rate to adjust run times to meet the turf's moisture needs.
- Manually adjust automated ET data to reflect wet and dry areas on the course.
- Irrigation quantities should not exceed the available moisture storage in the root zone.
- Irrigation rates should not exceed the maximum ability of the soil to absorb and hold the water applied at any one time.
- Use infrequent, deep irrigation to supply sufficient water for plants and to encourage deep rooting in fairways and roughs.
- To maximize turf health during summer, irrigate to the depth of the turf root in early morning.
- Visually monitor for localized dry conditions or hot spots to identify poor irrigation efficiency or a failed system device.

- Irrigation schedule should coincide with other cultural practices (for example, the application of nutrients, herbicides, or other chemicals).
- Generally, granular fertilizer applications should receive 0.25" of irrigation to move the particles off the leaves while minimizing runoff.
- Proper cultural practices such as mowing height, irrigation frequency, and irrigation amounts should be employed to promote healthy, deep root development and reduce irrigation requirements.

Drought Planning

- Create a drought management plan for the facility that identifies steps to be taken to reduce irrigation/water use and to protect critical areas but that also recognizes the more susceptible and valuable course ares (e.g. greens).
- Adhere to water use restrictions in time of drought. Use appropriate turfgrass species adapted to the location of the golf course being managed and use drought-tolerant species whenever possible.

4 SURFACE WATER MANAGEMENT

Surface waters on golf courses encompass a wide range of natural and man-made water features. These features can be part of a stormwater management treatment system, such as retention basins and filter strips. They can also include previously existing wetlands or floodplains, as well as artificially created ponds.

The successful management of surface water incorporates BMPs to protect water quality from potential impacts from contaminants in runoff and sedimentation, particularly in areas with steeper slopes. These practices can often enhance habitat on the course, which has the added benefit of increasing aesthetic appeal.

4.1 Regulatory Considerations

4.1.1 Water Quality

The EPA administers the protection of streams and lakes under the CWA. At the same time, the NDEQ creates state-specific regulations and water quality standards based on federal recommendations.

The CWA requires states to prepare a list of impaired surface waters every other year. Impaired waters are those that do not meet the state water quality standards. From this list of impaired waters, states prepare Total Maximum Daily Loads (TMDLs) that include pollution control goals and strategies necessary to improve the quality of impaired waters and remove the identified impairments. TMDLs can include goals for nutrient loading (e.g. nitrogen or phosphorus). NDEQ provides a list of finalized TMDLs in the state.

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

4.1.2 Dams

NeDNR regulates the construction, operation, and maintenance of dams in Nebraska under the Safety of Dams and Reservoirs Act. Construction, reconstruction, enlargements, alterations, breaching, or removing dams or their abandonment must be approved by the department. The NeDNR's Dam Safety web page provides more information on the approval process.

Storage permits are required from NeDNR for dams with an impounding capacity of more than 15 acre-feet below the lowest open overflow or if the water in the reservoir will be pumped or released for a beneficial purpose. This falls under the regulatory authority of NeDNR and is administered under the Surface Water Section.

4.1.3 Surface Water Permits

NeDNR is the state agency authorized by Nebraska statute to regulate surface water quantity and quality. It is also responsible for the permitting of groundwater wells and any water transfers outside of the legal boundaries of the property owner. All diversions of surface water for irrigation, hydropower, industrial use, municipal use, domestic use, storage, and other uses require a state permit. Reporting requirements are identified in permits, and all reports should be submitted on time.

Limits may be placed on the issuance of new surface water permits, such as in river basins that have been declared fully or over appropriated. When a river basin or portion of a river basin is determined to be fully appropriated, the NeDNR and the affected NRDs must work cooperatively to develop an integrated management plan for that specific area. NeDNR provides groundwater monitoring and the development of modeling tools for studying surface water/groundwater interactions and impacts of water uses. The NRDs can develop integrated water management plans, including voluntary integrated water management plants, which may further limit surface water appropriations.

For more information, see the following:

- Find Your Natural Resources District.
- NeDNR Water Planning.
- UNL's Water Regulations & Policies page.

4.1.4 Aquatic Pesticides

Aquatic pesticides that control nuisance aquatic plants like Eurasian milfoil, as well as algaecides that control algae, are available from commercial distributors. They are regulated by NDA in the same way as any other pesticide and may require a NPDES general permit from NDEQ. (See also the "Pesticide Management" chapter of this document.) Some pesticides are listed as restricted use and must be purchased and applied by a licensed aquatic applicator certified in the aquatic category.

As with any pesticide application, the label must be followed. Labels on aquatic herbicides for algae control may specifically state that only a portion of the surface water area can be treated at a time to prevent massive algae and other plant die-offs and the low dissolved oxygen (DO) conditions that result from decaying organic matter.

For more information on registered pesticides, see:

- Database of all pesticides registered in Nebraska.
- Database of restricted-use pesticides in Nebraska.

4.1.5 Grass Carp

Though not prohibited in Nebraska, using grass carp (also known as white amur) for aquatic plant control is not recommended by Nebraska Game and Parks Commission. For more information on the disadvantages of stocking grass carp, see Resolving Common Maintenance Problems /Aquatic Vegetation, Nebraska Game and Parks Commission.

4.2 Water Quality Protection

Best practices related to protecting the water quality of surface waters center on preventing nutrients, chemicals, and sediments from reaching waterbodies and wetlands. By managing stormwater effectively, maintaining buffers, and considering the special needs of wetlands, floodplains, lakes, and ponds, superintendents can effectively protect Nebraska's water resources.

4.2.1 Stormwater Management

As discussed in the "Planning, Design, and Construction" chapter, golf course design should include features that manage stormwater by slowing it down and allowing contaminants to infiltrate into the soil without leaching past the root zone or be taken up by plants. Control structures, vegetative practices, and constructed wetlands can all be utilized to protect water quality. Each requires maintenance to perform efficiently.

Structural Controls

Structural controls are used on golf courses to detain and treat stormwater and therefore protect surface water quality. They reduce the level of contaminants, such as nutrients and pesticides, by inexpensive techniques such as settling, biological uptake of substances, and infiltration structures. Two commonly used structural controls are retention basins and infiltration devices. Periodic inspection and maintenance of all structural controls are essential to ensure they function as designed.

Dry retention basins (also called retention ponds) temporarily detain a portion of stormwater runoff for a specific length of time, releasing the stormwater slowly to reduce flooding and remove a limited amount of pollutants. These devices dry out between rain events. These basins are effective at reducing peak stormwater discharges, controlling floods and preventing downstream channel scouring. Planting wetland species in the bottoms of these basins achieves additional quality control through biological filtering and uptake.

Wet retention basins (also called wet ponds) are one of the most effective structural BMPs for protecting water quality. Wet ponds maintain a permanent pool of water in addition to temporarily detaining stormwater and releasing the excess stormwater slowly over a period of days. Wet ponds at the golf course use a permanent water surface to achieve a high removal rate for sediment, nutrients, and other contaminants. Aquatic plants and biochemical processes within the ponds enhance the removal of nutrients, metals, and other pollutants. Secondary benefits include aesthetics and creation of wildlife habitat.

Structures such as infiltration basins, infiltration trenches, and french drains treat stormwater by utilizing the infiltration process to remove pollutants and to recharge groundwater. These devises can remove pollutants very effectively through adsorption onto soil particles, as well as biological and chemical conversion in the soil. Infiltration basins with long retention times and grass bottoms enhance this pollutant removal process.

Vegetative Practices

Vegetation is an important part of the stormwater treatment train concept of stormwater management, often utilized before stormwater enters another treatment device, such as a wet, dry, or infiltration basin. Vegetation reduces stormwater flow velocity, allowing it to infiltrate into the soil and settle particulates, as well as to prevent erosion. Such use of vegetation occurs in filter strips, grassed swales, and riparian areas (Figure 16).

Figure 16. Vegetation around the irrigation pond at Heritage Hills Golf Course. Photo Credit: Bill Bieck.

Filter strips are typically bands of close-growing vegetation, such as turfgrass, planted between pollutant source areas and a receiving water. Filter strips can include shrubs or woody plants that help to stabilize the grass strip or can be composed entirely of trees and other natural vegetation. Filter strips function best when they are level in the direction of stormwater flow toward a surface water.

Grassed swales are earthen channels covered with a dense growth of a hardy grass such as tall fescue. Because swales have a limited capacity to convey runoff from large or intense storms, they often lead into other stormwater control structures. However, significant stormwater volume reductions can be created by placing check dams (small, sometimes temporary, dams constructed across a swale, drainage ditch, or waterway to counteract erosion by reducing water flow velocity) across the swale. A grass swale with check dams functions similarly to a series of retention basins.

Constructed Wetlands

Constructed wetlands are designed specifically for water treatment. They feature poorly drained soils and wetland plants. These wetlands efficiently remove certain pollutants (nitrogen, phosphorus, metals, sediment, and other suspended solids) and can treat wastewater (such as washwater) before the water enters streams, natural wetlands, or other surface waters. Once these areas are constructed, however, they are considered wetlands and require consultation with NDEQ to determine regulatory status.

4.2.2 Buffers

Buffers around the shore of surface waters, wetlands, or other sensitive areas filter runoff as it passes across the buffer. Buffers can be vegetated filter strips, such as those used as part of a stormwater treatment system. When used as a buffer along shorelines, stream banks, and wetland boundaries, filter strips are the last line of defense to keep sediment out of streams and to filter out fertilizers and pesticides that might otherwise reach waterways. Buffers also provide valuable food, cover, and travel corridors for some wildlife. Buffer widths as narrow as 15 feet have been shown to be effective in protecting water quality. Care needs to be taken when applying pesticides or fertilizers near or in buffer strips to prevent movement into the nearby surface water.

A riparian forest buffer is an area of trees and shrubs located adjacent to surface waters, including streams, lakes, ponds, and wetlands above the high water mark. Riparian forest buffers of sufficient width intercept sediment, nutrients, and pesticides in surface runoff and reduce nutrients and other contaminants in shallow subsurface water flow. Woody vegetation in buffers provides food and cover for wildlife, stabilizes stream banks, and slows out-of-bank flood flows.

4.3 Wetlands

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. With thoughtful design and management, many golf holes have successfully been threaded through sensitive areas. When incorporated into a golf course design, wetlands should be maintained as preserves and separated from managed turf areas by means of native vegetation, structural controls to protect water quality, and low/no maintenance activities to avoid nutrient or pesticide contamination (Figure 17).

Figure 17. Wetlands at The Players Club. Photo Credit: Steve Merkel.

4.4 Floodplains

During the design and construction phase, re-establishing natural water systems to the extent possible helps mitigate flooding. Structures that can be included in the design, such as retention basins, can store water and thereby reduce flooding and protect stream banks. Vegetated buffers and re-establishment of natural water systems help mitigate flooding and control stormwater. Therefore, high sediment and nutrient loads should be addressed, as should vertical and lateral stream migration, which causes unstable banks, flooding, and reductions in groundwater recharge. Land use decisions and engineering standards must be based on the latest research science.

4.5 Lakes and Ponds

The management of lakes and ponds should include a clear statement of goals and priorities to guide the development of the BMPs necessary to meet those goals. Some of the particular issues superintendents should address to maintain the water quality of golf course lakes and ponds include:

- Designing ponds.
- Low DO levels.
- Aquatic plant management.

- Near-shore management zones.

4.5.1 Pond Location and Design

Designing a new pond requires considerations such as the size of the drainage area, water supply, soil types, and water depth. In addition to potentially serving as an irrigation water source, ponds support aquatic life and the construction of ponds should consider the needs of aquatic ecosystems (such as discouraging excessive growth of aquatic vegetation, DO needs for aquatic species, etc.). Careful design may significantly reduce future operating expenses for pond and aquatic plant management.

4.5.2 Dissolved Oxygen

Dissolved oxygen is the amount of oxygen present in water and is measured in milligrams per liter (mg/L). Adequate DO levels are required to sustain life in aquatic organisms and vary by species, the organism's life stage, and water temperature.

The amount of DO that water can hold depends on the physical conditions of the body of water (water temperature, rate of flow, oxygen mixing, etc.) and photosynthetic activity. Colder water has higher DO levels than warmer water. Dissolved oxygen levels also differ by time of day and by season as water temperatures fluctuate. Similarly, a difference in DO levels may occur at different depths in deeper surface waters if the water stratifies into thermal layers. Fast-flowing streams hold more oxygen than impounded water. Lastly, photosynthetic activity also influences DO levels. As aquatic plants and algae photosynthesize during the day, they release oxygen. At night, photosynthesis slows down considerably or even stops, and algae and plants pull oxygen from the water. In impoundments with excessive plant and algae growth, several cloudy days in a row can increase the potential for fish kills due to low DO during warm weather. Therefore, preventing excessive aquatic growth helps to maintain DO levels. The use of artificial aeration (diffusers) can also be used to maintain adequate DO, especially in small impoundments or ponds.

4.5.3 Aquatic Plants

Aquatic plants include algae and vascular plants. Phytoplankton, or algae, give water its green appearance and provide the base for the food chain in ponds. Tiny animals called zooplankton use phytoplankton as a food source. Large aquatic plants (aquatic macrophytes) can grow rooted to the bottom and supported by the water (submersed plants), rooted to the bottom or shoreline and extended above the water surface (emerged 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).

Aquatic plants are part of aquatic ecosystems. They provide a number of benefits, such as:

- Habitat for aquatic organisms (e.g. food and nesting sites).

- Oxygenation.
- Shoreline stabilization.
- Aesthetic appeal.

Aquatic plants growing on a littoral shelf may help protect receiving waters from the pollutants present in surface water runoff. Ideally, littoral zones should have a slope of about 1 foot vertical to 6-10 foot horizontal to provide the best substrate for aquatic plant growth. In open areas, floating-leaved and free-floating plants suppress phytoplankton because they absorb nutrients from the pond water and create shade.

Particularly in shallow or nutrient-enriched ponds, aquatic plant growth can become excessive. Non-native plants, in particular, can aggressively colonize aquatic environments. The excessive growth of any aquatic plant requires management. Following the principles laid out in the "Integrated Pest Management" chapter of this document, a number of controls should be considered to deal with excessive aquatic plant growth, including:

- Prevention, such as reducing nutrient enrichment and avoiding the introduction of invasive species.
- Cultural practices, such as benthic barriers to prevent vascular plant growth.
- Mechanical removal.
- Chemical control.

Although grass carp are a biological control sometimes used to control aquatic plants, the use of this exotic species is not recommended, as discussed in the Regulatory Considerations section earlier in this chapter.

For more on pond management in Nebraska, see the following:

- Nebraska Pond Management Guide. Nebraska Game and Parks Commission.
- Resolving Common Maintenance Problems / Aquatic Vegetation. Nebraska Game and Parks Commission
- Aquatic Invasive Species page. Nebraska Game and Parks Commission.
- Noxious Weed Program web page. Nebraska Department of Agriculture (NDA).
- Lakes, Ponds, and Streams web page. UNL.

4.5.4 Shoreline Management

Special management zones should be established around the edges of lakes and ponds. The management specifications should include a setback distance when applying fertilizers, as well as reduced mowing. Grass clippings should be collected, as the phosphorus and nitrogen in clippings can impact the water quality.

4.5.5 Waterfowl

The deposits of fecal matter by resident and migrating waterfowl (such as Canada geese) can substantially impact water quality through nutrient enrichment. On golf courses, shallow ponds with significant populations of waterfowl are most likely to be affected. In addition, large numbers of Canada geese can erode shorelines and thin the grass cover on greens and fairways, contributing to the potential for erosion. Efforts to control waterfowl have met with mixed success. Loud sounds, dogs, and hunting have been tried in order to deter them. However, many of these efforts do not lend themselves to golf courses, especially in more urban areas. For more information, see Managing Canada Geese, UNL Extension.

4.6 Surface Water Management Best Management Practices

Water Quality Protection

- ❖ Conduct an initial evaluation of the rate of dewatering after large storms and the depth of sediment buildup for each structure.
- ❖ Maintain an inspection log for each control structure.
- ❖ Monitor each control structure regularly, at least once per year.
- ❖ Remove sediment buildup, clean inlets, and mow as needed to maintain performance of structural controls.
- ❖ Inspect filter strips annually and examine for damage from foot or vehicle traffic, encroachment, gully erosion, or evidence of concentrated flows through or around the strip.
- ❖ Install vegetated swales and slight berms around water edges, including retention basins, to slow water and allow for infiltration.
- ❖ Maintain dense grass cover on grassed swales by mowing, spot-seeding, controlling weeds, and watering as needed.
- ❖ Regularly remove any excessive sediment buildup behind check dams on grassed swales.
- ❖ Separate constructed wetlands from managed turf areas with native vegetation or structural buffers.
- ❖ Use turf and native plantings to enhance buffer areas; increase the height of cut if mowing in buffer areas.
- ❖ Riparian buffers should be unfertilized and left in a natural state.

Wetlands

- ❖ Establish and maintain an appropriately sized buffer around wetlands, springs, and spring runs.
- ❖ Maintain appropriate erosion and sedimentation controls on projects upstream to prevent sedimentation and nutrient enrichment of wetlands.

Floodplains

- ❖ Install retention basins to store water and reduce flooding at peak flows.

- Install stream buffers to restore natural water flows and flooding controls.

