# Environmental Best Management Practices for Virginia's Golf Courses









*Prepared by*

Virginia Golf Course Superintendents Association

Virginia Chapter GCSAA
GOLF COURSE SUPERINTENDENTS ASSOCIATION OF AMERICA

BMP



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"Our efforts in developing and using this document demonstrate the Virginia Golf Course Superintendents Association's commitment to environmental stewardship."

# Foreword



I am pleased to endorse the *Environmental Best Management Practices for Virginia's Golf Courses.* This manual reflects the current state of scientific knowledge and years of experience of the collaborative partners who developed this document: the Virginia Golf Course Superintendents Association, Virginia Polytechnic Institute and State University, Virginia's regulatory agencies, and private sector partners. This comprehensive document spans all facets of golf course operation, from design and planning of new golf courses, to renovation of existing golf courses, and maintenance operations. These non-regulatory guidelines are designed to protect Virginia's environmental quality and conserve precious water resources. In addition to protecting our commonwealth's natural resources, the adoption and use of these best management practices by the Virginia golf course industry will minimize the need for future regulations while continuing to demonstrate a commitment to sound environmental stewardship.

—Doug Domenech
*Secretary, Virginia Department of Natural Resources*

Golf courses within the state of Virginia vary widely—from coastal courses with ocean views to mountain courses with panoramic views. Protecting all of our state's ecosystems by following these recommended best management practices is a responsibility Virginia's golf course superintendents take seriously. Our efforts in developing and using this document demonstrate the Virginia Golf Course Superintendents Association's commitment to environmental stewardship. The Virginia Golf Course Superintendents Association wishes to acknowledge the time, effort, and expertise of the staff of state regulatory agencies, Virginia Polytechnic Institute and State University faculty, experienced golf course superintendents, and other members of the private sector who partnered with us to help develop these voluntary guidelines for enhancing the environment on Virginia's golf courses.

—Jeff Berg
*President, Virginia Golf Course Superintendents Association*



Kinloch Golf Club *Source:* Larry Lambrecht



"Protecting Virginia's ecosystems by following these recommended Best Management Practices is a responsibility Virginia's golf course superintendents take seriously."

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# Acronyms

| | |
|---|---|
| **A** | acre |
| **AAPFCO** | Association of American Plant Food Control Officials |
| **Al** | aluminum |
| **ASGCA** | American Society of Golf Course Architects |
| **ASIC** | American Society of Irrigation Consultants |
| **AST** | above ground storage tank |
| **B** | boron |
| **BCSR** | basic cation saturation ratio |
| **BMP** | best management practice |
| **Buff** | buffalograss |
| **Ca** | calcium |
| **$CaCO_3$** | calcite |
| **CAD** | computer aided design |
| **$CaMg(CO_3)_2$** | dolomite |
| **$CaSO_4$** | gypsum |
| **CBG** | creeping bentgrass |
| **CBPA** | Chesapeake Bay Protection Area |
| **CCE** | calcium carbonate equivalence |
| **CEC** | cation exchange capacity |
| **CFR** | code of federal regulations |
| **Cl** | chlorine |
| **CMC** | chemical mixing center |
| **CRN** | controlled release nitrogen |
| **CRSUN** | controlled release soluble urea nitrogen |
| **Cu** | copper |
| **CWA** | Clean Water Act |
| **DAP** | diammonium phosphate |
| **DCR** | Department of Conservation and Recreation |
| **DEM** | Department of Emergency Management |
| **DEQ** | Department of Environmental Quality |
| **DO** | dissolved oxygen |
| **DU** | distribution uniformity |
| **E&S** | erosion and sediment |
| **EE** | enhanced efficiency |
| **EPA** | Environmental Protection Agency |
| **ET** | evapotranspiration |
| **Fe** | iron |
| **FEMA** | Federal Emergency Management Agency |
| **FEPCA** | Federal Environmental Pesticide Control Act |
| **FIFRA** | Federal Insecticide, Fungicide, and Rodenticide Act |
| **FF** | fine fescue |
| **GCBAA** | Golf Course Builders Association of America |
| **GIS** | geographic information system |
| **GPS** | global positioning system |
| **GWMA** | Ground Water Management Areas |
| **HDPE** | high density polyethylene pipe |
| **HOC** | height of cut |
| **IBDU** | isobutylidene diurea |
| **IGR** | insect growth regulators |
| **IPM** | integrated pest management |
| **K** | potassium |
| **$K_2O$** | potash |
| **KBG** | Kentucky bluegrass |
| **$K_{oc}$** | partition coefficient |
| **lbs/A** | pounds per acre |
| **$LC_{50}$** | lethal concentration 50 |
| **$LD_{50}$** | lethal dose 50 |
| **LEPC** | Local Emergency Planning Committee |
| **LID** | low impact development |
| **MAP** | monoammonium phosphate |
| **Mg** | magnesium |
| **Mn** | manganese |
| **Mo** | molybdenum |
| **MSDS** | Material Safety Data Sheet |