Lakes and Ponds

- Select an appropriate site to allow for adequate water levels to be maintained, including in times of drought.
- Constructing a pond on a perennial (always flowing) stream should be avoided.
- Peninsular projections and long, narrow fingers into ponds may prevent water mixing. Ponds that are too shallow may promote algal growth, excess sedimentation, and exhibit high temperatures and low DO levels.
- Follow construction BMPs and ensure erosion and sediment control devices are in place prior to disturbing earth for pond construction and inspect regularly.
- Consult with a professional engineer when constructing a dam.
- Establish minimum DO thresholds to prevent fish kills, which occur at levels of 2-3 mg/L.
- Reduce stress on fish by keeping DO levels at 5-10 mg/L.
- Use artificial aeration (diffusers) if needed to maintain adequate DO, especially those less than 6 feet in depth, and especially at night during the warmer months.
- Keep phosphorus rich material (e.g. natural or synthetic fertilizers, organic tissues like grass clippings, or unprotected topsoil) from entering surface water.
- Install desirable native plants to naturally buffer DO loss and fluctuation.
- Develop a comprehensive management plan that includes strategies to prevent and control the growth of nuisance aquatic vegetation.
- To control excessive aquatic plant growth, use an IPM approach that incorporates prevention, cultural practices, and mechanical removal methods in addition to chemical control.
- To reduce the risk of DO depletion, use an algaecide containing hydrogen peroxide instead of one with copper or endothall.
- Dredge or remove sediment as needed to improve aquatic habitat.
- Establish special management zones around lake and pond edges.
- Reduce the frequency of mowing near shorelines. Collect clippings or direct them to upland areas.
- All or most of the out-of-play waterbodies should have shoreline buffers planted with native or well-adapted non-invasive vegetation to provide food and shelter for wildlife and to reduce sediment and nutrients in runoff.
- Maintain the required setback distance when applying fertilizers near waterbodies.
- 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.
- Reverse-grade around the waterbody perimeters to control surface water runoff and to reduce nutrient loads.
- Discourage large numbers of waterfowl from colonizing golf course waterbodies.
- Use a multi-faceted, IPM approach to control nuisance animals.

5 GROUNDWATER PROTECTION

Nebraska has abundant groundwater resources. The High Plains Aquifer is centered in Nebraska and covers much of the state. Other important aquifers include the Paleovalley, Dakota, and Niobrara aquifers. For general information on aquifers, see the UNL web page Groundwater System.

Because groundwater is so plentiful, most of the state's citizens use groundwater as drinking water. However, in some parts of the state groundwater is contaminated, primarily with nitrates, other nutrients, and agricultural chemicals (such as pesticides). In addition, groundwater levels have declined in some areas of the state, though this has not occurred throughout the state. For more information on groundwater levels, see the UNL School of Natural Resources' maps of groundwater-level changes in Nebraska. Because groundwater is the primary source of drinking water in the state, preventing leaching, protecting wellheads, and conserving water are important aspects of golf course management in Nebraska.

5.1 Regulatory Considerations

State and regional agencies regulate and manage groundwater. Title 196 - Rules and Regulations Pertaining to Ground Water Management Areas (GWMA) governs NDEQ's nonpoint source ground water management program. Title 118 - Ground Water Quality Standards and Use Classification gives NDEQ the authority to require responsible parties to clean up point sources, such as underground or above ground storage tank leaks or spills, chemical spills, or other contaminants that don't have another program to address point source contamination. NDEQ is required to issue an annual report to the Legislature concerning the quality of the groundwater in Nebraska. NDEQ also houses the State Wellhead Protection program, a voluntary program to protect water supplies through assistance to communities and other public water suppliers.). NDEQ also regulates the installation of septic tanks or on-site waste water lagoons (Title 124)

The NRDs get their authority for their ground water management activities from the Ground Water Management and Protection Act. Each NRD in the state enacts rules, regulations, and programs to protect groundwater. Specifically, NRD authority includes the ability to allocate groundwater, require flow meters, institute well drilling moratoriums, require water use reports and restrict groundwater withdrawals for irrigation. As described on the NRD website, "Individual NRDs use these regulations in different combinations and to different degrees depending on their respective geographic areas of concern." Maps of all 23 NRDS and how they are currently implementing their regulations with respect to groundwater quality and quantity are available on the internet and should be reviewed by superintendents.

The NeDNR requires registration of new wells, notices of change of ownership or contact updates, and notices of well decommissions or modifications.

The Nebraska Department of Health and Human Services (NHHS) requires wells to be drilled or decommissioned by licensed well drillers (Title 178). NHHS regulates water well siting and construction for public drinking water supply (Title 179).

5.2 Preventing Leaching

Leaching refers to the loss of water-soluble plant nutrients or chemicals from the soil as water moves through the soil profile and reaches the saturated zone. Some of the factors that can influence leaching potential include the depth to groundwater, soil type and structure, geology, rate of precipitation, and amount of irrigation. Leaching potential across the state, as described as recharge rate, is published by UNL on the Nebraska Water Map. The Applicator's Map and Guide to Prevent Groundwater Contamination also shows leaching potential in Nebraska. The NDA publishes county guides -- on paper or in PDF format -- that show leaching potential for all Nebraska counties. County guides are currently available on the NDA website for Sioux County, Platte County, and Pierce County; all the guides are available upon request by calling NDA at 402-471-2351.

Especially in areas with high recharge rates, irrigation should only be sufficient to reach the root depth. More information on making irrigation decisions can be found in the "Irrigation" chapter of this document. When applying fertilizers or pesticides, the rate, timing, and location of applications should be considered to minimize the potential for losses due to leaching. Sandy soils, for example, have a low potential to fix phosphorus and therefore are more likely to leach phosphorus. Nitrogen, in the form of nitrate (NO_3-N) presents leaching concerns for groundwater quality. Fertilizers with solubility > 30 mg/L (or 30 ppm) can pose a risk for leaching. UNL publishes leaching potential in the *Guide to Weed Management* (updated regularly; the latest version available for sale from the UNL Extension Publication page).

5.3 Protecting Water Supplies

Figure 18. New well installation at Pioneers Golf Course. Photo Credit: Casey Crittenden.

Establishing protection zones and safe land-use practices around water supply wells protects aquifers from accidental contamination. Protecting wellheads from physical impacts and contaminants, keeping them secure, and sampling wells according to the monitoring schedule required by the regulating authority are all best practices for ensuring drinking water is adequately protected.

Before installing new wells, the appropriate NRD should be contacted to determine the permitting and any setback requirements. New wells should be located up-gradient as far as possible from potential pollutant sources, such as petroleum storage tanks, septic tanks, chemical mixing areas, and fertilizer storage facilities. Most pesticide labels now prohibit mixing/loading pesticides within 50 feet (or other specified setback distance) from any well. Licensed water-well contractors are needed to drill new wells, which must meet regulatory and code requirements.

5.4 Groundwater Protection Best Management Practices

Preventing Leaching

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

Wellhead Protection

- ❖ Use backflow-prevention devices at the wellhead, on hoses, and at the pesticide mix/load station to prevent contamination of water sources.
- ❖ Follow pesticide labels for set back distance requirements (typically a minimum of 50 feet).
- ❖ Properly decommission illegal, abandoned, or flowing wells.
- ❖ Surround new wells with bollards or a physical barrier to prevent impacts to the wellhead.
- ❖ Inspect wellheads and the well casing routinely for leaks or cracks; make repairs as needed.
- ❖ Maintain records of new well construction and modifications to existing wells.
- ❖ Obtain a copy of the well log for each well to determine the local geology and the well's depth; these factors will have a bearing on how vulnerable the well is to contamination.
- ❖ Develop a written Wellhead Protection Plan that minimizes environmental risk and potential contamination.

6 WATER QUALITY MONITORING

Aligning golf course management practices with BMPs protects water quality on and downstream from the facility. A water quality monitoring program can confirm the effectiveness of a BMP-based program and provide important feedback on areas needing improvement.

Golf course superintendents seeking to develop and implement a monitoring program to document water quality conditions should first review available baseline water quality data. Baseline data can be assessed to determine the likely origin of contaminants, measure the extent of sedimentation and nutrient inputs, and estimate the potential impacts to surface water and groundwater. Following implementation of BMPs, routine monitoring can be used to measure water quality improvements and identify any areas where corrective actions should be taken.

Water quality monitoring on golf courses is voluntary. However, monitoring results demonstrate a commitment to water quality and implementing BMPs that protect water resources downstream. Furthermore, providing monitoring information to local, regional, and state regulatory authorities and watershed groups can help foster positive relationships with these stakeholders.

6.1 Regulatory Considerations

Surface water quality is regulated under the CWA. NDEQ is the state's lead agency with regulatory authority for surface and groundwater quality. Surface water monitoring on golf courses is not a regulatory requirement, but it does demonstrate to regulators and the interested public the role of golf course superintendents can adopt in protecting the state's natural resources. The results of any monitoring programs should be compared with Title 117, Nebraska Surface Water Quality Standards.

6.2 Existing Water Quality Information

Several sources of existing surface water and groundwater monitoring data may be available that can prompt a course-based water quality monitoring program. These potential data sources include:

- Nebraska's Natural Resource Districts.
- NDEQ's Surface Water Monitoring and Assessment and Groundwater Assessment Programs web pages, which offer water quality reports and other information.
- NeDNR's Groundwater Data page.
- U.S. Geological Survey's Water-Quality Data for Nebraska page, which offers results of surface water and groundwater monitoring collected from 50 locations across the state.
- Quality Assessed Agrichemical Contaminant Database for Nebraska Groundwater

6.3 Developing a Water Quality Monitoring Program

A water quality program begins with the development of a monitoring plan. The plan should identify specific conditions such as the presence of a watershed, stream flows, soil type, topography, drainage, and vegetation. In addition, the plan needs to document the hydrologic conditions and drainage, monitoring objectives, monitoring locations and frequency, and monitoring parameters. Baseline reference conditions can be established by collecting upstream water samples and comparing them with collection sites downstream of the areas influenced by golf course management practices.

Surface water collection sites can include streams, rivers, ponds, wetlands, etc., with the number and location of collection sites dependent upon the monitoring objectives. For example, a simple monitoring program can consist of the collection of DO data in surface waterbodies to ensure that these waterbodies can support aquatic life. Regardless of the extent of the monitoring program, the location of monitoring sites should remain consistent over time to establish trends in data. A more comprehensive monitoring program should include both field measurements at the time of sampling and analytical testing. Field measurements include pH, temperature, specific conductance, and DO. Lab testing should be conducted by a certified laboratory. Typical testing parameters include nutrients (such as nitrates and phosphorus), total dissolved solids (TDS), alkalinity, sediments, and selected pesticides used on the course. For more information on surface water monitoring programs, sampling procedures, and parameters specific to golf turf, the Environmental Stewardship Guidelines for Oregon courses can provide detailed guidance.

Developing a water quality monitoring program on golf courses is often limited to surface water monitoring. Sampling of stream macrobenthic invertebrates is a useful addition to a monitoring program, as macrobenthic species composition and diversity can be used as a relative assessment tool for stream health. For more information on macrobenthic invertebrate sampling, see New Mexico State University's Stream Biomonitoring Using Macrobenthic Invertebrates. Such sampling can often be undertaken by university students in fulfillment of course work or by watershed association volunteer groups.

In some instances, groundwater monitoring may be desired. Groundwater monitoring from wells located at the hydrologic entrance and exit from the course may be the best way to evaluate a golf course’s impact on water quality. If groundwater monitoring data from these locations are not available from existing sources, monitoring wells at the hydrologic entrance and exit from the course can be installed by private companies, though this can be relatively expensive and requires sample collection by a Department of Health and Human Services-certified NRD employee. Groundwater quality parameters can be limited to test only the ones directly influenced by course management, such as levels of pesticides and organic and inorganic nitrogen.

Water quality monitoring of irrigation sources (particularly water supply wells and storage lakes) provides valuable agronomic information that can influence nutrient programs. Immunoassay analysis may be possible and a cost effective method for monitoring, depending on the analytical goals and the number of samples. To save money, several golf courses could pool resources and share immunoassay analyzer equipment and kits. Several NRDs also have this equipment and may be able to share their resources. See the “Irrigation” chapter of this document for more information on irrigation water quality issues.

6.4 Interpreting Water Quality Testing Results

Interpretation and use of water quality monitoring data depends to a large extent on the goal of the monitoring program. For example, the results may be analyzed to compare:

- Values over time.
- Values following implementation of BMPs, such as IPM measures.
- Monitoring points entering the site and leaving the site.

Results should also be interpreted and compared with the Nebraska Surface Water Quality Standards and groundwater standards (Title 118), if water quality standards have been established for the parameter being evaluated.. In addition, the NDA publishes a "Pesticides of Interest" summary that includes references to EPA web pages for both human health and aquatic life "benchmarks" for approximately 70 active ingredients in pesticides. These benchmarks aren't enforceable standards, but are developed by EPA to serve as screening levels in their assessments, as well as for states and others to use for comparing water quality results.

Data analysis can also be used to identify issues that may need corrective action, based on findings such as a spike in nutrient levels. For example, operator error in nutrient applications, an extreme weather event, or some combination of factors may be responsible. Water quality problems can often be addressed by simple changes to a course’s existing nutrient management program.

6.5 Water Quality Monitoring Best Management Practices

Developing a Water Quality Monitoring Program

- ❖ Review existing sources of groundwater and surface water quality information.
- ❖ Develop a water quality monitoring program.
- ❖ Establish baseline quality levels for water.
- ❖ Identify appropriate sampling locations and sample at the same locations in the future.
- ❖ Visually monitor/assess any specific changes of surface waterbodies.
- ❖ Follow recommended sample collection and analytical procedures.
- ❖ Conduct seasonal water quality sampling. The recommendation is four times per year.

Interpreting Water Quality Testing Results

- ❖ Compare water quality monitoring results to benchmark quality standards.
- ❖ Use corrective measures when necessary.

7 NUTRIENT MANAGEMENT

Proper nutrient management plays a key role in the reduction of environmental risk and also increases course profitability. Among other benefits, applied nutrients increase the available pool of nutrients and allow turfgrass to recover from damage, increase its resistance to stress, and increase its playability. However, the increase in available nutrients also increases the potential risk of environmental impact. Nutrients may move beyond the turfgrass via leaching or runoff, which may directly impact water quality. Other organisms also respond to increases in nutrients and, in some cases, these organisms may deleteriously alter our ecosystem. The goal of a proper nutrient management plan should be to apply the minimum necessary nutrients to achieve an acceptable playing surface and apply these nutrients in a manner that maximizes their plant uptake.

7.1 Fertilizers Used in Golf Course Management

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

7.1.1 Terminology

Grade or analysis is the percent by weight of nitrogen (N), phosphorous (P) and potassium (K) that is guaranteed to be in the fertilizer at minimum. Bagged fertilizers are regulated by enforcement of the grade standards stipulated by the Nebraska Commercial Fertilizer and Soil Conditioner Act. Complete fertilizers contain N, P, and K.

7.1.2 Label

The label is intended to inform the user about the contents of the fertilizer. When applied according to the label, the use of fertilizer presents little to no environmental risk. In Nebraska, fertilizer labels must be registered with the NDA and contain the following information:

- Manufacturer’s name and address.
- Brand name.
- Website.
- Nutrient guarantee (i.e. guaranteed minimum amounts of nutrients, given as a ratio).

Additional information that may be found on the label include characteristics such as size guide number (SGN), water- insoluble nitrogen (WIN), water-soluble nitrogen (WSN), and release characteristics.

7.1.3 Macronutrients

Macronutrients are required in the greatest quantities and are most likely to be deficient in agronomic soils are N, P, and K. Secondary macronutrients (calcium, magnesium, and sulfur) are also taken up in relatively high quantities but are rarely deficient in turf soils. Understanding the role of each macronutrient within the plant provides a greater understanding of why these nutrients play such a key role in proper turfgrass management.

The Role of N

Nitrogen is required by the plant in greater quantities than any other element except carbon, hydrogen, and oxygen. Nitrogen plays a role in numerous plant functions and is 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 below, in addition to the fate and transport mechanisms of runoff and leaching, leads to sound decision making and ultimately leads to an increase in course profitability and a reduction in environmental risk. These nitrogen processes are:

- *Mineralization*: the microbial mediated conversion of organic N into plant-available NH_4.
- *Nitrification*: the microbial-mediated conversion of NH_4 to NO_3.
- *Denitrification*: the microbial mediated conversion of NO_3 to N gas; this primarily occurs in low-oxygen environments and is enhanced by high soil pH.
- *Volatilization*: the conversion of NH_4 to NH_3 gas.

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

Soluble Nitrogen Sources

Soluble N sources include:

- Urea (46-0-0).
- Ammonium nitrate (34-0-0).
- Ammonium sulfate (21-0-0).

- Diammonium phosphate (18-46-0).
- Monoammonium phosphate (11-52-0).
- Calcium nitrate (15.5-0-0).
- Potassium nitrate (13-0-44).

Slow-release Nitrogen Sources

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

- Coated urea (sulfur, polymer, or both).
- Urea-formaldehyde/ureaformaldehyde reaction products (methylene urea).
- Isobutylidene diurea (IBDU).
- Natural organic compost (plant material or animal manure and biosolids).

Urease and Nitrification Inhibitors

Urease inhibitors reduce the activity of the urease enzyme resulting in a reduction of volatilization and an increase in plant-available N. Nitrification inhibitors reduce the activity of *Nitrosomonas* bacteria, which converts NH_4 to NO_2. This reduced activity results in a reduction of N lost via denitrification and an increase in plant-available N. These compounds are best applied to turfgrass sites that are not irrigated.

The Role of Phosphorous

Phosphorus forms high-energy compounds that are used to transfer energy within the plant. Phosphorus may remain in an inorganic form or may become incorporated into organic compounds.

Phosphorus can be a growth-limiting factor for many unintended organisms and is a major contributor to eutrophication of waterbodies. Therefore, the goal of P fertilization is to supply enough to sustain healthy turfgrass growth yet minimize environmental risk. Phosphorous application rates should be based on soil test results. Fortunately, phosphorus binds tightly to native soils and organic matter. The most important way to limit phosphorus movement off-site is to maintain dense and healthy vegetation.

P Fertilizer Sources

Phosphorus sources include:

- Diammonium phosphate.
- Concentrated superphosphate.
- Monoammonium phosphate.
- Potassium phosphate.
- Natural organics.

The Role of Potassium

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

Potassium Fertilizer Sources

Potassium fertilizer sources include:

- Potassium chloride.
- Potassium nitrate.
- Potassium phosphate.
- Potassium sulfate.

7.1.4 Secondary Macronutrients

Fertilization with secondary macronutrients is rarely justified in a turfgrass systems. Calcium (Ca), magnesium (Mg), and sulfur (S) are essential to plant function, but fibrous turfgrass root systems and Nebraska soils typically satisfy demand for these nutrients. Soil test interpretations for these nutrients are unsubstantiated in turf because nutrient deficiencies for these nutrients are exceedingly rare. Nutrient deficiencies for these nutrients have only been created in hydroponic culture (no soil). Therefore, suspected secondary nutrient deficiencies should be confirmed with tissue tests. Also confirm suspected deficiencies with small-test applications of fertilizer. If there is not a turfgrass response, then a widespread nutrient application is not warranted. Secondary nutrient sources can be found in Table 7-1.

Table 7-1. Secondary macronutrients

Nutrient	Role	Sources
Calcium	Primarily a component of cells walls and structure.	Gypsum Limestone Calcium chloride
Magnesium	Central ion in the chlorophyll molecule and chlorophyll synthesis.	S-Po-Mg Dolomitic limestone Magnesium sulfate
Sulfur	Metabolized into the amino acid cysteine, which is used in various proteins and enzymes.	Ammonium sulfate Elemental sulfur Gypsum Potassium sulfate

7.1.5 Micronutrients

Micronutrients are just as essential for proper turfgrass health as macronutrients but are required in very small quantities compared with macronutrients. Micronutrients include iron (Fe), manganese (Mn), boron, copper, zinc, molybdenum, and chlorine. They play a variety of roles in turf biology, including roles in photosynthesis, nitrogen fixation, protein synthesis, etc. Micronutrient deficiencies can be confirmed by tissue testing or small fertilizer applications to turf to verify fertilizer response. Soil testing for micronutrients is not recommended and soil interpretations for these nutrients can be ignored.

Iron and manganese deficiency symptoms can be common in bluegrasses and bentgrass during summer. Deficiency symptoms include yellow colored (chlorotic) turf that does not respond to nitrogen fertilization. In many instances, nitrogen fertilization will intensify the chlorosis. The chlorosis is most severe when soils are warm, wet, and have high pH (>7.3). It is believed that root function is lost under these conditions. As a result, foliar iron and manganese applications will effectively correct the deficiency. Deficiency symptoms subside as the soil cools into the fall.

7.2 Soil pH

Soil pH influences nutrient availability and microbial communities. Unlike some pH-sensitive plant species, turfgrasses are largely pH-independent. The dense and fibrous root system of turfgrasses allow turf plants to thrive across a broad pH range. Soil pH ranging from 5.5 to 8.0 provides acceptable nutrient availability for most turf stands.

Application of lime following soil test recommendations may be recommended if soil pH is less than 5.5 to optimize nutrient availability and reduce the risk of aluminum toxicity. Lowering pH is rarely successful in Nebraska because many of our soils are highly buffered with calcium carbonate (limestone) parent material. This is typically true if the soil pH is >7.3. Note that sensitive species may benefit from iron and manganese fertilizer during the summer in these high pH soils.

7.3 Soil Testing

Soil tests estimate nutrient availability and predict a plant's response to an applied nutrient. Accurate and consistent sampling and analysis provides useful soil test information over time. Soil test sampling and analytical testing recommendations are published in the NebGuide Simplifying Soil Test Interpretations for Turf Professionals and includes the following:

- Soil Sampling: 4-6" depth from representative areas of similar management.
- Soil Testing Lab: Exclusively use one trusted soil testing laboratory.
- Soil Testing Method: Mehlich-3 pH independent method.

Soil testing is best to provide guidance for soil pH, organic matter content, plant available phosphorus and potassium, and salinity and soil sodicity. Soil tests results and interpretations are provided in Table 7-2. Soil test result recommendations for other nutrients are not supported by turf science and should be ignored. The best way to utilize soil testing is to monitor changes in the above nutrients over time. Declining soil test phosphorus and potassium, for example, indicates that fertilization with P_2O_5 and K_2O should be increased relative to nitrogen fertilization rate, unless the values for those nutrients are deemed to be high. Nitrogen fertilizer drives uptake of all other nutrients in turf. Therefore, P_2O_5 and K_2O should be looked at relative to N fertilization rate and not just the total amount applied. More information on N-driven nutrient demand can be found in the Turf Fact Sheet What's the Ideal Fertilizer Ratio for Turfgrass? UNL.

7.4 Nutrient Management Planning

Fertilizer programs are ultimately designed to supply nutrients to the turf as they become unavailable with time and space. For example, nutrients can leave a turf system through soil and water runoff, nutrient leaching, volatilization, and mowing. Nutrients can also be temporally removed from a system through processes of nutrient fixation and immobilization. Nitrogen is particularly difficult to manage because it can be quickly immobilized and then mineralized depending on a soil's physical, chemical, and biological properties.

The goal of a successful nutrient management program should be to sustain even levels of plant available nutrients for a uniform growth rate and sustain adequate recuperative potential to meet expectations of quality and turf performance, while minimizing excessive growth and the risk of nutrient loss to the environment.

7.4.1 Nitrogen Fertilization

Nitrogen is the most important nutrient managed by golf course superintendents. Nitrogen fertilizer drives turf growth rate. During the growing season, slow growth is an indication of low soil nitrogen status. Additional N fertilizer may be required in this instance. Alternatively, excessive amounts of growth typically indicate there is large pool of available N. That fertilizer may have come from fertilizer application or organic N mineralization within the soil. Additional N fertilizer is not required in this instance.

Table 7-2. Soil test results and recommendations

Soil Test Result	Desired Value	Soil Test Result	Annual Fertilizer Recommendation
Soil pH	5.5-8.0[c]	Less than 5.5	Consider lime application
		6.0-8.0	No remediation required
		Greater than 8.0	Consider use of acidifying fertilizer; potential micronutrient limitation
Soil organic matter (SOM)	No recommended range	Much greater than previous year	Reduce inputs (nitrogen and water) Increase cultivation and topdressing
		Slightly greater or same as previous year	Some increase is normal in new turf stands / continue good management.
		Much less than previous years	Likely the result of aggressive cultivation and/or reduced inputs
Phosphorus (P)	25-50 ppm[a]	Less than 25	>0.25 lbs. P_2O_5 per lb. N applied [b]
		25-50	0.25 lbs. P_2O_5 per lb. N applied [b]
		Greater than 50	No P fertilizer required
Potassium (K)	40-80 ppm[a]	Less than 40 ppm	>1 lb. K_2O per lb. N applied [b]
		40-80 ppm	0.75 to 1 lb. K_2O per lb. N applied [b]
		Greater than 80 ppm	No K_2O required
Salinity	< 3 dS/m[c]	Less than 1.5 dS/m	Low salinity risk
		1.5 to 3.0 dS/m	Bluegrasses sensitive, leach soil
		Greater than 3.0 dS/m	Most turfgrasses sensitive, leach soil
Sodicity (native soils only)	< 5% ESP	Less than 5% ESP	Low sodium risk in fine-texture soil
		5-15% ESP	Consider gypsum treatment to improve permeability of native soils
		Greater than 15%	Sodic soil, treat native soils with gypsum
All other nutrients (Ca, Mg, S, N, Fe, etc.)	No reliable, science-based soil test interpretations	Confirm deficiency with tissue testing or small applications to turf to verify fertilizer response	All other nutrients (Ca, Mg, S, N, Fe, etc.)

[a] Mehlich-3 soil test method.

[b] Demand for P and K fertilizer is affected by N fertilizer, soil type/environment, and clipping management. For example, turf on a native soil, clippings removed, and fertilized annually with 4 lbs of N/1,000 ft^2 would need about 1 lb of phosphorus (P_2O_5) and 3 lbs of potassium (K_2O)/1000 ft^2 to sustain soil test levels. Returning clippings reduces those P and K requirements by 50%. These ratios are good starting values and may need to be adjusted to sustain soil test P and K levels at any particular location. More information can be found in What's the Ideal Fertilizer Ratio for Turfgrass?, UNL.

[c] Saturated soil paste extract method.

Research on a Kentucky bluegrass lawn showed that only one of the three pounds of N taken up during a year came from synthetic fertilizer. The remainder came from the soil or clippings.

Soil N mineralization is typically greatest right after winter (during spring green-up) and when the soil is warm and wet during mid-summer. During these periods, turfgrass growth rate is accelerated and N fertilization should be avoided. Soils with high levels of organic matter generally have more mineralization than newer turf stands with less organic matter. As a result, N fertilizer requirements will be higher in new turf stands than well-established turf stands. Those requirements will decline as the turf stand ages. The exact time depends on many management, use, and soil factors.

Optimum N fertilization times occur when soil nitrogen mineralization is low. This typically occurs in late May and into June and then from September into October, across Nebraska. While mineralization is low in late fall and during winter, plant uptake is also diminished as it starts to gain cold-hardiness into and through winter. Nitrogen fertilizer should not be applied after late-October, because uptake is low and loss to the environmental is greatest. Winter has been shown to be the period of greatest nitrogen loss from leaching and runoff when the soil it frozen.

Monitor turfgrass performance, including color, growth rate, and traffic recovery to help schedule N application timings. Best cool-season turf application times are in late spring and early fall, following traditional spring and summer growth flushes. Cool-season turf stands can benefit from summer fertilizer application if mineralization is low and turf is underperforming. Warm season turf should be fertilized after green-up and again in mid to late summer. Late summer applications can help sustain green color of warm-season grasses into the fall.

7.4.2 Nitrogen Application Rates

Turfgrass is extremely responsive to N fertilizer. Highly maintained turf areas (greens and tees) are traditionally fertilized by “spoon-feeding” small amounts of N frequently. This approach has several advantages. First, the small quantity of N (typically sprayed on the turf) presents a smaller risk for a large leaching or other loss event. Light and frequent applications also increase control because managers can vary fertilizer rates and intervals based on the performance of the turf. Highly soluble sources are recommended for these applications because they are fast-acting and short-lived. Application rates when spoon-feeding with soluble N sources typically range from 0.0 to 0.5 lbs of N per 1,000 square feet. Applications at rates above 0.75 lbs. of N per 1,000 square feet can increase the risk of fertilizer burn and N loss. In most cases, fertilizer should be watered-in with less than 0.2” of irrigation to minimize the risk of burn or nutrient loss.

Turf areas that are less intensively managed are traditionally treated with granular products, which can range from 100% water soluble products to 100% controlled-release products. Most application rates range from 0.5 to 2.0 lbs of N per 1,000 square feet (Table 7-3). Lower rates are more common for quick release fertilizers and fertilizers with a small size guide number (SGN), the median prill diameter in millimeters x 100. Products with SGN <100 are best for putting greens, 120-180 are best for fairways, and >200 are best for roughs. Higher N rates are most common with large SGN products and products that have very slow release characteristics or large SGN materials. Some slow release fertilizer products can release fertilizer over a period of 75 to 120 days after application. An obvious advantage to these very slow release products is fewer applications. A disadvantage is the manager forfeits control; little can be done if the turf is growing too rapidly following an application. The ideal time to fertilizer cool-season species is late spring and early fall and warm-season species during the summer. Products with more water soluble (quick-release) N should be used as the season starts to end. All fertilizer N should have become available by the end of the growing season.

Table 7-3. Annual nitrogen application rates

Turf managed area and species	Pounds of actual N / 1,000 sq. ft. annually*
Greens	
Bentgrass	2-4
Annual bluegrass	2-5
Tees	
Creeping bentgrass	1-5
Annual bluegrass	2-5
Kentucky bluegrass	2-5
Perennial ryegrass	2-6
Bermudagrass	1-3
Zoysiagrass	1-3
Buffalograss	1-3
Fairways	
Creeping bentgrass	0-3
Kentucky bluegrass	1-3
Perennial ryegrass	2-5
Bermudagrass	0-3
Zoysiagrass	0-2
Buffalograss	0-3
Roughs	
Kentucky bluegrass	0-3
Perennial ryegrass	2-4
Turf-type fall fescue	0-2
Bermudagrass	1-3
Zoysiagrass	0-3
Buffalograss	0-3

** Annual N fertilizer rates will be affected by soil organic matter, climate, length of growing season, traffic, and aesthetic expectations. Mature turf sites with little traffic may require little to zero N. However, new sites that are highly trafficked may require more than the values in this table.*

7.4.3 Phosphorus and Potassium Recommendations

The goal of P and K fertilization is to supply enough to sustain healthy turfgrass growth yet minimize unnecessary cost and environmental risk. Soil test calibration and interpretations suggest that soil test P levels should remain above 20 ppm Mehlich-3 P. Potassium levels should be greater than 40 ppm Mehlich-3 K. To ensure a margin of safety, turf managers should strive to keep soil test P levels between 25 and 50 ppm and K between 40 and 80 ppm and apply P and K following recommendations in Table 7-2.

7.5 Fertilizer Applications

Because N and P are two of the major sources contributing to both surface and groundwater pollution, fertilizers must be applied considering the application site and prevailing conditions. For example, sandy soils often have a lower potential to fix P and are more likely to have a leaching problem than other soils. Fertilizer applications should be avoided whenever possible on steep slopes and should not be allowed to be deposited on impervious surfaces, such as paved cart paths and parking areas. Avoid applying fertilizer to soils that are at, or near, field capacity or following rain events that leave the soils wet to avoid both runoff and leaching. In addition, maintaining a vegetated buffer or filter strip around surface waterbodies significantly filters out any nutrients in surface runoff.

The selection and calibration of application equipment is an important aspect of nutrient management. 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. Therefore, choosing the appropriate spreader for a given material (walk-behind rotary drop spreader, bulk rotary, or spray) is important.

Accurately calibrated sprayers or spreaders are essential for proper application of fertilizers. Incorrectly calibrated equipment can easily apply too little or too much fertilizer, resulting in damaged turf, excess cost, and greater potential of nutrient movement off-site. An excellent resource for spreader care and calibration can be found at Penn State's Department of Plant Science. Spreaders should also be thoroughly cleaned after use due to the high salt content that corrodes metal parts and in keeping with the BMPs for equipment washing.

7.6 Nutrient Management Best Management Practices

- ❖ Because turf is extremely responsive to soil N status, evaluate changes in clipping yield during the growing season to estimate N availability.
- ❖ Reduce N inputs on more mature turfgrass stands.
- ❖ Use N fertilizer to produce even growth rate. This increases golf course playability and minimizes the risk to the environment, while excessive fertilization reduces playability and increases the risk of N leaching.

- Use soluble N sources (0.05-0.50 lbs N per 1,000 square feet) to fine-tune clipping yield on highly managed turf surfaces.
- Fertilizer products with a blend of quick and slow release fertilizer are frequently applied to non-intensively managed areas. Optimum timing for cool-season species are late spring/early summer and again in late summer/early fall.
- Summer fertilizer applications can benefit young turf stands or stands growing on poor soils.
- Apply fertilizer when turf is actively growing to minimize loss.
- Light irrigation after P application has been shown to reduce P runoff.
- Maintain dense turf stand through proper nitrogen fertilization to reduce soil runoff.
- Monitor K and P by testing soil regularly.

Fertilizer Applications

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

8 CULTURAL PRACTICES

Cultural practices play a large role in turf quality. Proper cultural management can help produce a dense, healthy turf playing surface. These practices are used on all areas of a golf course, including putting greens, fairways, tee boxes, and rough and include a variety of methods, such as mowing, cultivation, cultivar selection, and rolling. These practices typically manage the top 3-4" of soil and improve plant nutrient/water uptake and the overall health of the plant.

8.1 Mowing

Mowing is the most commonly used cultural practice on golf courses. Mowing practices impact turf density, texture, color, root development, and wear tolerance. Failure to mow properly will result in weakened turf with poor density and quality. Mowing height decisions are typically based on the turf species and location on the course. Other factors affect mowing as well, such as frequency, shade, equipment, time of year, root growth, and abiotic and biotic stress. Mowing should increase tillering and shoot density while not decreasing root and rhizome growth as much as possible.

Figure 19. Mowing greens at Omaha Country Club. Photo Credit: Eric McPherson.

8.1.1 Height of Cut

Height of cut (HOC) is important for a healthy playing surface. Proper mowing HOC is a function of the species/cultivar being managed and the intended use of the site. While taller grown turf is more likely to withstand pests and stresses, a well-groomed turf stand is preferred by many golfers for playability and aesthetic appeal.

Various heights of cut are used on different locations on a golf course. The table shown below shows recommended HOC for turf species (Table 8-1). These HOC ranges maximize turf density, assuming water, nutrient, and cultivation needs are being met. Following a rule of thumb that no more than one-third of the plant should be removed at one time avoids scalping, which reduces turf density and can result in a dramatic reduction in root growth.

Mowing heights can vary seasonally, due to such factors as sun availability, weather, and drought stress. During the spring and fall, when turf does not experience heat stress, certain mowing heights can affect the plants disease susceptibility. Throughout the heat of the summer, lower cuts can increase stress. Therefore, a higher HOC is recommended to help insulate the crown from heat stress, reduce weed competition, and reduce water needs. In shaded areas, photosynthetically active radiation is restricted, and turfgrass response is to grow upright in an effort to capture more light to meet photosynthetic needs. To counterbalance this effect, mowing HOC should be increased for turf grown in shaded environments.