| | |
|---|---|
| **MU** | methylene urea |
| **N** | nitrogen |
| **$NH_{4+}$** | ammonium cation |
| **$NH_3$** | ammonia |
| **NMP** | Nutrient Management Plans |
| **$NO_{3-}$** | nitrate |
| **NOAA** | National Oceanic and Atmospheric Administration |
| **NRCS** | Natural Resources Conservation Service |
| **NTEP** | National Turfgrass Evaluation Program |
| **OMD** | Organic Matter Dilution |
| **OSHA** | Occupational Safety and Health Administration |
| **P** | phosphorus |
| **$P_2O_5$** | phosphate |
| **PAW** | plant available water |
| **PCU** | polymer coated urea |
| **PET** | potential evapotranspiration |
| **PLC** | PLC programmable logic controllers |
| **PPE** | PPE personal protective equipment |
| **ppm** | parts per million |
| **PR** | perennial ryegrass |
| **RCRA** | Resource Conservation and Recovery Act |
| **RPA** | resource protection area |
| **RPZ** | reduced pressure zone |
| **RUP** | Restricted Use Pesticide |
| **S** | sulfur |
| **SAR** | sodium adsorption ratios |
| **SARA** | Superfund Amendments and Reauthorization Act |
| **SAV** | submerged aquatic vegetation |
| **SC** | scheduling coefficient |
| **SCU** | sulfur-coated urea |
| **$SO_4^{2-}$** | sulfate |
| **SLAN** | sufficiency level of available nutrients |
| **SWPPP** | Stormwater Pollution Prevention Plan |
| **TF** | tall fescue |
| **TKN** | total Kjeldahl nitrogen |
| **TMDL** | Total Maximum Daily Load |
| **TSS** | total soluble salts |
| **UF** | urea formaldehyde |
| **USACE** | United States Army Corps of Engineers |
| **USDA** | United States Department of Agriculture |
| **UST** | underground storage tank |
| **VAC** | Virginia Administrative Code |
| **VCE** | Virginia Cooperative Extension |
| **VDACS** | Virginia Department of Agriculture and Consumer Services |
| **VESCH** | Virginia Erosion and Sediment Control Handbook |
| **VGCSA** | Virginia Golf Course Superintendents Association |
| **VDGIF** | Virginia Department of Game and Inland Fisheries |
| **VFD** | variable frequency drives |
| **VOC** | volatile organic compound |
| **VPCB** | Virginia Pesticide Control Board |
| **VPDES** | Virginia Pollutant Discharge Elimination System |
| **VSMP** | Virginia Stormwater Management Program |
| **VWPP** | Virginia Water Protection Permit |
| **WIN** | water insoluble nitrogen |
| **WIP** | watershed implementation plan |
| **WSN** | water soluble nitrogen |
| **Zn** | zinc |

# 1

# Introduction



“Nearly 37,000 acres of land are devoted to golf courses in Virginia.”



# 1 Introduction

The golf industry in Virginia contributes to the economic health of the Commonwealth while providing recreational opportunities and valuable open space. In 2005, Virginia's direct golf economy was approximately $1.6 billion and 40,189 jobs. The total direct and indirect impact to the state economy is nearly double this amount (SRI International 2006).

With nearly 37,000 acres of land devoted to golf courses in Virginia, golf courses provide abundant recreational opportunities to the state's citizens and tourists, as well as valuable open space. Often located within large population centers such as Northern Virginia, Richmond, and the Hampton Roads areas, golf courses provide advantages over other types of development, such as habitat for birds and other wildlife (Figure 1-1), absorption of stormwater and its potential pollutants, oxygen from photosynthesis, and the cooling effect of evapotranspiration (ET).

Because 70% of the state's golf courses are located within the Chesapeake Bay watershed (Figure 1-2), protection of water quality is of particular importance in the design, construction, and management of golf courses. The golf industry also seeks to protect water quality, conserve water, and provide habitat in order to enhance the environment on and near golf courses. The use of best management practices (BMPs) helps to achieve these goals, not only within the Chesapeake Bay watershed, but also statewide.

The guidance within the *Environmental Best Management Practices for Virginia's Golf Courses* was developed by the Virginia Golf Course Superintendents Association (VGCSA) in cooperation with representatives of Virginia Tech, Virginia governmental agencies, and private sector partners. The summary BMPs (Table 1-1) and the accompanying recommendations emphasize water quality protection and have been specifically adapted for golf courses in Virginia using the results of current research, the experience of golf course superintendents in implementing BMPs, golf industry representatives, and state regulators.



Figure 1-1. Heron at Robert Trent Jones Golf Club. *Source:* David Norman

## Table 1-1. Summary BMP statements for the protection of water quality

| Category | Summary BMP Statements |
|---|---|
| *Planning (Chapter 2)* | Assemble a team of qualified professionals.<br>Develop project goals and objectives.<br>Conduct a feasibility study.<br>Identify site opportunities and constraints.<br>Evaluate site data and develop project alternatives. |
| *Design (Chapter 2)* | Avoid or minimize environmental impacts.<br>Manage stormwater using proper drainage and stormwater management devices.<br>Select appropriate turfgrass species and/or cultivars.<br>Develop a comprehensive master plan.<br>Prepare detailed golf course construction documents. |
| *Construction (Chapter 2)* | Plan for construction.<br>Implement environmentally sound construction techniques.<br>Implement a construction monitoring program. |
| *Irrigation (Chapter 3)* | Conduct water supply analysis to verify quantity and quality of water supply.<br>Plan for water conservation, integrating practices and technology for precision irrigation control and uniform coverage.<br>Design the irrigation system for the efficient and uniform distribution of water.<br>Program and schedule the irrigation system to conserve water.<br>Know the drought resistance differences between turfgrass species.<br>Conduct an audit of the irrigation system. |
| *Surface Water Management (Chapter 4)* | Reduce sedimentation and nutrient enrichment to surface waters.<br>Reduce chemical runoff near surface waters.<br>Maintain dissolved oxygen levels.<br>Use native aquatic plants.<br>Manage aquatic plants by implementing an IPM strategy, considering non-chemical means of control first. |
| *Water Quality Monitoring (Chapter 5)* | Conduct periodic water quality sampling.<br>Follow recommended sample collection and analytical procedures.<br>Interpret water quality reports and take corrective action as needed. |
| *Nutrient Management (Chapter 6)* | Base all fertilization practices other than standard N fertility needs on a soil test.<br>Supplement soil tests with plant tissue tests when necessary.<br>Optimize nutrient use efficiency and reduce leaching potential of readily available nitrogen sources.<br>Use Enhanced Efficiency (slow release or stabilized) N sources to optimize nutrient use efficiency and reduce nutrient leaching potential.<br>Use iron as a supplement to standard nitrogen programs to promote turfgrass greening without flushes of shoot growth.<br>Maintain appropriate soil pH in order to optimize nutrient availability.<br>Apply nitrogen during periods of optimal turfgrass growth.<br>Consider site-specific conditions before making a fertilizer application. |