Table 8-1 Mowing HOC recommendations by species and location

Turf Species	Greens	Tees, Collars, Approaches	Fairways	Roughs
	(in inches)			
Creeping bentgrass	0.10-0.16	0.2 – 0.6	0.25 – 0.5	-
Kentucky bluegrass	-	0.6 – 0.8	0.6 – 0.8	2 – 4
Perennial ryegrass	-	0.4 – 0.6	0.4 – 0.6	2 – 4
Tall fescue	-	-	-	2 – 4
Fineleaf Fescue	-	-	0.6 – 0.8	2 – 4
Buffalograss	-	-	0.6 – 0.75	1.5 - 3

8.1.2 Frequency

Mowing frequency should be based on vertical leaf growth. Maintaining an optimal root-to-shoot ratio is critical. Turfgrass plants that are mowed too low will require a substantial amount of time to provide the food needed to produce shoot tissue for future photosynthesis. If turf is mowed too low in one event, an imbalance occurs between the remaining vegetative tissue and the root system, resulting in more roots being present than the plant needs physiologically. As a result, the plants will slough off the unneeded roots. Root growth is least affected when no more than 30% to 40% of leaf area is removed in a single mowing. Mowing frequency should be decreased to allow the turf to recover when is under extremes, such as heat, drought, heavy traffic, increased mowing frequency, or other cultural practice (e.g. aeration).

8.1.3 Patterns

Mowing patterns influence both the aesthetic and functional characteristics of a turf surface. Changing the direction of cut is used to prevent excessive lateral growth and avoid lay over, providing a cleaner playing surface and an easier maintained HOC. While patterns should be varied regularly throughout the course, the direction of cut should be changed on putting greens every time it is mowed, including changing the direction of clean up and skipping some clean-up mows. Varying mowing patterns also provides aesthetic value.

8.1.4 Clipping Management

Turfgrass clippings are a source of nutrients, containing 2% to 4% nitrogen on a dry-weight basis, as well as significant amounts of phosphorus and potassium. These nutrients can be sources of pollution, and therefore should be handled properly to avoid contaminating water resources. Clippings should be returned to the site during the mowing process unless the presence of grass clippings will have a detrimental impact on play, such as on greens, or when the amount of clippings is so large that it could smother the underlying grass.

Collected clippings should be disposed of properly to prevent undesirable odors near play areas and to prevent a fire hazard due to the heat generated by composting that can occur when clippings accumulate. Consider composting clippings or dispersing them evenly in natural areas where they can decompose naturally without accumulating in piles, though care should be taken to ensure that clippings are free from pesticides.

8.1.5 Mowing Equipment

Different mowing equipment is typically used on different locations of a golf course. For example, reel mowers are ideally suited for maintaining turfgrass stands that require a HOC below 1.5” and provide the best quality cut when compared with other types of mowers. Rotary mowers, when sharp and properly adjusted, deliver acceptable cutting quality for turf cut above 1” in height. Flail mowers are most often used to maintain infrequently mowed areas.

Maintaining blades by sharpening and adjusting them regularly provides the best quality cut. Dull blades shred leaf tissue, increase water loss, and increase the potential for disease development.

8.2 Aeration

Cultivation practices -- aeration practices and surface cultivation practices -- disturb the soil or thatch through the use of various implements to achieve important agronomic goals that include relief of soil compaction, thatch/organic matter reduction, and improved water and air exchange.

Aeration practices consist of core aeration, deep drilling, solid tining, and high-pressure water injection. Light and frequent sand topdressing applications are also beneficial for smoothing the surface, diluting organic matter, and improving playability.

Figure 20. Fairway aeration at Kearney Country Club. Photo Credit: Scott Shurman.

Aeration frequency depends upon traffic intensity, thatch/organic matter build up, black layer and level of soil compaction. Even though aeration is very beneficial, it disturbs the playing surface and takes some time to heal. Table 8-2 shows advantages/disadvantages of multiple aeration practices.

Table 8-2. Aeration practices

Method	Compaction relief	Surface disruption	Water/air movement	Disruption of play
Hollow-tine aeration	High	Medium	High	Medium to High
Deep drilling	Medium	Medium	High	High
Solid-tine aeration	Low	Low	High	None to Medium
High-pressure water injection	None	Low	High	None to Low

8.2.1 Hollow-tine Aeration

Hollow-tine (or core) aeration is effective at relieving soil compaction, improving internal drainage soil drainage and increasing of oxygen in the soil. Aeration involves physically removing cores, varying in depth, diameter, and distance apart. Table 8-3 shows different core sizes used for aeration.

Table 8-3. Core size options for aeration

Tine Size (in.)	Spacing (in.)	Holes/ft^2	Surface Area of One Tine (in.)	Percent Surface Area Affected (Outside tine)
1/4	1.252	100	0.049	3.4%
1/4	2.52	25	0.049	0.9%
1/2	1.252	100	0.196	13.6%
1/2	2.52	25	0.196	3.4%
5/8	2.52	25	0.307	5.3%

8.2.2 Deep Drilling

Deep-drill aeration creates deep holes in the soil surface profile through use of drill bits. Soil is brought to the surface and distributed into the canopy. Holes can be backfilled with new root-zone materials if a drill-and-fill machine is used. These machines allow replacement of heavier soils with sand or other materials in an effort to improve water infiltration into the soil profile.

8.2.3 Solid-Tine Aeration

Solid tines cause less disturbance to the turf surface and can be used to temporarily reduce compaction and soften surface hardness during months when the growth rate of grasses is reduced. Benefits of solid-tine aeration are temporary because no soil is removed from the profile. Solid tining without sand topdressing will impact infiltration but has little impact on organic matter management.

8.2.4 High-Pressure Water Injection

High-pressure water injection promotes water penetration and air exchange (Figure 21). Streams of water are injected at high velocities 4-8” into the soil at 1/8 to 1/4” diameter. High-pressure water injection doesn’t disrupt play.

Figure 21. Side view of high pressure water injection. Photo Credit: USGA.

8.3 Surface Cultivation

The goals of surface cultivation are to manage organic matter accumulation above the soil, reduce the formation of leaf grain, improve infiltration, and improve surface consistency. While these methods are generally less disruptive than traditional aeration practice, some newer technologies are quickly impact a large percentage of the turfgrass canopy. They usually have low to no impact on soil compaction relief.

Table 8-4. Surface Cultivation practices

Method	Compaction relief	Surface disruption	Water/air movement	Disruption of play
Vertical mowing	Low	Medium to High	Medium	Low to High
Spiking/slicing	None	Low	Low	None

8.3.1 Vertical Mowing

Vertical mowing can be incorporated into a cultural management program to achieve a number of goals (Figure 23). The grain of a putting green can be reduced by setting a verticutter to a depth that just nicks the surface of the turf. Frequent, light vertical mowing minimizes grain formation. Deeper penetration of knives stimulates new growth by cutting through stolons and rhizomes while removing accumulated thatch. A more aggressive, deep vertical mowing can reach a depth of 0.5-1", removing a greater amount of thatch compared with other cultivation practices. Even though this is beneficial, deeper vertical mowing should not be used when the grass is growing slowly because aggressive growth is needed to fill in disturbed areas.

8.3.2 Spiking/Slicing

Spiking/slicing reduces surface compaction and promotes water infiltration with minimal surface damage. Slicing is faster than core aeration but is less effective. Spiking can break up crusts on the soil surface, disrupt algae layers, and improve water infiltration.

Figure 22. Vertical mowing. Photo Credit: Jim Nedrow.

8.4 Topdressing

Sand topdressing is used to improve the soil structure (Figure 23). Proper topdressing programs can relieve surface compaction, dilute organic matter, help in recovery from cultural practices, increase water and air infiltration, and protect the crowns. Layering can occur in the soil if proper programs aren't followed, limiting water and air infiltration. Table 8-5 shows application rates for light and frequent topdressing. These applications can be applied once every 2-3 weeks for even distribution in the soil layer.

When purchasing sand for topdressing, the source, budget, texture, and overall quality of the sand is important. Sand deposits from Nebraska's rivers are spherical in shape. However, the more expensive angular sand performs better for topdressing. Particle size is important. It should be matched to the existing soil particle size if possible (Figure 24). A coarse particle size is better than fine.

Table 8-5. Light and frequent topdressing rates

Quantity (ft^3/1,000 ft^2)	Quantity (lbs/1,000 ft^2)	Quantity (tons/acre)	Depth of Application (inches)
0.50	50	1.1	0.006
0.75	75	1.7	0.009
1	100	2.2	0.012
2	200	4.4	0.24
4	400	8.8	0.48

Figure 23. Sand topdressing following aeration. Photo Credit: Steve Merkel.

Figure 24. Sand particle application rate differences. Photo Credit: USGA.

8.5 Rolling

Rolling can help smooth the putting surface and maintain speeds at higher HOC. Even with a raised HOC, rolling can increase ball roll by 10 percent. Light-weight rollers typically have little negative impact on soil compaction unless the practice is over-utilized or the practice is used on high silt and clay soils when saturated with water. This can also help alleviate some stress. Rolling can also be used to remove dew off the playing surface, which reduces the possibility of dollar spot.

8.6 Cultural Practices Best Management Practices

Mowing

- ❖ Follow the recommended HOC for different turf species.
- ❖ Raise HOC by at least 30% in heavily shaded areas to improve turf health.
- ❖ Routinely use plant growth regulators, if needed, to improve overall turf health in shaded environments.
- ❖ Increase HOC in times of stress such as heat, drought, or prolonged cloudy weather to increase photosynthetic capacity and rooting depth of plants.
- ❖ If turf becomes too tall, it should not be mowed down to the desired height all at once. Tall grass should be mowed frequently and HOC gradually decreased until the desired HOC is achieved.
- ❖ Mowing frequency should increase during periods of rapid growth and decrease during dry, stressful periods.
- ❖ Decrease mowing frequency and increase HOC when the turf is stressed.
- ❖ Change mowing patterns on all locations of the golf course.
- ❖ Change direction of mow on greens every time it is mowed.
- ❖ Rarely use inefficient mowing patterns (e.g. 9-3) on areas other than putting greens to save time, fuel, and labor.
- ❖ Return clippings to the canopy whenever possible.
- ❖ Use compressed air to blow off clippings from mowing equipment over grassed areas and before washing equipment.
- ❖ Collect pesticide-free clippings and compost or distribute in natural areas, away from surface waters.
- ❖ Use proper mowing equipment.
- ❖ Regularly sharpen and adjust blades.

Aeration

- ❖ When thatch levels are excessive, core aeration programs should be designed to remove 15% to 20% of the surface area and to minimize grain formation.
- ❖ High traffic areas may require a minimum of two to four core aerations annually.
- ❖ Core aeration should be conducted only when grasses are actively growing to aid in quick recovery of surface density; midsummer for buffalograss and spring/fall for cool season grasses.
- ❖ Aeration events should be as deep as practical to prevent development of compacted layers in the soil profile as a result of cultivation.

- ❖ Consider timing of core aeration to avoid time of *Poa annua* (annual bluegrass) seed head formation.
- ❖ Backfill holes with new root-zone materials if a drill-and-fill machine is used.
- ❖ High pressure water injection can be applied once every 3-4 weeks throughout the summer.

Surface Cultivation

- ❖ Initiate vertical mowing when thatch level reaches 0.25-0.5” in depth. Shallow vertical mowing should be completed at least monthly on putting greens to prevent excessive thatch accumulation.
- ❖ Vertical mowing depth for thatch removal should reach the bottom of the thatch layer and extend into the surface of the soil beneath the thatch.
- ❖ Aggressive or deep vertical mowing should not be used when the turf is growing slowly.
- ❖ Frequent shallow vertical mowing on putting greens prevents excessive thatch build up and grain formation.

Topdressing

- ❖ Use light and frequent topdressing applications following aeration, according to Table 8-5.
- ❖ Use sand particle size distribution similar to the existing soil, to avoid layering.
- ❖ Know the sand source, and ensure sand is weed-free, uniform, and of appropriate quality.

Rolling

- ❖ Daily rolling of putting surfaces following mowing can increase putting speeds and allow for improved ball roll without lowering HOC.
- ❖ Avoid rolling on saturated soils, to avoid compaction.
- ❖ Use lightweight rollers to minimize potential compaction.

9 INTEGRATED PEST MANAGEMENT

IPM is an effective and environmentally sensitive approach to pest management that takes advantage of all appropriate pest management options including physical/mechanical, biological, cultural, and chemical controls.

IPM utilizes regular monitoring and record keeping to determine if and when treatment is needed. This approach takes the form of a combination of strategies and tactics to prevent unacceptable damage. When warranted, pesticides can be used after a considered selection process and applied following state and federal regulations. In addition to regulations, BMPs safeguard non-target species and water quality.

9.1 Regulatory Considerations

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

Controlled burns (discussed in section 9.6.3 of this document) require local permits. Some controlled burns could require a state burn permit as well, and the NDEQ Air Program should be contacted for more information. In general, a state burn permit is required for the following burns:

- "Community" burn permits issued for five years, for a central location where residents drop off tree branches and brush
- "General" burn permits issued for six months, for:
    - Dangerous materials, diseased vegetation, abatement of a fire hazard
    - Trees, brush, etc. from road and utility right-of-ways
    - Trees, brush, untreated lumber, etc. from land clearing and construction
    - Straw used as winter insulating cover on ag products
    - Untreated wood and trees at community land disposal sites (separate area from materials not burned)

9.2 IPM Overview

IPM is comprised of a range of pest control methods or tactics designed to prevent pests (insects, pathogens, nematodes, weeds, etc.) from reaching economically or aesthetically damaging levels while creating the least risk to the environment. IPM programs have basic components that provide the opportunity to make informed decisions on the control of pests at a golf course. Five steps for an effective IPM program for turf are as follows:

Step 1: Monitor pests and their damage and record information.

Step 2: Identify pests and understand their biology.

Step 3: Determine threshold levels.

Step 4: Consider a variety of control methods.

Step 5: Evaluate the IPM program.

IPM is flexible, and superintendents can usually balance course quality and environmental goals through its implementation. Growing healthy turf is the best and first line of defense against pests. For example, cultural conditions that predispose turfgrass to diseases include close mowing, inadequate or excessive nitrogen fertility, frequent or excess irrigation, inadequate thatch management, poor drainage, and shade. Following cultural BMPs and nutrient BMPs can help alleviate these conditions. However, under the right conditions, pests can sometimes cause excessive damage to highly managed turfgrass.

A number of non-chemical and chemical control options are available. When chemicals are needed, selection of an appropriate pesticide should follow an evaluation process that considers potential impacts on beneficial organisms and the environment, as well as the potential for development of pesticide resistance. Pesticide products should be rotated, based on their resistance classification, as discussed in further detail in section 9.6.5 of this chapter.

9.3 Monitoring Pests and Recording Information

In the IPM plan, pest monitoring or "scouting" efforts should be described for all areas of the course such as putting greens, tees and fairways, roughs, and landscaped areas. Scouting methods include visual inspection, soil sampling, soap flushes, and trapping for insects. Additional monitoring efforts can include weather tracking, which is especially helpful for predicting potential disease outbreaks. Here is one potential scouting schedule: daily on putting greens, at least weekly on tees and fairways, twice-monthly on roughs, and whenever the potential for pests increases due to weather. For example, warmer temperatures combined with high humidity favor the development of diseases such as dollar spot and brown patch. UNL's Turf Info page provides timely notifications on turf-related topics, such as disease outbreaks.

When pests are discovered during monitoring, the pest pressure should be quantified with measurements such as:

- Number of insects per unit area.
- Disease patch sizes.
- Percent of area affected.

Documentation should include useful information, such as photographs, delineation of pest boundaries on an area map, outbreak date, description of the prevailing weather conditions, and recent management practices. This information can be used to build a database for reference in future seasons and for updating the IPM plan.

9.4 Identifying and Understanding Pests

Once detected, pests must be properly identified. Understanding the biology of pest species and their vulnerable life stages assists in later control efforts. UNL Extension guides can help with identification of species, as can diagnostic services from the university. Just as important as identifying pests is recognizing and understanding beneficial organisms and their life cycles so their populations are not unduly negatively affected while managing pests. Superintendents and staff should continually hone their diagnostic skills by attending training seminars and field days, obtaining reference materials, and providing peer-to-peer training.

The following are resources for assistance in identifying and understanding pest species:

- Turfgrass Weed Control for Professionals, which ncludes color images and descriptions of many turf weeds.
- Managing Turf and Landscape Weeds.
- Extension Publications site, which offers species-specific information.
- Plant and Pest Diagnostic Clinic at UNL. To submit a sample, review the instructions for submitting turf samples.
- Panhandle Plant Diagnostic Clinic, which focuses specifically on identification of any plant disease encountered in the Nebraska panhandle.

9.4.1 Diseases

In many cases, diseases develop when conditions are favorable, regardless of management strategies. However, the severity of disease is often greatly reduced by using cultural, biological, and genetic techniques. As a rule, healthy, well-managed turf better withstands disease outbreaks and recovers more rapidly than unhealthy turf. Some common diseases in Nebraska include brown patch, dollar spot, summer patch, powdery mildew, and pythium. If unrecognized diseases occur, samples should be sent to the Plant and Pest Diagnostic Clinic at UNL.

Figure 25. Dollar spot. Photo credit: Casey Crittenden.

9.4.2 Weeds

High-quality turfgrass outcompetes seedling weeds for light, water, and nutrients, and thus prevents them from establishing large weed stands that decrease turf playability and aesthetics. Weeds can also harm turf by hosting other pests such as plant pathogens, nematodes, and insects.

The potential for invasive weeds can be limited through implementation of the BMPs identified in this document related to turfgrass selection, nutrient management programs, irrigation, and cultural practices. Some common Nebraska turfgrass weeds include crabgrass, yellow nutsedge, annual bluegrass, and broadleaf weeds. The Turfgrass Weed Control for Professionals guide provides detailed weed identification and management information.

9.4.3 Nematodes

Plant-parasitic nematodes adversely affect turfgrass health by debilitating the root system of susceptible species, thus decreasing the efficiency of water and nutrient uptake. Turf weakened by nematode infestations favors further pest infestation, especially weeds. Over time, turf in the affected areas thins out and, with severe infestations, may die. Turfgrass often begins showing signs of nematode injury during additional stresses, including drought, high or low temperatures, and wear.

9.4.4 Insects/White Grubs

Insects such as billbugs, chinch bugs, mealy bugs, webworms, armyworms, cutworms, and ants impact turfgrass in Nebraska. Armyworm and cutworm larvae feed at night on many varieties of turfgrass on the surface and then rest during the day. They are easier to detect using visual inspection and other methods based on irritating detergent-based solutions (soap flushes) to assess larval numbers.

White grubs are the larval stage of a group of beetles collectively known as scarabs (family Scarabaeidae). While there are many species of scarab beetles in Nebraska, the larvae of only a relative small number cause significant injury by feeding on the roots of cool season grasses. Among those causing turf injury are:

- Masked chafers, *Cyclocephala* spp. (annual grubs).
- May/June beetles, *Phyllophaga* spp. (three-year grubs).
- Black turfgrass ataenius, *Ataenius spretulus.*
- Japanese beetle, *Popillia japonica*.

White grubs can destroy significant areas of turfgrass, with damage appearing in the later part of summer (mid-August through early September). Summer drought stress and insufficient irrigation may compound the damage to turf by grubs. Additional information on their biology and scouting methods is available on UNL's White Grub Management page.

Figure 26. Grub damage can be significant. Photo Credit: Casey Crittenden.

9.5 Determining Threshold Levels

A key feature of IPM programs is the identification of tolerance thresholds. Thresholds are based on the pest population, the stage of the pest, and the life stage of the plant. Injury thresholds represent the pest level population that causes unacceptable injury. Treatment thresholds are less than the injury threshold and indicate the number of pests or level of damage that would justify treatment to prevent the pest population from causing unacceptable turf loss.

9.6 Control Methods

Once a pest problem reaches the established treatment threshold, different methods can be used to control the problem, including cultural, mechanical, biological, and chemical. Selecting the most appropriate approach depends on a number of factors, including the site-specific location on the golf course, efficacy of non-chemical controls for the particular situation, economics, and pest populations.

9.6.1 Cultural Controls

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

As an example of the role of non-chemical controls in disease management, the following practices can reduce the incidence and severity of dollar spot:

- Planting resistant cultivars. Consult NTEP trial results to evaluate dollar spot resistance.
- Minimizing moisture stress and leaf wetness.
- Removing morning dew as early as possible.
- Rolling putting greens three or more times per week.
- Applying biological organisms known to suppress dollar spot such as *Bacillus licheniformis.*

9.6.2 Mechanical or Physical Controls

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

9.6.3 Controlled Burns

As many golf courses convert maintained turfgrass areas to native grassed sanctuaries, many facilities use prescribed or controlled burns to reduce undesirable plants and encourage desirable species, enrich wildlife, and remove excessive plant debris (Figure 27). Prescribed burning is especially effective in suppressing cool-season grasses and woody plant materials to a more desirable stand of a links-style resemblance of a tallgrass prairie. Use of a prescribed burn, along with other control methods, is an IPM approach to effectively manage these eco-sensitive areas. For more information, see Grassland Management With Prescribed Fire, UNL, and Conducting a Prescribed Burn and Prescribed Burning Checklist, UNL.

Figure 27. Prescribed burn before (top) and after (bottom) at Wild Horse Golf Course. Photo Credit: Josh Mahar.

9.6.4 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. Several organisms known to have some efficacy against turfgrass pests have been marketed as pest control products and are commercially available in Nebraska, such as *Bacillus licheniformis.* Natural enemies (e.g. ladybird beetles, green lacewings, and mantids) of some insect pests may be purchased and released near pest infestations. Areas on the golf course can also be modified to better support natural predators and beneficial organisms, especially in landscaped areas.

9.6.5 Pesticides/Chemical Controls

Chemical control is an acceptable IPM practice when other methods will not alleviate the pest problem. Reduced-risk pesticides and biopesticides provide a number of advantages over conventional pesticides and should be considered if applicable. The selection of conventional pesticides should follow a selection process and these criteria:

- They must be registered for use in Nebraska.
- They should be effective in treating the pest problem.
- Pesticide rotation, based on resistance classification, as classified by Fungicide Resistance Action Committee [FRAC], Herbicide Resistance Action Committee [HRAC], and Insecticide Resistance Action Committee [IRAC].
- Costs should be considered.
- Environmental risk and potential for water quality impacts must be evaluated.

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

The use of all pesticides should follow the label and adhere to state and federal regulations, as described in the "Pesticide Management" chapter.

For more information, see:

- NebGuide publications for specific pest control methods.
- UNL's Turf Info page for recommendations on dealing with various pests.

Reduced Risk Pesticides and Biopesticides

The EPA's Conventional Reduced Risk Pesticide Program registers reduced-risk pesticides, which are commercially viable alternatives to conventional pesticides. Reduced-risk pesticides must be registered for use in Nebraska. The EPA characterizes the advantages of reduced-risk pesticides as follows:

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

Biopesticides, which are derived from such natural materials as animals, plants, bacteria, and certain minerals, are classified separately by the EPA. For more information on biopesticides, see the EPA's Biopesticide Registration page.

9.7 Evaluation and Record Keeping

It is essential to record the results of IPM-related efforts to develop historical information, document patterns of pest activity, and evaluate successes and failures. Records of pesticide use are required by Nebraska law for restricted use pesticides For IPM purposes, records should be kept for all pesticide applications and should include additional information, such as monitoring records, weather records, cultural management logs, and pest response.

9.8 IPM Best Management Practices

- ❖ Develop a facility-specific, written IPM plan. Available resources for writing an IPM plan include the Golf Course Superintendents Association of America (GCSAA) IPM information and on-line tools.
- ❖ Select turfgrass cultivars and species recommended for use in Nebraska and best suited for the intended use and environmental conditions of the specific site.
- ❖ Correct the soil's physical and chemical properties that may impact turfgrass health and its ability to resist pests.
- ❖ Evaluate the potential impact of the timing of cultural practices and nutrient applications on the incidence of pest problems.
- ❖ Use a defined pesticide selection process to select the most effective pesticide with the lowest toxicity and least potential for off-target movement.
- ❖ Document all IPM-related activities, including non-chemical control methods and pesticide usage.

Monitoring Pests and Recording Information

- ❖ Monitor prevailing environmental conditions for their potential impact on pest problems.
- ❖ Train personnel how to regularly monitor pests by scouting or trapping.

- Identify alternative hosts and overwintering sites for key pests.
- Assess pest damage when it occurs, noting particular problem areas, such as the edges of fairways, shady areas, or poorly drained areas.
- Document when the damage occurred. Note the time of day, date, and flowering stages of nearby plants.
- Map pest outbreak locations to identify patterns and susceptible areas for future target applications.

Identifying and Understanding Pests

- Identify key pests in the IPM plan.
- Determine the pest’s life cycle and know which life stage to target (e.g. for insect pests, whether it is an egg, larva/nymph, pupa, or adult).
- Identify pests accurately. For diseases, correctly identifying the disease pathogen often involves sending samples to UNL's diagnostic clinic.

Determining Thresholds

- Establish injury and treatment thresholds levels for key pests and document them in the IPM plan.

Control Methods

- Implement proper cultural, irrigation, and turf management practices to reduce stress and pressure of pest establishment.
- Maintain a proper fertilization schedule to improve turf density and quality and reduce pest populations.
- Always use pest-free materials, such as topdressing materials.
- Apply a preventative pesticide to susceptible turfgrass when unacceptable levels of disease are likely to occur.
- Address damage from turfgrass pests such as diseases, insects, nematodes, and animals to prevent density/canopy loss to broadleaf weeds.
- Divert traffic away from areas that are stressed by insects, nematodes, diseases, or weeds.
- When nematode activity is suspected, an assay of soil and turfgrass roots is recommended to determine the extent of the problem.
- Release insect-parasitic nematodes to naturally suppress insect pests such as white grubs.
- Identify areas on the golf course that can be modified to attract natural predators, provide habitat for them, and protect them from pesticide applications.
- Install flowering plants that can provide parasitoids with nectar or sucking insects (aphids, mealybugs, and 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.
- Follow a selection process when conventional pesticide use is warranted.
- Rotate pesticide modes-of-action to reduce the likelihood of resistance, following guidelines and advice provided by the FRAC, HRAC, and IRAC.

- Evaluate use of reduced-risk pesticides and biopesticides to treat the pest problem.

Evaluation and Record Keeping

- After treatment, determine whether the corrective actions reduced or prevented pest populations, were economical, and minimized risks. Record and use this information when making similar decisions in the future.
- Observe and document turf conditions regularly, noting which pests are present, so that informed decisions can be made regarding the damage the pests are causing and what control strategies are necessary.

10 PESTICIDE MANAGEMENT

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

Storage and handling of pesticides in their concentrated form poses the highest potential risk to groundwater or surface water. For this reason, it is essential that facilities for storing and handling pesticides be properly sited, designed, constructed, and operated in accordance with federal and state regulations.

10.1 Regulatory Considerations

The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) is the federal law regulating the manufacture, distribution, sale, and use of pesticides. The EPA has given the NDA the authority to regulate pesticides in Nebraska under FIFRA on behalf of the EPA. In addition to FIFRA, the NDA regulates pesticides in accordance with the Nebraska Pesticide Act (NPA) (§§2-2622 – 2-2659) enacted in 1994 and revised in 2013, which includes the registration, transportation, storage, sales, use, and disposal of pesticides in the state.

The NDA identifies the UNL Extension as responsible for providing training for private, commercial, and non-commercial pesticide applicators. People who attend these training sessions and pass certification tests are considered competent to apply pesticides. Maintaining a certification license requires attending a recertification session every three years. For more information on pesticide training, see the Pesticide Safety Education Program website. For general information regarding pesticide regulation in the state, see the NebGuide Pesticides Laws and Regulations.

The NDEQ regulates agricultural chemical containment and releases under Title 198 regulations. The NDEQ publishes the Fertilizer and Pesticide Containment in Nebraska Fact Sheet and UNL publishes the NebGuide Nebraska Pesticide Container and Secondary Containment Rules that can be used to determine if these regulations, such as secondary containment (diking) and load-out facilities (load or rinse pad), apply. Releases of pesticides that are not contained must be reported to NDEQ pursuant to Title 126 regulations.

Additional resources for more information on pesticides usage in Nebraska include:

- Database of all Nebraska registered pesticides.
- Database of Restricted Use Pesticides in Nebraska.
- Nebraska Pesticides of Interest Evaluation Summary.
- NebGuide Understanding the Pesticide Label.

10.2 Human Health Risks

Pesticides belong to numerous chemical classes that vary greatly in their toxicity. Acute toxicity refers to a single exposure by mouth, skin, or inhalation, or repeated exposures over a short time. Chronic toxicity effects are associated with long-term exposure to lower levels of a toxic substance, such as ingestion in drinking water. Pesticide toxicity and level of exposure can be a risk to human health. This idea is expressed by the risk formula: Risk = Toxicity x Exposure.Therefore, risk can be held to an acceptably low level if the amount of exposure is kept low. A number of measures can be taken to mitigate risk of exposure, including:

- Reading the pesticide product label and complying with all directions.
- Dressing appropriately and using personal protective equipment (PPE).
- Storing, handling, mixing, and applying pesticides with caution and following all safety precautions.

Pesticide labels provide information on PPE and first-aid information specific to the product. Therefore, applicators should always read and follow the label before using a pesticide, in addition to following standard safe practices. Safety Data Sheets (SDS; formerly called Material Safety Data Sheets [MSDS]) provide important information on hazardous chemicals. In addition, exposure to pesticides can be mitigated by practicing good work habits and adopting modern pesticide mix/load equipment (e.g. closed loading) that reduce potential exposure.

A special concern and awareness should be exercised with respect to pesticide exposure to golfers. Potential routes of exposure include via shoes, clothing, and equipment. Pesticide labeling addresses reentry restrictions and any application should be allowed to thoroughly dry before play resues. When evaluating and selecting pesticides, superintendents should select lower risk pesticides whenever possible.

For more information on human health related pesticide issues, see the NebGuide Managing the Risk of Pesticide Poisoning and Understanding the Signs and Symptoms of Pesticide Poisoning.

10.3 Personal Protective Equipment

PPE protects workers from exposure through one or more pathways: skin, eyes, oral ingestion, or respiratory tract. Pesticide labels list legal requirements for minimum PPE, such as specific types of clothing, goggles, and respirators. The type of PPE needed depends both on the toxicity of the pesticide and the formulation. If a pesticide label does not have specific PPE requirements, the route of entry and other information on the label can be used to determine the type and degree of appropriate protection. To avoid contamination, PPE should not be stored in a pesticide storage area. For more information on PPE, see the following NebGuides:

- Protective Clothing and Equipment for Pesticide Applicators.
- Pesticide Safety: Choosing the Right Gloves.
- Respirators for Handling Pesticides.

- Fit Testing a Respirator for Pesticide Applications (in press)

10.4 Environmental Fate and Transport

Environmental characteristics of a pesticide can often be determined by the environmental hazards statement found on pesticide product labels. The environmental hazards statement (referred to as “Environmental Hazards” on the label and found under the general heading “Precautionary Statements”) advises the user of product specific concerns. Potential environmental impacts include toxicity to non-target organisms and contamination of surface water or groundwater.

If endangered species are present on or near the course, labeling on applicable pesticide products directs users to the limitations found in Endangered Species Protection Bulletins. For more information, see the NebGuide Pesticides and the Endangered Species Protection Program.

The key to preventing pesticide impacts to water quality is an understanding of the physical and chemical characteristics that determine a pesticide's interaction with the environment: solubility, adsorption, persistence, and volatilization. Pesticide characteristics influence the potential for runoff, leaching, or drift. Once applied, pesticides can move off-site in several ways: in water, in air, attached to soil particles, and on or in objects, plants, or animals.

To prevent pesticides from moving off-site, pesticide characteristics, site-specific characteristics, and prevailing conditions should all be evaluated. Pesticide characteristics, such as solubility, and site-specific characteristics, such as soil type, depth to the water table, geology, and proximity to surface water, should be considered before selecting and applying pesticides. Prevailing weather conditions, such as the chance of precipitation, the prevailing wind, and humidity, should be evaluated with respect to the timing of pesticide applications.

10.4.1 Leaching and Runoff

Most pesticide movement in water is either by surface movement off the treated site (runoff) or by downward movement through the soil (leaching). Runoff and leaching may occur when:

- Too much pesticide is applied or spilled onto a surface.
- Too much rainwater or irrigation water moves pesticide through the soil off-site or into groundwater.
- Highly water-soluble or persistent pesticides are used.

Pesticide movement in soil and water is affected by its water solubility, adsorption by soil, and persistence. Pesticides with greater adsorption by soil are less likely to be moved by leaching or surface runoff but can be carried to surface water with eroding soil. In addition to following the pesticide BMPs to reduce the likelihood of pesticides moving off-site in surface runoff, buffer strips (as discussed in the “Surface Water Management” chapter of this document) slow down runoff and allow pesticides to adhere to soil particles and plant tissue, preventing contamination of surface water.

Pesticides with less adsorption by soil are more likely to leach through the soil and reach groundwater. For example, if rainfall is high and soils are permeable, water that carries dissolved pesticides may take only a few days to percolate down to the groundwater. The Applicator's Map and Guide to Prevent Groundwater Contamination shows leaching potential in Nebraska. The NDA also has county guides -- on paper or in PDF format -- that show leaching potential for all Nebraska counties. County guides are currently available on the NDA website for Sioux County, Platte County, and Pierce County and all are available from NDA upon request by calling 402-471-2351

10.4.2 Drift

Air movement causing pesticide transwer away from the application site is called drift. Pesticides may be carried off-site in the air as spray droplets, vapors, or even on blowing soil particles.

- Spray drift: Airborne movement of pesticide particles to non-target sites during application.
- Vapor drift: Volatilization of particles from plant and other surfaces during and after application and movement as a gas or vapor to a non-target site in sufficient concentrations to affect plant processes.

The potential for spray drift is strongly related to droplet size; smaller droplets have smaller mass and remain airborne and exposed to air movement longer than larger droplets. Equipment selection and operation characteristics, such as nozzle type, spray pressure, nozzle spray angle, and spray volume, impact the potential for spray drift. Weather related considerations that can influence the potential for spray drift include wind speed, wind direction, air stability, relative humidity, and temperature.

The formulation of combination products as an amine or ester can also impact the potential for drift. Esters have higher vapor pressures than amines, but typically provide better weed control. In cooler weather, ester formulations can often be used safely. In higher temperatures, the risk of volatization increases and calls for switching to an amine formulation if drift is a concern.

Vapor drift can sometimes be difficult to predict and depends on the factors such as the pesticide's chemical characteristics and weather, even days after the application. Volatility increases as the pesticide's vapor pressure increases and as air temperature and wind speed increase. Irrigating shortly after surface application of volatile pesticides reduces the potential for vapor drift.

To avoid either kind of drift, wind speeds of 3-10 mph are best for applying pesticides; less than 3 mph indicates stagnant air and the potential for temperature inversions while more than 10 mph indicates an increasing potential for particle drift. Temperature inversions can result in long distance drift. They occur when lighter warm air rises upward into the atmosphere and heavier cooler air settles near the ground. Under these conditions, air does not mix and spray droplets do not disperse. Any subtle airflow can move this mass of pesticide spray droplets off-target. Temperature inversions typically start at dusk and break up around sunrise as air mixes vertically.

Drift management directions are typically an integral component of product labeling. Therefore, the pesticide label should be reviewed for specific information on drift reduction techniques or requirements. Weather-related instructions on the label must be followed as well.

For more information on preventing drift, see the NebGuide Spray Drift of Pesticides. Some specialty crops are especially sensitive to pesticides. Therefore, pesticide applicators can check the DriftWatch and BeeCheck websites, online mapping services from FieldWatch that allow those with commercial specialty crops, organic crops, beehives, and other sensitive crops to report their field locations. All applicators applying pesticides outdoors are encouraged to sign up for free access to the FieldCheck app and/or free email notices. In addition, the NebGuide Protecting Sensitive Crops is available on line for further guidance.

10.5 Pesticide Application Equipment and Calibration

Application equipment must apply the pesticide to the intended target at the proper rate. Information on the pesticide label specifies the legal application rate and sometimes suggests the appropriate equipment for use with the product.