| Category | Summary BMP Statements |
|---|---|
| *Cultural Practices (Chapter 7)* | Choose the appropriate species or cultivar within a species to match the mowing height needed for use.<br>Raise HOC slightly during summer to improve stress tolerance.<br>Consider rolling to maintain green speeds in the summer.<br>Raise height of cut and lower inputs on shaded turf.<br>Vary the direction of mowing to improve aesthetics and quality of cut.<br>Return clippings to recycle nutrients.<br>Cultivate and topdress to dilute organic matter on putting greens. |
| *Integrated Pest Management (Chapter 8)* | Use biological controls when possible.<br>When needed, select the appropriate conventional pesticides and use judiciously.<br>Manage turfgrasses for reduced disease pressure.<br>Identify problems that limit turfgrass competitiveness for weed control. |
| *Pesticide Management (Chapter 9)* | Select the least toxic pesticide with the lowest exposure potential.<br>Select pesticides that have a low runoff and leaching potential.<br>Consider the impact of site-specific and pesticide-specific characteristics before applying a pesticide and time applications to avoid heavy rain or prolonged irrigation.<br>Minimize off-target drift potential by using properly-configured application equipment and appropriate methods and timing.<br>Store, mix, and load pesticides at least 100 feet away from sites that directly link to surface water or groundwater.<br>Apply pesticides according to label directions, paying careful attention to application site conditions, methods, equipment calibration, and rates specified on the label.<br>Prepare only the amount of pesticide mix needed for the immediate application.<br>Keep records of all pesticide use to meet legal requirements, evaluate pest control efforts, and plan future management tactics. |
| *Maintenance Operations (Chapter 10)* | Store and handle all chemicals appropriately using secondary containment as required.<br>Store fertilizers and pesticides separately and away from other chemicals.<br>Store pesticide and fertilizer application equipment in covered areas to protect from rainfall.<br>Remove grass from grass-covered equipment before washing.<br>Dispose of or recycle wash water appropriately and never discharge to surface waters or septic systems.<br>Store wastes separately and dispose of according to legal requirements. |

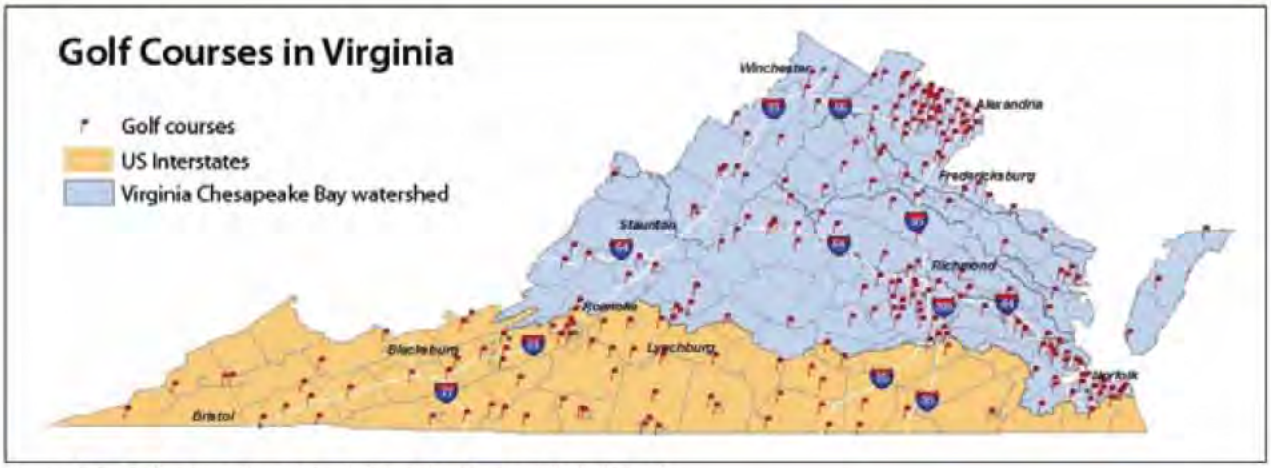



Figure 1-2. Golf course locations in Virginia. *Source:* Virginia Tech.