To apply liquid or granular pesticides at the proper rate, properly calibrated application equipment is essential. Such equipment mitigates environmental and human health concerns, reduces the chances of over-or under-applying pesticides, and optimizes pesticide efficacy. In addition, applicators must be especially careful to avoid exposure through inhalation when applying granular products. Equipment should also be checked frequently for leaks and malfunctions.

For spray applications, the size of the equipment (tank size, boom width, etc.) should be matched to the scale of the facility. Nozzle selection and coverage, in particular, is important in the control of drift. The type of nozzle, nozzle orifice size, sprayer pressure, and the height or distance of the nozzles from the target affect the potential for off-site movement of pesticides. A nozzle that primarily produces coarse droplets is usually selected to minimize off-target drift.

For more information on selecting application equipment to prevent drift, see the NebGuide Spray Drift of Pesticides.

10.6 Pesticide Record Keeping

Maintaining accurate records of pesticide-related activities (e.g. purchasing, storage, inventory, and applications) is essential. Nebraska requires that pesticide application records be maintained for three years and be made available to the NDA upon request. NDA regulations require information from commercial and non-commercial applicators of restricted-use pesticides and commercial applicators applying general-use pesticides. Details of reporting requirements are published by the NDA in Pesticide Record Keeping Requirements in Nebraska.

10.7 Pesticide Transportation, Storage, and Handling

Storage and handling of pesticides in their concentrated form poses the highest potential risk to groundwater or surface waters. For this reason, it is essential that care be taken in transporting pesticides and that the facilities for storing and handling these products be properly sited, designed, constructed, and operated. More information and a pesticide storage checklist can be found in the UNL Extension's Safe Transport, Storage, and Disposal of Pesticides.

The NDEQ requires secondary containment and a load-out facility when bulk pesticide storage capacity exceeds 500 gallons. Custom applicators must have a load-out facility when using pesticides from original containers larger than 3 gallons or when using pesticide or fertilizer mixtures of more than 100 gallons. For more information on these requirements, see the NDEQ's Fertilizer and Pesticide Containment in Nebraska Fact Sheet.

Storing large quantities of pesticides for long periods of time should be avoided. Adopting a “first in-first out” management system for pesticide purchase and storage helps to avoid a buildup of large quantities of chemicals.

10.8 Mixing/Washing Station

As described above, the NDEQ requires secondary containment and a load-out facility when bulk pesticide storage capacity exceeds 500 gallons, when using pesticides from original containers larger than 3 gallons, or when using pesticide or fertilizer mixtures of more than 100 gallons. For more information on these requirements, see the NDEQ's Fertilizer and Pesticide Containment in Nebraska Fact Sheet, the NebGuide Nebraska Pesticide Container and Secondary Containment Rules, and Title 198 regulations

The NebGuide Cleaning Pesticide Application Equipment provides detailed information on cleaning equipment. UNL Extension recommends a sprayer cleanout procedure described in the University of Missouri publication Cleaning Fields Sprayers to Avoid Crop Injury.

10.9 Disposal

The safest way to dispose of leftover pesticide from professional applications is to use all of the chemical according to directions on the label. This includes the washwater from pesticide equipment washing, which must be used in accordance with the label instructions.

Often pesticide storage facilities accumulate unuseable or unwanted pesticide products. They can accumulate for a variety of reasons, e.g. mistakes made in calculating the amount of product needed or the launch of new product chemistries that may be more effective at controlling target pests. Disposing of these stockpiles properly may be challenging. Simply keeping them in storage eventually becomes problematic when packaging inevitably deteriorates or corrodes and creates a hazard. NDA, UNL Pesticide Safety Education Program, or NDEQ's Waste Service Provider Directory can be contacted for guidance on disposing of excess pesticides.

10.10 Pesticide Container Management

Handling of empty pesticide containers must be done in accordance with label directions as well as with all laws and regulations. Under the federal Resource Conservation and Recovery Act, a pesticide container is not empty until it has been properly rinsed. Non-refillable pesticide containers that have been properly rinsed can be handled and disposed of as non-hazardous solid waste; some plastic containers can be recycled. Refillable containers may be returned to the supplier unrinsed. More information on pesticide containers can be found in the NebGuide Nebraska Pesticide Container and Secondary Containment Rules.

Detailed procedures for cleaning pesticide containers, such as pressure rinsing and triple rinsing, and storing empty containers are described in NebGuide Rinsing Pesticide Containers. Pesticide containers can be either recycled through an approved program, such as the UNL Pesticide Safety Education Program-coordinated plastic pesticide container annual recycling program, or disposed of by depositing them in a licensed sanitary landfill after pressure rinsing or triple rinsing. Ways to reduce the amount of waste that requires handling include identifying and implementing waste-reduction practices and purchasing bulk packaging when possible.

10.11 Emergency Preparedness and Spill Response

Pesticide leaks or spills, if contained, will not percolate down through the soil into groundwater or be carried away in runoff. However, if not contained, controlled, and cleaned up properly, pesticide spills can harm human health, the environment, or both through leching or runoff. The NebGuide Managing Pesticide Spills provides guidance on spill response. A facility emergency response plan that outlines these procedures and emergency contacts should be developed, provided to staff, and accompanied by training. Local emergency response agencies can also be provided a copy of the plan.

In Nebraska, spills do not have to be reported if they do not pose any potential harm to human health or the environment, such as when a spill is contained, such as on a concrete floor or in an enclosed area. The following pesticide and fertilizer spills must be reported, according to NDEQ Title 126 regulations:

- Pesticide or fertilizer spill of any amount to streams or lakes.
- Concentrated pesticide spill of 1 quart or more to the soil or a mixing pad.
- Dilute pesticide solution spill of 5 gallons or more to the soil or a mixing pad.
- Fertilizer spill greater than 50 gallons to the soil or a mixing pad.
- Pesticide or fertilizer spills of smaller quantities if they can cause damage because of the specific compound or spill location.

For human injuries, medical emergencies, or fires, first responders/EMT should be notified. After controlling and containing the spill, the NDEQ should be notified about reportable spills during normal working hours (Monday to Friday, 8 a.m. to 5 p.m.) at (402) 471-2186 Or toll free (877) 253-2603, or after hours, holidays and weekends to Nebraska State Patrol Dispatch at (402) 471-4545. Contained wastes must be handled, contained, and disposed of as per NE Title 128. CHEMTREC (800) 424-9300 can also be notified for assistance as needed.

A spill kit is a necessity at any facility where pesticides are used or stored. Spill kits should contain the items specified in the NebGuide Managing Pesticide Spills.

10.12 Pesticide Management Best Management Practices

Human Health Risks

- ❖ Follow the pesticide label for rentry period requirements or recommendations following applications.
- ❖ Allow all pesticide applications to dry thoroughly before allowing play to resume.
- ❖ Priotitize using lower risk products whenever possible.

Personal Protective Equipment

- ❖ Follow pesticide labels for appropriate PPE.
- ❖ 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.
- ❖ Ensure that respirators are seal- and fit-tested properly and the person is thoroughly traied and has no medical limitations to respirator use.
- ❖ Store PPE where it is easily accessible, but not in the pesticide storage area.
- ❖ Forbid employees who apply pesticides from wearing facility uniforms home by providing laundering facilities or a uniform service.
- ❖ Meet requirements for the OSHA 1910.134 Respiratory Protection Program.

Pesticide Applications

- ❖ Consider pesticide characteristics in the chemical selection process.
- ❖ Identify any areas on the course prone to leaching losses (e.g. shallow water tables, sand-based putting greens, coarse-textured soils, etc.) and do not use highly soluble pesticides in these areas.
- ❖ Select low or non-volatile pesticides.
- ❖ If listed species or species of concern are present, specifically select pesticides that have no known effects on these species.
- ❖ Check the forecast before applying pesticides and apply when conditions favorable, such as minimal wind velocity, temperature inversions not forecast, rain not forecast, etc.
- ❖ Follow the pesticide label to avoid drift.

- Use spray additives within label guidelines.
- Schedule the timing and amount of irrigation needed to water-in products (unless otherwise indicated on label) without over-irrigating.
- If sites adjacent to the application area are planted with susceptible plants or crops, allow a buffer area between the two, or wait until winds are blowing away from the area of concern.

Pesticide Application Equipment

- Use an appropriately sized applicator for the size of area being treated.
- Ensure the spray technician is experienced, certified, and properly trained.
- Properly calibrate all application equipment at the beginning of each season (at a minimum) or after equipment modifications.
- Check equipment daily when in use.
- Use recommended spray volumes for the targeted pest to maximize efficacy.
- Calibration of walk-behind applicators should be conducted for each person making the application to take into consideration walking speed, etc.
- Avoid high spray boom pressures; consider 45 PSI a maximum for conventional broadcast ground spraying.
- Use drift-reduction nozzles that produce larger droplets when operated at low pressures.
- Use wide-angle nozzles and low boom heights and keep boom stable.
- When possible, use lower application speeds to avoid drift.

Pesticide Record Keeping

- Use electronic or hard-copy forms and software tools to properly track pesticide inventory.
- Keep and maintain records of all pesticides used in order to meet legal reporting requirements.
- Use records to monitor pest control efforts and to plan future management actions.

Pesticide Storage and Handling

- Routinely undergo a “risk assessment” to identify any potential risks to the applicator or environment.
- Do not transport pesticides in the passenger section of a vehicle.
- Never leave pesticides unattended during transport.
- Maintain an inventory of all pesticides used and the SDS for each chemical.
- Avoid purchasing large quantities of pesticides that require storage for more 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.
- Locate pesticide storage facilities away from other structures to allow fire department access.
- Store, mix, and load pesticides away from sites that directly link to surface water or groundwater (e.g. wells).

- Store pesticides in a lockable concrete or metal building separate from other buildings.
- Shelving should be made of sturdy plastic or reinforced metal.
- Metal shelving should be kept painted to avoid corrosion. Wood shelving should never be used, because it may absorb spilled pesticides.
- When storing pesticides on shelves, place liquid pesticides on lower shelves and dry formulations above them.
- Store herbicides, insecticides, and fungicides in separate areas within the storage unit.
- Storage facility floors should be impervious and sealed with a chemical-resistant paint.
- Floors should have a continuous sill to retain spilled materials and should not have drains, although a sump may be included.
- Sloped ramps should be provided at the entrance to allow the use of wheeled handcarts for moving material in and out of the storage area safely.
- Automatic exhaust fans and an emergency wash area should be provided. Light and fan switches should be located outside the building, so that both can be turned on before employees enter the building and turned off after they leave the building.
- Avoid temperature extremes inside the pesticide storage facility.

Mixing/Washing Station

- Follow secondary containment requirements as required.
- Load and mix pesticides over an impermeable surface, such as a concrete pad.
- Mix pesticides at least 150 feet downslope from any well.
- Mix materials according to label directions and in amounts that will be used for the application to avoid excess that will need disposal.
- Either use anti-backflow devices when mixing pesticides or maintain a 6” air gap between mixing container and water source.
- Pump the sump dry and then clean it at the end of each day. Liquids and sediments should also be removed from the sump and the pad whenever pesticide materials are changed to an incompatible product (i.e. one that cannot be legally applied to the same site).

Disposal

- Collect washwater (from both inside and outside the application equipment) and use it as a pesticide in accordance with the label instructions.
- The rinsate may be applied as a pesticide (preferred) or stored for use for the next compatible application.
- Annually review pesticide inventories and properly dispose of unusable and unwanted pesticides.

Pesticide Container Management

- Rinse pesticide containers immediately in order to remove the most residue.

- ❖ Rinse containers during the mixing and loading process and add rinsate water to the finished spray mix.
- ❖ Rinse emptied pesticide containers by either triple rinsing or pressure rinsing.
- ❖ Use refillable containers only for pesticides.
- ❖ Recycle non-refillable containers when possible.
- ❖ Puncture empty and rinsed pesticide containers prior to disposal and dispose of them according to the label.

Emergency Preparedness

- ❖ Develop a facility emergency response plan that outlines the procedures to control, contain, and clean up spilled materials.
- ❖ Train all employees on the emergency response plan and emergency procedures.
- ❖ Keep an appropriate spill containment kit in a readily available space.
- ❖ For small liquid spills, use absorbents such as cat litter or sand and apply as a topdressing in accordance with the label rates, or dispose of as a waste.
- ❖ For small solid spills, sweep up and use as intended.
- ❖ Ensure that SDS documents are present and that all employees have been properly trained on their location and contents.
- ❖ Report releases to the NDEQ when required.
- ❖ For larger spills, follow guidance from the NDEQ and CHEMTREC for cleanup and disposal.

11 POLLINATOR PROTECTION

Wild pollinators and managed bees, such as honeybees, contribute to Nebraska's biodiversity and support the state's agricultural economy. Most flowering plants need pollination to reproduce and grow fruit. In Nebraska, pollinators include species of bees, butterflies, hummingbirds, moths, beetles, ants, flies, and bats. These pollinators are economically important to agriculture in the state as cultivated crops requiring pollination have a combined annual value of $10 billion. These crops include alfalfa, vetch, sweet clover, sunflower, and other seed crops, as well as many vegetable and fruit crops. Plants that promote soil conservation, such as wildflowers in woodlands and meadows, also require pollination.

Pollinators around the world are facing a number of threats that impact their health, abundance, and distribution. In Nebraska, 18 pollinator species, such as the monarch butterfly (*Danaus plexippus*) and the western bumble bee (*Bombus occidentalis)*, have been identified as at risk due to declining populations. One such threat is pesticides, which can have negative effects ranging from gene expression within individuals to colony level impacts. In particular, neonicotinoids have been a focus of research with respect to their impact on pollinators and their prevalent use in agricultural and ornamental settings. At this point, the potential connection between increased neonicotinoid use and recent pollinator decline is the subject of scientific research and debate.

Figure 28. Halictid Bee, Agapostemon, (female). Photo Credit: Jim Kalisch, UNL Entomology Department.

Figure 29. Bumblebee on coneflower. Photo Credit: Jim Kalisch, UNL Entomology Department.

Pesticide applicators need to be mindful of the impact that pesticides used in golf course management may have on pollinator species and their habitat. In addition to adhering to best management practices related to pesticide management and applications, golf course managers can protect and enhance habitat on the course in a number of ways to help pollinators.

For general information on protecting pollinators in Nebraska, see:

- Bee Aware: Protecting Pollinators from Pesticides. UNL Extension.
- Conservation Strategy for Monarchs and At-Risk Pollinators in Nebraska. Nebraska Monarch and Pollinator Initiative and Nebraska Game and Parks Commission.

11.1 Regulatory Considerations

Pollinator protection language is a requirement for pesticide labels, and following the label is mandatory. Pesticide applicators must be aware of honey bee toxicity groups and be able to understand precautionary statements (Figure 30). In addition to following legal requirements, pesticide applicators should understand the effects of pesticides on bees and other pollinators and the routes of potential exposure. The USGA publication Making Room for Native Pollinators and the United State Department of Agriculture (USDA) Forest Service and Pollinator Partnership Publication Bee Basics: An Introduction to Our Native Bees provide basic pollinator biology information useful for pesticide applicators. In addition, recordkeeping may be required by law to use some pesticides. Many of the IPM best management practices, such as record keeping, are valuable tools for protecting pollinators.

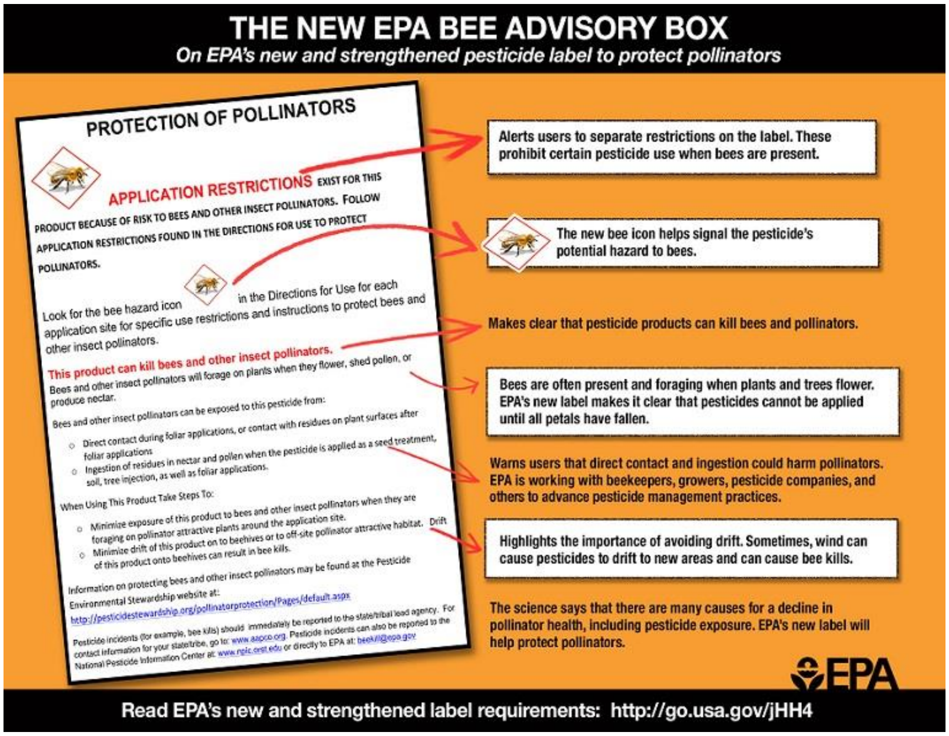

Figure 30. Information protecting pollinators on pesticide labels must be followed. Source: EPA.

11.2 Pest Management Practices

Protecting pollinators on the golf course does not preclude the use of pesticides, but instead minimizes any potential impact from these chemicals. Pesticide applicators must use appropriate tools to help manage pests while safeguarding pollinators, the environment, and humans.
Using IPM best management practices is an important key to protecting pollinators because they reduce pesticide usage and minimize the potential of exposure. Before applying pesticides on the course, applicators are encouraged to utilize FieldWatch to locate any nearby apiaries. For more information on best practices to protect pollinators when using chemical control, see Best Management Practices for Turf Care and Pollinator Conservation: Fast Facts.

11.3 Habitat Protection and Enhancement

Habitat for pollinators includes nesting sites, water, and foraging habitat for adults and their young. Pollinator-friendly habitat contains a diversity of plants, including a mix of blooming plants with different bloom colors, heights, and blooming times; grasses that provide habitat and larval food; and trees that provide early season pollen. Though wildflowers are most often thought of as pollinator-friendly plants, grasses such as big bluestem are a major pollen source for native bees in Nebraska. In addition, many sedge species are larval hosts, hollow stem grasses provide nesting habitat, and sturdy grasses shelter insects from harsh weather. Milkweed provides habitat specifically for monarch butterflies (Figure 31).

Figure 31. Milkweed provides quality habitat for monarch butterflies at Wild Horse Golf Course. Photo Credit: Josh Mahar.

Providing nesting sites for native species can be accomplished by taking simple steps in out-of-play areas, such as:

- Leaving exposed patches of bare soil.
- Leaving dead trees, stumps, and posts.
- Planting hollow stem grass species.
- Providing stem bundles of hollow plant stems like bamboo.
- Creating bee blocks for solitary nesters such as mason and leafcutter bees.
- Creating artificial boxes for bumble bees.

Bee boxes can be purchased or constructed following simple instructions. The UNL Extension publication Attracting Pollinators to Your Landscape offers instructions for constructing a simple bee box (Figure 32).

Figure 32. Bee habitat the UNL Backyard Farmer garden. Photo Credit: Jim Kalisch, UNL Entomology Department.

A clean, reliable source of water is another essential habitat consideration for pollinators. Pollinators can use natural and human-made water features such as running water, pools, ponds, and small containers of water. Water sources should have a shallow or sloping side so the pollinators can easily approach the water without drowning. In addition, irrigation management practices that preserve ground-nesting pollinators include irrigating at night and avoiding flooding any areas.

Increasing habitat to meet pollinator needs can be simply adding to existing plantings or more intensive efforts to establish a larger native area. To convert existing out-of-play areas to a new native area, site preparation is key. It may require more than one season of effort to reduce competition from invasive or other undesirable plants prior to planting. These out-of-play pollinator habitats have been shown to help nearly 50 species of pollinating insects (Dobbs and Potter, Golf Course Management). For more information on establishing a native area, see Pollinator Meadow Upper Midwest Installation Guide and Checklist. In addition, a number of Nebraska-specific lists are available to help select plants for pollinator-related efforts:

- Eastern Nebraska's Flowers for Pollinators. Nebraska Statewide Arboretum.
- Western Nebraska's Flowers for Pollinators. Nebraska Statewide Arboretum.
- Pollinator Plants of the Central United States Native Milkweeds (*Asclepias* spp.). Xerces Society.
- Application for Nebraska Pollinator Habitat Certification Program, which includes plant lists by flowering time. UNL Extension.
- How to Attract Pollinators, which includes a list of larval plants for Nebraska butterflies and a list of plants to promote pollinators in Nebraska landscapes. UNL.

11.4 Pollinator Protection Best Management Practices

Pest Management Practices

- ❖ Before applying a pesticide, inspect the area for both harmful and beneficial insect populations, and use pesticides only when a threshold of damage has been indicated.
- ❖ Consider biological control agents, lures, baits, and pheromones as alternatives to insecticides for pest management.
- ❖ When pesticides are needed, select those with a lower impact on pollinators, such as chlorantraniliprole.

- If a granular formulation will control the pest, choose it over liquid. formulations. Granular versions of pesticides are known to be less hazardous to bees.
- Restrict applications to early morning or evening when pollinators are not as active.
- Avoid applying pesticides during bloom season, and mow first to remove blooms, including those of flowering weeds such as white clover.
- Avoid application during unusually low temperatures or when dew is forecast.
- Use the latest spray technologies, such as drift-reduction nozzles to prevent off-site translocation of pesticide.

Habitat Protection and Enhancement

- Follow site preparation guidelines when renovating areas to ensure success.
- Choose south-facing sites whenever possible for establishing native areas.
- Place plants in masses (three or more) to attract pollinators.
- Select plants of different shapes, sizes, and colors and that bloom at different times of the year.
- Select native grasses that provide foraging and nesting habitat.
- Use both perennials and annuals.
- Leave stems and coarse, woody debris in native areas for pollinator nesting.
- Leave exposed patches of well-drained soil in native areas for pollinator nesting.
- Provide water sources with shallow sides for pollinators.

12 MAINTENANCE OPERATIONS

It is the objective to manage the potential environmental risks associated with golf course maintenance operations. Our industry has a need and responsibility to implement, manage, measure, and improve, pertaining to all aspects of environmental stewardship. It is imperative that hazardous materials be handled, stored, recycled, and disposed in a safe, healthy, and environmentally sound manner.

Pollution prevention includes the proper delivery, storage, handling, and disposal of all chemicals, washwater, and wastewater. For example, washwater from pesticide application equipment must be managed as a pesticide. Conversely, wastewater not contaminated with harmful chemicals can be reused or discharged to a permitted stormwater treatment system. The "Pesticide Management" chapter discusses many maintenance operations-related BMPs specifically for pesticides. This chapter provides additional guidance for maintenance operations and points out differences between managing fertilizer equipment and pesticide equipment.

For unintended releases of any chemicals, an emergency plan, spill kit, and first-aid kit should be readily available. More information on spill kits is discussed in the "Pesticide Management" chapter and a list of spill kit materials is provided in the NebGuide Managing Pesticide Spills.

12.1 Regulatory Considerations

As discussed in the "Pesticide Management" chapter of this document, the NDA regulates the registration, transportation, storage, sales, use, and disposal of pesticides in the state. The NDEQ regulates agricultural chemical containment under Title 198 regulations. The NDEQ publishes the Fertilizer and Pesticide Containment in Nebraska Fact Sheet that can be used to determine if secondary containment (diking) and load-out facilities (load or rinse pads) are required when handling such chemicals. Local regulations may also be in place with respect to the siting of maintenance facilities.

Owners and operators of underground storage tanks (UST) and above-ground storage tanks (AST) for petroleum products must obtain a permit from the Nebraska State Fire Marshal to install new and replacement tanks and piping. Local regulatory authorities should be contacted as well before installing an AST. Underground storage tanks (USTs) for golf course facilities are regulated by EPA under the Technical Standards and Corrective Action Requirements for Owners and Operators of USTs (40 C.F.R. Part 280). A registration form for USTs may be obtained by contacting the Fuels Division of the Nebraska State Fire Marshal.

NDEQ's Petroleum Remediation Program oversees investigation and cleanup of petroleum contamination due to leaks from above-ground and underground storage tanks and must be contacted when leaking is suspected.

12.2 Storage and Handling of Chemicals

Storage facilities that are well designed and well maintained protect people from exposure, reduce the potential of environmental contamination, protect chemicals from extreme temperatures and excess moisture, and, in general, reduce liability concerns and potential environmental risks. The storage area should be secure and provide containment features. In addition, storing and maintaining equipment properly extends its useful life and reduces repairs. Information specifically related to pesticide storage and handling can be found in the UNL Extension's Safe Transport, Storage, and Disposal of Pesticides.

12.3 Equipment Washing

It is an objective to ensure that equipment washing is conducted under controlled conditions in an appropriate contained area with minimal risk to the environment and to prevent adverse washwater and stormwater runoff impacts. Equipment washing guidelines and restrictions should be established that reduce the potential for pollutants to reach stormwater runoff, surface water or groundwater.

Proper cleaning of equipment helps prevent residues from reaching surface waters, groundwater, drainage pipes, or storm sewers. The residues from washing equipment include grass clippings, soil, soaps, oil, fertilizers, and pesticides.

A primary concern when washing mowing equipment is the nitrogen and phosphorus nutrients in grass clippings. Using compressed air to blow clippings off mowers before washing can help reduce the amount of nutrients that enter drains via washwater. The best practice is to have a dedicated wash area with a catch basin to collect remaining grass clippings. Clippings can be collected, then composted or removed to a designated debris area. When formal washing areas are not available, a “dog leash” system using a short, portable hose to wash off the grass at random locations, away from surface waters, wells, or storm drains, is an option.

For equipment with possible pesticide residue, BMPs should be followed to ensure that washwater does not become pollution source. Captured washwater can be used as a dilute pesticide per label, or it may be pumped into a rinsate storage tank for use in the next application and used as a dilute pesticide per the label.

12.4 Equipment Storage and Maintenance

Like chemical storage facilities, equipment storage and maintenance facilities should be designed to prevent the accidental discharge of chemicals, fuels, or contaminated washwater from reaching water sources. Properly storing and maintaining equipment also extends the useful life of machines and reduce repairs (Figure 33).

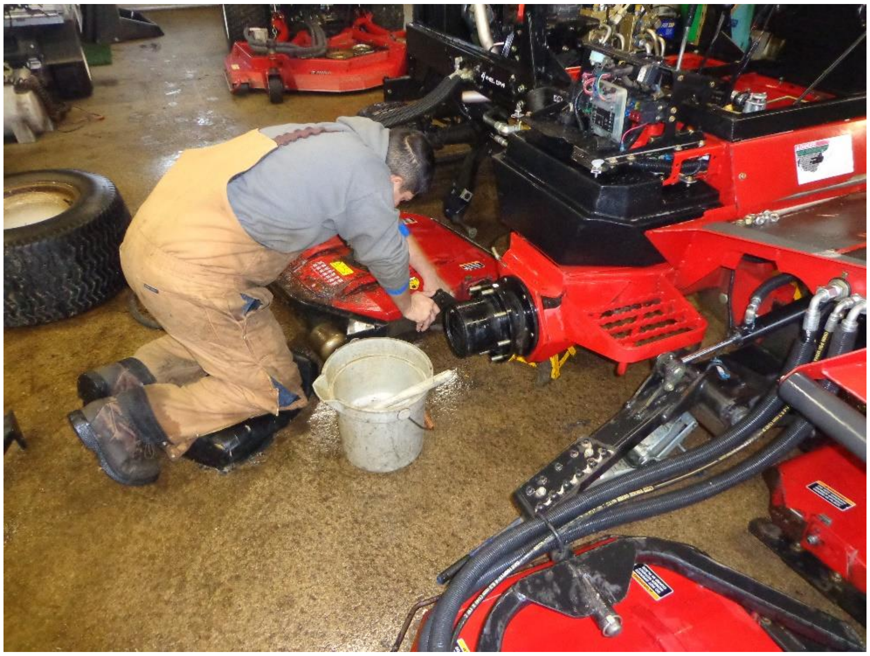

Figure 33. Maintaining equipment extends the useful life of machinery. Photo Credit: Casey Crittenden.

12.5 Fueling Facilities

Fueling areas should be properly sited, designed, constructed, and maintained to prevent petroleum products from being released into the environment through spills or leaks. Regulations and compliance issues differ depending on whether the facility utilizes AST or UST. Above-ground tanks are easier to monitor for leakage and are therefore the approved storage method. Because of the potential for groundwater contamination from leaking USTs, leak detection monitoring is a critical aspect of UST compliance.

Permits from the Nebraska State Fire Marshal are required to install new and replacement tanks and piping. Any leaks or spills must be contained and cleaned immediately. If any potential for petroleum contamination occurs from either a AST or UST, NDEQ's Petroleum Remediation Program should be consulted.

Fueling areas should be sited on impervious surfaces, equipped with spill containment and recovery facilities, and located away from surface waters and water wells. Catch basins in fueling areas should be directed toward an oil/water separator or sump to prevent petroleum from moving outside any containment structure. Floor drains in fueling areas should be eliminated unless they drain to containment pits or storage tanks.

12.6 Waste Handling

Facilities need to regularly review how they handle the disposal of unwanted, expired, or accumulated items, including chemicals, paints, pesticides, tires, batteries, used oils, solvents, paper products, plastic or glass containers, and aluminum cans. Developing recycling programs reduces waste and minimizes the quantity of waste reaching landfills. In some cases, recycling of some wastes may be required locally and superintendents should be aware of these requirements.

All packaging from chemicals, their containers and other wastes should be properly disposed of. Pesticide-specific waste handling requirements are identified on the pesticide label and are discussed in more detail in the "Pesticide Management" chapter of this document.

12.7 Maintenance Operations Best Management Practices

Storage and Handling of Chemicals

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

Equipment Washing

- Brush or blow off accumulated grass clippings from equipment using compressed air before washing.
- Wash equipment on a concrete pad or asphalt pad that collects the water. After the collected material dries, collect and dispose of it properly.
- 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 equipment used to apply pesticides on pads with oil/water separators. Do not wash near wells, surface water, or storm drains.

- ❖ Use spring-loaded spray nozzles to reduce water usage during washing.
- ❖ Minimize the use of detergents. Use only biodegradable, non-phosphate detergents.
- ❖ Use non-containment washwater for field irrigation.
- ❖ Do not discharge non-contaminated wastewater during or immediately after a rainstorm, since the added flow may exceed the permitted storage volume of the stormwater system.
- ❖ Do not discharge washwater to surface water, groundwater, or susceptible/leachable soils either directly or indirectly through ditches, storm drains, or canals.
- ❖ Never discharge to a sanitary sewer system without written approval from the appropriate entity.
- ❖ Never discharge to a septic tank.
- ❖ Do not wash equipment on a pesticide mixing and loading pad. This keeps grass clippings and other debris from becoming contaminated with pesticides.
- ❖ Solvents and degreasers should be used over a collection basin or pad that collects all used material.

Equipment Storage and Maintenance

- ❖ Store equipment in areas protected from rainfall. Rain can wash residues from equipment and potentially contaminate the surrounding soil or water.
- ❖ Perform equipment maintenance activities in a completely covered area with sealed impervious surfaces.
- ❖ Drains should either be sealed or connected to sanitary sewer systems with the approval of local wastewater treatment plants.
- ❖ Solvents and degreasers should be stored in locked metal cabinets away from any sources of open flame.
- ❖ Complete a chemical inventory and keep SDS of each on-site. A duplicate set of SDS should be kept in locations away from the chemicals, but easily reached in an emergency.
- ❖ Use PPE when working with solvents.
- ❖ Use containers with dates and contents clearly marked when collecting used solvents and degreasers.

Fueling Facilities

- ❖ Above-ground fuel tanks are preferred as they are more easily monitored for leaks as compared with USTs.
- ❖ Fueling stations should be located under roofed areas with concrete pavement whenever possible.
- ❖ Fueling areas should also have spill containment and recovery facilities located near the stations.
- ❖ Develop a record-keeping process to monitor and detect leakage in USTs and ASTs.
- ❖ Visually inspect any AST for leakage and structural integrity.
- ❖ Secure fuel storage facilities and allow access only to authorized and properly trained staff.

Waste Handling

- Label containers for collecting used solvents, oils and degreasers.
- Recycle lead-acid batteries. If not recycled, batteries are classified as hazardous waste.
- Store old batteries on impervious surfaces in areas protected from rainfall.
- Recycle used tires, paper products, plastic or glass containers, aluminum cans, and used solvents, oils, and degreasers.
- Provide a secure and specifically designated storage for the collection of recyclable waste products.
- Recycle or properly dispose of light bulbs and fluorescent tubes.

13 LANDSCAPE

The fundamental principle for the environmentally sound management of landscapes is "choose the right plant, in the right place." Ideal landscape plants are native and adapted specifically to the soil, degree and direction of slopes, precipitation type and amounts, wind direction and speed, light patterns, and microclimate. Susceptibility to major damage by insects and other pests is another selection criterion, as are the nutrient levels of the area. By using native or adapted plants that mimic natural ecosystems, landscapes that are designed for the specific location, management capabilities and desired style can reduce overall management inputs, attract pollinators, provide multi-season interest, and enhance out-of-play areas.

13.1 Planning and Design

Planning begins with a careful assessment of existing conditions. Slopes and drainage patterns impact not only the playability of the course, but the survival of existing and proposed plants. A majority of the non-play areas on the golf course should remain in natural cover. Supplemental planting of native or adapted trees, shrubs, and herbaceous vegetation can enhance wildlife habitat, including non-game species, birds, and pollinators, in non-play natural areas, limit soil erosion, and protect stream banks. Mimicking natural ecosystems by leaving dead trees (snags), brushy understory plants, and native grasses and forbs in these areas also reduces maintenance work, by minimizing or eliminating the need to mow or apply fertilizer or pesticide.

Higher-impact, higher-use landscape areas, such as around the clubhouse, should be designed to utilize natural drainage patterns and channel runoff away from impervious surfaces (e.g. paved areas), conserve water, and lower nutritional input requirements once mature. Installing rain gardens in locations where they catch and temporarily hold water (such as near roofs and other impervious surfaces) helps control stormwater runoff, remove contaminants before releasing water into the surrounding soil or aquifer, and conserve water by reducing supplemental irrigation needs. For more information on rain gardens, see the Nebraska Extension publications Rain Garden Design and Plant Selection for Rain Gardens in Nebraska.

Golf courses are excellent facilities for zoning the landscape, using designations of high-impact zones, transition zones, and perimeter zones, and matching high-use and high-impact areas to plants that need more water and likely more-intense management. Taking into consideration the lay of the land, including differences in soil and changes in sunlight levels throughout the day, planning for landscaped areas should include consideration of the water needs in each area. A zoned approach is an efficient way to plan, as follows:

- High-use and high-impact zones: Match plants that need the most water to small, highly visible areas that will be watered as needed.
- Transition zones: Choose plants that require moderate amounts of water to be applied only when they show signs of moisture stress, such as wilting.
- Perimeter zones: Use plants with minimal water requirements. Water during establishment and in periods of extreme drought.