Virginia's golf course superintendents are cooperating to develop and implement BMPs adapted specifically to Virginia's climate and environment. The widespread adoption of these BMPs will result in lower nutrient loading to waterways, decreased pesticide usage and runoff, and improved water conservation. Furthermore, the voluntary adoption of these BMPs will help to achieve Total Maximum Daily Load (TMDL) goals established by the US Environmental Protection Agency (EPA) for the Chesapeake Bay. TMDLs define the amount of a given pollutant that a body of water can accept and still meet water quality standards.

When golf courses adopt BMPs, they improve not only the environment, but also the quality of the golf course–benefits which encourage the voluntary adoption of BMPs. Specific incentives for Virginia golf courses to implement BMPs include the following:

- reduced environmental impacts
- improved turf quality
- improved golf outing experiences
- improved worker safety
- efficient allocation of resources
- reduced maintenance expenditures

## 1.1 BMP Stakeholders

This document will help a wide variety of stakeholders to understand the use of BMPs for the protection of environmental quality. These audiences include the following groups:

- *Golf course superintendents.* Golf course superintendents are encouraged to perform an environmental assessment of their current operations. This assessment process identifies the BMPs that will achieve the greatest environmental and economic benefit based on site-specific circumstances. Sharing this guidance document with staff will also provide the context for any changes in golf course management activities that may result from an assessment.
- *Current and prospective golf course owners.* Current and prospective golf course owners are encouraged to review these BMPs prior to designing or renovating golf courses in order to plan for environmental stewardship. From site selection to planning for maintenance, it is never too early to begin the efficient incorporation of BMPs.
- *Golfers and other stakeholders.* Golfers and other stakeholders are encouraged to review this document to understand the Virginia golf industry's efforts to protect the state's environment. For example, if golf club members understand the role of BMPs, the members may accept changes in golf course management such as the use of lower maintenance areas and vegetation buffers that protect water quality near streams or ponds. Many golf courses have found that members accept and encourage these changes and are proud of the efforts undertaken by golf courses.
- *Federal, state, and local regulators and officials.* Government regulators and officials can review this document to understand the efforts and commitment of Virginia's golf industry to voluntarily protect Virginia's environment. In this manner all parties are encouraged to work together to enhance environmental quality while continuing to realize the economic and social benefits that golf facilities have to offer.
- *The public and citizen advocacy groups.* Golf course managers should welcome the opportunities for community involvement, such as groups with local citizen water monitoring programs[1]. Interactions between golf superintendents and the local community allow people unfamiliar with golf turf management to understand how a properly maintained golf course benefits the environment, not detracts from it.

[1]See DEQ's Citizen Monitoring web page (www.deq.virginia.gov/cmonitor/links.html). Additional resources are provided in *Virginia Citizen Water Quality Monitoring Program Methods Manual* (DEQ 2007).

## 1.2 Impact of BMPs on Environmental Quality

An ecosystem is a complex set of relationships among the living resources, habitats, and residents of an area, including plants, trees, animals, microorganisms, water, soil, and people. Golf courses are one type of ecosystem that can be effectively managed to sustain a healthy environment for all of the ecosystem inhabitants. Management activities can protect and enhance the ecosystem, while other practices may have negative impacts. For example, the use of vegetative buffers near surface waters can remove nutrients from stormwater runoff and thereby improve water quality. Conversely, poor vegetative cover on a slope can result in soil erosion as well as airborne dust, leading to declines in water and air quality on and around the golf course.

The BMPs outlined in this manual protect golf course ecosystems with the added benefit of enhancing the golfer

experience. A general summary of the environmental benefits provided by golf course ecosystems are provided below. Additional references for more information include *Golf Course Management & Construction: Environmental Issues* (Balogh and Walker 1992) and *Water Quality and Quantity Issues for Turfgrasses in Urban Landscapes* (Beard and Kenna 2004).

### 1.2.1 Air Quality

Compared to urban/suburban environments, golf courses have a positive impact on air quality. Oxygen evolution and air purification due to plant growth significantly outweigh the negatives of fossil fuel emissions from equipment usage, building heating and cooling, and irrigation pump operation. Keeping gas-powered equipment fine-tuned, using electric or propane-powered engines, and designing or upgrading buildings with energy efficiency in mind can also collectively contribute to air pollution reductions. Additional air-pollution offsets can be achieved through increasing secondary and tertiary management acreage (Chapter 2), which require less (or no) irrigation or mowing, with the added benefit of reduced nutrient and pesticide use.

### 1.2.2 Soil and Water Quality

Each Virginia golf course has a role to play in improving soil and water quality within its local watershed (Figure 1-4), which ultimately contributes to reduced pollutant loads into our largest watersheds (including the Chesapeake Bay watershed). Properly designed and managed golf courses maintain nearly 100% perennial vegetative cover, which filters runoff and rarely allows soil erosion. Minimal impervious surfaces, soil test-based fertilizer applications, and non-mowed vegetative buffers around surface waters can actually improve the quality of the water (Chapter 5). Preserving soil and water quality in and around the golf course ecosystem requires practices that prevent soil erosion (Chapters 2 and 7), provide irrigation (Chapter 3), properly use plant nutrients (Chapter 6) and pesticides (Chapters 8 and 9), and manage waste materials (Chapter 10) as discussed in this document.

Preventing soil erosion during golf course construction or renovation projects preserves valuable topsoil and reduces deposition of sediments to streams, ponds, and lakes, within and downstream from the golf course (Chapters 2, 4, and 5). Soil and sediments can introduce pollutants into surface waters from fertilizers, such as nitrogen (N), phosphorus (P), and from pesticides (Chapters 4, 6 and 9). Too much N and P can cause water quality impairments to aquatic species. The protection aquatic life is crucial within the Chesapeake Bay watershed, where the fish, oysters, and crabs provide important environmental, industrial, recreational, and economic benefits to the state. Contributions of N and P from golf courses are likely to be very small if BMPs for stormwater runoff such as vegetative buffers (Chapters 2 and 4), and nutrient management planning (Chapter 6 and Appendix F) are given adequate attention. Water quality monitoring programs (Chapter 5) can be used to determine nutrient loading to waterways; fine-tuning BMPs can address findings of concern.

Pest control also affects golf course soil and water quality. Frequent mowing to low heights, intense foot and cart traffic, and Virginia's hot, humid transition zone climate predispose golf turf to more pest pressure than many other landscape types. Consequently, facilities must use pesticides to control diseases, weeds, and insects in order to maintain functional golf turf surfaces and remain commercially viable. The correct use of pesticides controls specific pests without harmful effects on nontarget organisms such as pets, fish, birds, earthworms, and humans (Chapter 9). Pesticide use alone, however, cannot successfully control or reduce pest damage on golf courses. An integrated pest management (IPM) approach (Chapter 8) must serve as the basis of a successful and environmentally responsible pest control program.

### 1.2.3 Wildlife Habitat

Golf courses can provide high quality habitat to a large and diverse population of birds, mammals, and other wildlife. These contributions are particularly important in densely populated urban areas, where golf courses can provide habitat and serve as refuges and movement corridors for wildlife in an otherwise fragmented landscape. Protecting ecosystem functions and quality (air, soil, and water quality) helps to protect wildlife habitat. In addition, wildlife habitat on golf courses can be enhanced through design features and considerations in maintenance operations.