Ideally, 10% or less of the landscaped areas should be zoned for high water use, 30% or less of the area should be zoned for moderate water use, and 60% or more of the landscape should be zoned for low water use.

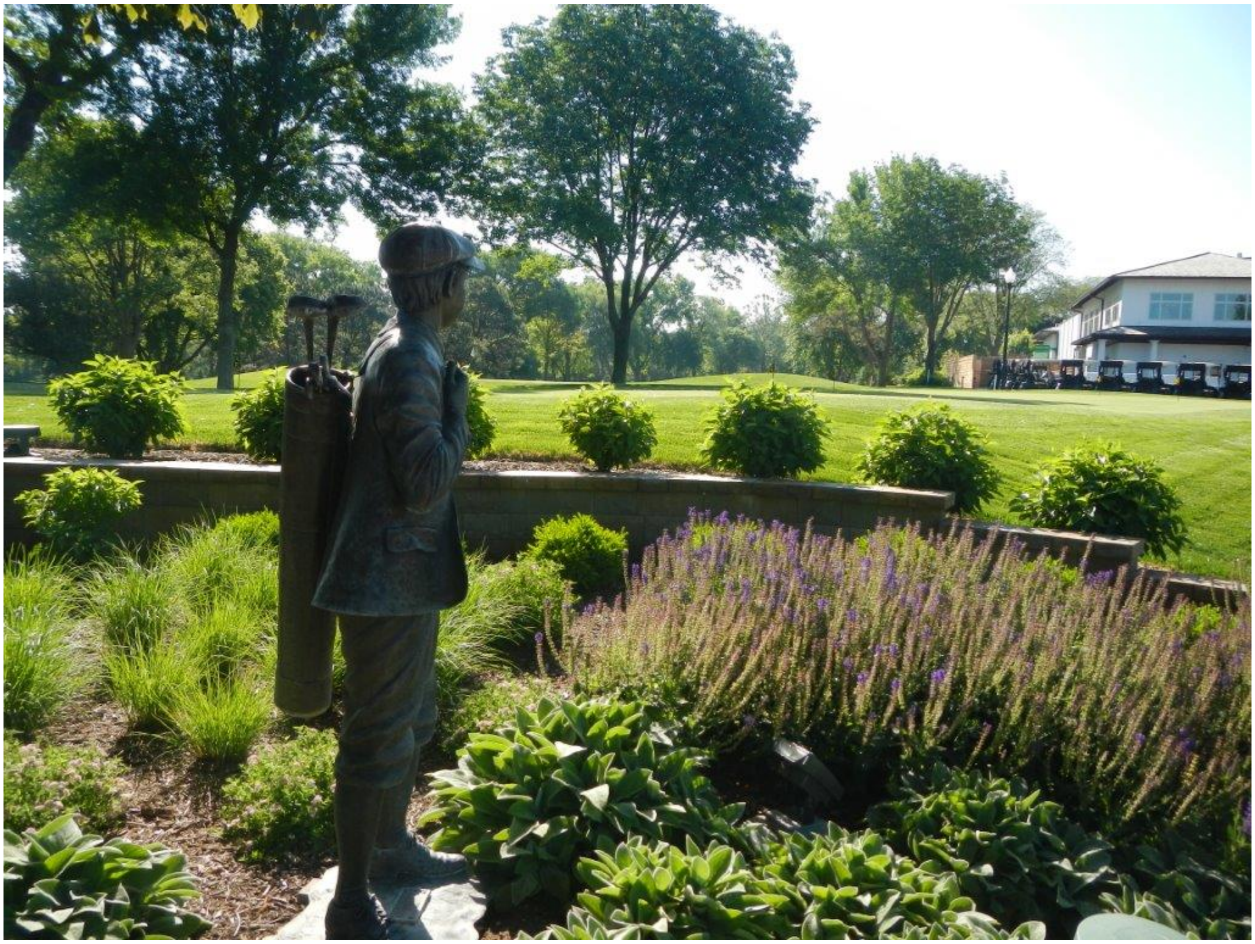

Figure 34. Landscaping at Country Club of Lincoln. Photo Credit: Steve Merkel.

13.2 Site Inventory and Assessment

Before developing a landscape plan, an inventory of existing plants, their condition and quality, their contribution to the overall style of the course, and how they've been managed should be conducted. For landscaped areas, a soils analysis and a soil test should be conducted. The soils analysis evaluates the structure and texture of the soil. The addition of soil amendments can improve the structure and texture of soil, increase its water-holding capacity, and reduce the leaching of fertilizers. Soil amendments, such as compost from clippings, can contribute to an overall healthier plant environment, allowing easier root development and fewer soil-related problems. The use of peat as an amendment should be very limited (such as in containers), as it is both expensive and originates from peat bogs, which are non-renewable. Fertilizers should be applied on the basis of the results of soil tests that have been conducted to identify plant nutritional needs and pH, as described in the "Nutrient Management" chapter of this document.

13.3 Plant Selection

Selection of specific plants should be based to the extent possible on natural ecosystems in the area. This is particularly true for the perimeter zones and out-of-play areas. Native plants can also enhance wildlife habitat by providing forage for different species, such as game and non-game wildlife and birds.

Additional considerations for species selection and placement include design intentions and knowing the ultimate sizes and growth rates of trees, shrubs, and ground covers. This reduces the need for future pruning and debris removal. In addition, the adaptability of plants to a specific site is important. Site-specific characteristics to consider include sun exposure, light intensity, wind conditions, drainage, and temperatures.

For recommended plant species in Nebraska, see:

- Annuals for Nebraska Landscapes, I. Flowering Plants. UNL Extension.
- Annuals for Nebraska Landscapes, II. Foliage, Grasses, Fruit and Vines. UNL Extension.
- Trees for Eastern Nebraska. Nebraska Statewide Arboretum.
- Trees for Western Nebraska. Nebraska Statewide Arboretum.
- Shrubs for Nebraska. Nebraska Statewide Arboretum.
- Native Nebraska Woody Plants. Nebraska Statewide Arboretum.
- Trees and Shrubs for Wildlife. Nebraska Statewide Arboretum.
- Ornamentals organized by water zone needs: https://water.unl.edu/landscapewater/zones
- Water-efficient plants: https://water.unl.edu/landscapewater/ornamentals

The introduction of invasive plants or plants that are potentially invasive should be avoided, and invasive or noxious weed species that are present on the site should be controlled. The Nebraska Invasive Species Program provides lists of invasive species by eco-region.

13.4 Installation

During landscape bed construction, native soil should be used and any hardpan or compaction from construction should be resolved. The beds should be sloped away from buildings, with a minimum percent slope away from buildings of at least 2% for at least 10 feet. Resolve drainage issues and establish clear drainage patterns prior to installing plants. Plants with higher moisture requirements can be planted at lower elevations and drought-tolerant plants at higher elevations.

In general, the best times to plant trees and shrubs in Nebraska are in early spring (March through early May) or in the fall (mid-August through October). These times reduce the stress on the plants by capitalizing on periods of cooler (but not cold) temperatures and more moisture. However, certain species, including some native plants, perform best if planted only in spring unless a high level of management during establishment is available. Herbaceous plants can also be planted during these time periods, although planting earlier in the fall will give these smaller plants a better chance to establish good root systems. Additional guidelines for planting and establishing trees in Nebraska are published by ReTree Nebraska and in Tree-Planting for Success, Nebraska Statewide Arboretum.

Figure 35. Planting trees at Holmes Golf Course. Photo Credit: Casey Crittenden.

13.5 Irrigation

Regardless of their ability to tolerate drought, all plants require supplemental irrigation during establishment. To increase water-use efficiency and improve plant establishment in landscaping, consider hand-watering individual plants for the first several months of the growing season. If the plants have been selected and placed in zones that match their water requirements, irrigation can be scheduled to help efficiently meet the water needs of the entire landscape, thus eliminating regular hand-watering. When needed, plants should be watered in the early morning to conserve water and avoid water loss due to evaporation.

Careful assessment of landscape watering patterns minimizes spray on impervious surfaces, blockage of spray by plants or other obstructions, and runoff on slopes, clay soils, or compacted sites. Focusing the irrigation of woody plants at or beyond the dripline promotes extensive rooting.

For existing irrigation systems, assess the coverage to determine whether changes should be made to identify areas where efficiency can be improved. Ideally, the irrigation system for the landscape beds should be zoned just like the landscape beds. Periodically throughout the growing season, the performance of the landscape irrigation system should be checked.

13.6 Use of Mulch

Mulch conserves soil moisture, mitigates temperature extremes, and reduces weed competition. In winter, mulch helps prevent soil cracks from forming and exposing roots to cold temperatures and winter dessication. Organic mulches include herbicide-free grass clippings (though avoiding applying too deeply to avoid matting and heating the soil), wood chips of varying dimensions. Organic mulches are preferred, as non-organic mulches such as stone may add heat stress around annuals and perennials.

Figure 36. Mulching conserves soil moisture and reduces weed competition. Photo Credit: Russ Cellar.

Annuals and perennials grow best with no more than 2 inches of mulch; mulch around trees and shrubs should be no more than 3-4" deep. With any planting, mulch should be placed between the plants and not on top of the crown or against tree trunks or shrub canes. In winter after the ground freezes, a deeper layer of coarse mulch (evergreen branches) over bulbs and other perennials can delay or prevent early growth.

13.7 Pruning

Correctly pruning trees, shrubs, and herbaceous perennials has multiple benefits throughout a landscape or golf course. Trees and shrubs are pruned first for safety. Pruning in some cases can increase plant health and result in better growth in future seasons. Typically, the ideal time to prune deciduous shade trees in Nebraska is February to March, except in times of drought. Shrubs should be pruned based on their season of bloom (if the flowers are significant). Plants that bloom on second-year or old wood set their flower buds immediately after flowering and can be pruned for the month following bloom. Plants that bloom on new wood, or current-season wood, can be pruned in early spring prior to dormancy break. For more information on pruning, see:

- Pruning Trees, Nebraska Forest Service.
- Pruning Drought Stressed Shade Trees. UNL Extension.

13.8 Pest Management

The same principles and methods identified in the IPM chapter of this document can be applied to landscaped areas. The UNL publication Integrated Pest Management for Landscapes provides guidance specifically for these areas.

13.9 Landscape Best Management Practices

Planning and Design

- ❖ Leave the majority of non-play areas in natural vegetation -- the perimeter zone.
- ❖ Enhance natural areas with supplemental plantings of native and adapted species.
- ❖ In landscaped areas, use natural drainage patterns and directional site grading to channel runoff away from impervious surfaces onto planted areas such as grass swales, filter strips, or rain gardens.
- ❖ Install rain gardens in locations where they can catch and temporarily hold runoff.
- ❖ Minimize the amount of area covered by paved surfaces. Where feasible, use permeable materials such as bricks laid on sand, interlocking pavers or pervious pavers, porous concrete, mulch, or plants.
- ❖ Use a zoned approach to plant management and water needs and minimize the areas zoned for high water use.

Site Inventory and Assessment

- ❖ Conduct an inventory of existing plants, their condition and quality, and their contribution to the overall style of the course.
- ❖ Conduct a soil analysis before choosing specific plants for landscape areas.
- ❖ Conduct a soil test before applying fertilizers. Modify pH if needed, based on soil test results.
- ❖ Amend the soil to improve soil texture and increase water infiltration.

Plant Selection

- ❖ Select native species whenever possible; use adapted species or cultivars of native plants where appropriate.
- ❖ Select trees, plants, and grass species to attract birds seeking wild fruits, herbs, seeds, nesting materials, cover, and insects.
- ❖ Know the ultimate sizes and growth rates of trees, shrubs, herbaceous plants, and ground covers.
- ❖ Select plants recommended for your specific location in Nebraska.
- ❖ Choose the most stress-tolerant species for a particular area.
- ❖ Do not introduce invasive species into the landscape.
- ❖ Control or remove existing invasive species and noxious weeds.

Irrigation

- ❖ Irrigate frequently during establishment.
- ❖ Water established plants based on their water needs and, when needed, deeply and infrequently.
- ❖ Irrigate in the early morning to conserve water.
- ❖ Avoid water runoff onto impervious surfaces or slopes.

- Evaluate landscape irrigation performance periodically.

Use of Mulch

- Use mulch in landscaped beds.
- Use organic mulches whenever possible.
- Use only herbicide-free grass clippings when using grass clippings as mulch.
- Protect bulbs and other perennials in winter with a layer of coarse mulch (evergreen branches) to delay or prevent early growth.

Pruning

- Hire a certified arborist to prune trees as the correct pruning cuts are essential to good tree health.
- Maintain pruning equipment to ensure clean cuts and less risk of damage to the plant.
- Prune deciduous shade trees in late winter (February to March), except in times of extreme drought.
- Prune shrubs based on their season of bloom.

Pest Management

- Use IPM for landscaped areas.

14 ENERGY

The use of energy for all activities in society is of great interest worldwide. Golf courses use a variety of energy sources, primarily electricity, gasoline, diesel, natural gas, propane, and heating oil. Renewable sources, such as solar, wind, and geothermal, are increasingly being utilized and considered by small business as the return on investment increases. These newer technologies offer opportunities to reduce dependencies on fossil fuels and our carbon footprint.

To establish effective energy BMPs, the facility's existing energy consumption should be evaluated and improvements should be achieved through energy reduction, conservation, and new technologies. Energy audits allow for identification of deficiencies. A written energy conservation plan is key to ensuring improvement.

Managers should evaluate current conservation practices based on these categories:

- Buildings, infrastructure, and facility amenities such as the clubhouse, restaurant, kitchen, swimming pool, parking lot, offices, maintenance building(s), tennis courts, restrooms, etc.
- Golf course and surrounding landscapes, and related agronomic operations (playing surfaces, equipment, turfgrass maintenance, etc.).
- Irrigation systems and pump station.
- Plant species selection.

The irrigation system and pump station are the largest consumers of energy on the golf course and should be evaluated. (Figure 37). Conserving and reducing water through irrigation BMPs also reduces energy consumption.

Some policies, financial incentives, and loan opportunities exist at the state and local level for renewables and energy efficiency measures at commercial enterprises such as golf courses. Energy providers can provide information, expertise, and incentives to help achieve these goals. For example, Lincoln Energy Services offers incentives related to heating and cooling, building sealing, insulation, and lighting.

For more information, see the following:

- Nebraska Energy Office.
- Database of State Incentives for Renewables & Efficiency.

14.1 Energy Audits and Evaluation

An energy audit of the facility should be conducted if not conducted previously. Energy audits identify areas most in need of energy conservation. Utility providers can be a source of expertise in conducting an audit, such as the Nebraska Public Power District's energy saver program. An energy audit should include these steps:

- Evaluate insulation in heated buildings.
- Evaluate heating, ventilation, and air conditioning (HVAC) system efficiency.
- Determine annual energy usage.
- Itemize usage according to various categories.
- Determine if energy usage during non-peak hours are maximized.
- Compare usage with similar small businesses.
- Identify areas of improvement.

Determining energy conservation goals and establishing an environmental plan is a first step in addressing energy efficiency. An energy management plan sets a baseline related to current energy use and incorporates quality management elements (plan, do, check, and act) for continual improvements. Once goals for energy conservation are established and documented, this policy should be communicated to all staff.

Evaluating the performance of an energy conservation program requires tracking and measuring energy use at the facility based on energy assessment units (e.g. kilowatt hour, BTU). Monitoring energy usage can be accomplished with energy management software or programs such as EPA's Portfolio Manager, which also incorporates features such as reporting, savings calculations, and carbon footprint calculations. To benchmark performance, energy consumption can be compared with other local golf facilities of similar size or more generally to buildings of similar size.

14.2 Energy Efficiency Improvements

The audit will identify opportunities to increase energy efficiency in buildings, amenities, and operations. For example, ground-based heat pumps conserve energy as compared to conventional heating sources and could be considered for new building construction or replacement for existing heat sources when the opportunities arise. Developing and implementing a viable energy conservation plan will lead to improvements over time.

14.3 Green and Alternative Energy

Green and alternative energy can be incorporated into golf course operations. Golf courses can become small-scale generators of energy through wind, solar, and photovoltaic installations and geothermal heating and pumping. Golf courses normally have the land, space, and natural resources available on the property to lend themselves to energy generation as newer technologies become more affordable. Financial and tax incentives may be available for installing these energy generators.

14.4 Energy Best Management Practices

Energy Audits and Evaluation

- Conduct an energy audit, including lighting, insulation, and HVAC systems.
- Monitor energy use by tracking statistics and "time of use" data.
- Install precision meters, gauges, etc.
- Develop an equipment inventory that documents individual equipment's energy use, traffic patterns, maintenance records, operation hours, etc.
- Benchmark performance against similar-sized facilities.
- Educate, train, and motivate employees on energy efficiency practices pertaining to golf course operations.

Energy Efficiency Improvements

- Evaluate and monitor all energy sources, tracking both costs and any usage trends.
- Add insulation where needed.
- Use non-peak electrical hours for charging golf carts and maintenance equipment.
- Prioritize pump station usage during non-peak hours.
- Limit high-consumption activities when demand is high.
- Install LED lighting and other high-efficiency alternatives.
- Install motion sensors for lights where appropriate.
- Install low-flow faucets.
- Install programmable thermostats.
- Consider energy management software.
- Utilize the EPA's Energy Star and Portfolio Manager programs.
- Utilize the EPA's WaterSense program.
- Maintain good record-keeping practices.
- Prioritize energy consumption as part of decision-making when making purchases concerning all aspects of facility management.
- Evaluate effectiveness of upgrades according to efficiency and conservation goals for energy use.

Green and Alternative Energy

- Consider pursuing the U.S. Green Building Council's LEED certification for new buildings and existing building retrofits.
- Use alternative energy from natural sources, such as solar, geothermal, and wind energy generation when possible.
- Assess the viability of small-scale wind, solar, and photovoltaic installations.
- Install geothermal heating and cooling systems.
- Install solar/geothermal pumps for pools and spas.

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