The BMP recommendations in this publication protect ecosystem functions and therefore wildlife habitat. In addition, a number of golf courses in the state are certified through the Audubon International Cooperative Sanctuary Program for Golf Courses, a program based on site-specific enhancement of natural areas and wildlife habitats[1] (Figure 1-3).

[1]www.audubonintenational.org/ge.html



Figure 1-3. Audubon International-certified Golden Horseshoe Golf Club. *Source:* David Norman.

### 1.2.4 Water Conservation

Urbanization and severe droughts have reduced the supply of affordable and plentiful fresh water for irrigation in Virginia. Therefore, economic, social, and environmental pressures dictate that water is used wisely on Virginia golf courses. Conserving water begins with a water availability analysis (Chapter 3) to ensure that the golf courses do not burden public water supplies. Reducing water needs is one option for conserving water. New and existing golf courses can make an effort to convert out-of-play areas from irrigated, mowed turf to naturalized zones (tertiary management areas) that conserve water while attracting wildlife and enhancing aesthetics. In addition, golf courses can conserve water through turfgrass selection and maintenance operation practices. Chapter 2 discusses planning for and managing areas to conserve water. Chapter 3 discusses irrigation sources and systems, with an emphasis on water conservation.

## 1.3 Virginia Environmental Conditions

### 1.3.1 Climate

The climate in Virginia is classified as "mild mid-latitude" in the subcategory of "humid subtropical", which means that the climate is mild, with no dry season and a hot summer. Virginia's climate can also be termed "transitional", or between the warm climates of the south and the cooler climates of the north. This transitional climate is a demanding environment for growing and cultivating quality turfgrass, significantly influencing turfgrass species selection, culture, pest management, and irrigation requirements. Additionally, climate conditions vary within the state and impact golf course management. For example, the first killing frost is typically early October in the Shenandoah Valley and Blue Ridge, mid-October in the Piedmont, and late October to early November in the Coastal Plain. Finally, within a golf course, microclimates may exist due to slope aspect, shade, soil conditions, and depth to water tables.

All golf courses in Virginia need some level of irrigation to establish and maintain turfgrasses (Chapter 3). In general, turfgrasses require 1–1.5 inches of rainfall or irrigation per week during the summer months to replace water lost during active growth via ET. Due to Virginia's location in the transition zone, most grasses grow moderately well for year-round golfing. Some combination of bentgrass greens and a warm-season playing surface in other primary play areas is typically recommended in most areas of the state, although climatic variations in Northern Virginia and the western mountainous counties may vary this general recommendation.

### 1.3.2 Topography

The variety of topography creates regional climate differences, such as the Shenandoah Valley in the west, the mountain terrain of the southwest, and the coastal plains in the east. Variations in topography can also create microclimates. These topographical differences and their impact on climate variations can require active management of irrigation systems to effectively and efficiently use water.

### 1.3.3 Watersheds

All land and water surfaces in Virginia are part of a watershed, which can be defined as "the area of land where all of the water that is under it or drains off of it goes into the same place" (Figure 1-4). Virginia's rivers and groundwater ultimately drain into vast geographical areas such as the Chesapeake Bay, the Albemarle/Pamlico Sound, the Atlantic Ocean, and the Gulf of Mexico. Golf course managers in particular should familiarize themselves with their immediate and endpoint watersheds to understand how management strategies might impact water sources throughout adjacent and downstream watersheds, including the Chesapeake Bay watershed.

## 1.4 Regulatory Considerations

A number of federal, state, and local regulations and other considerations apply to golf course design, construction, and management in Virginia. Applicable regulatory considerations are addressed in the first section of each chapter of this document. Adhering to these regulatory requirements protects environmental quality, conserves water and other resources, and thus benefits all citizens of Virginia.

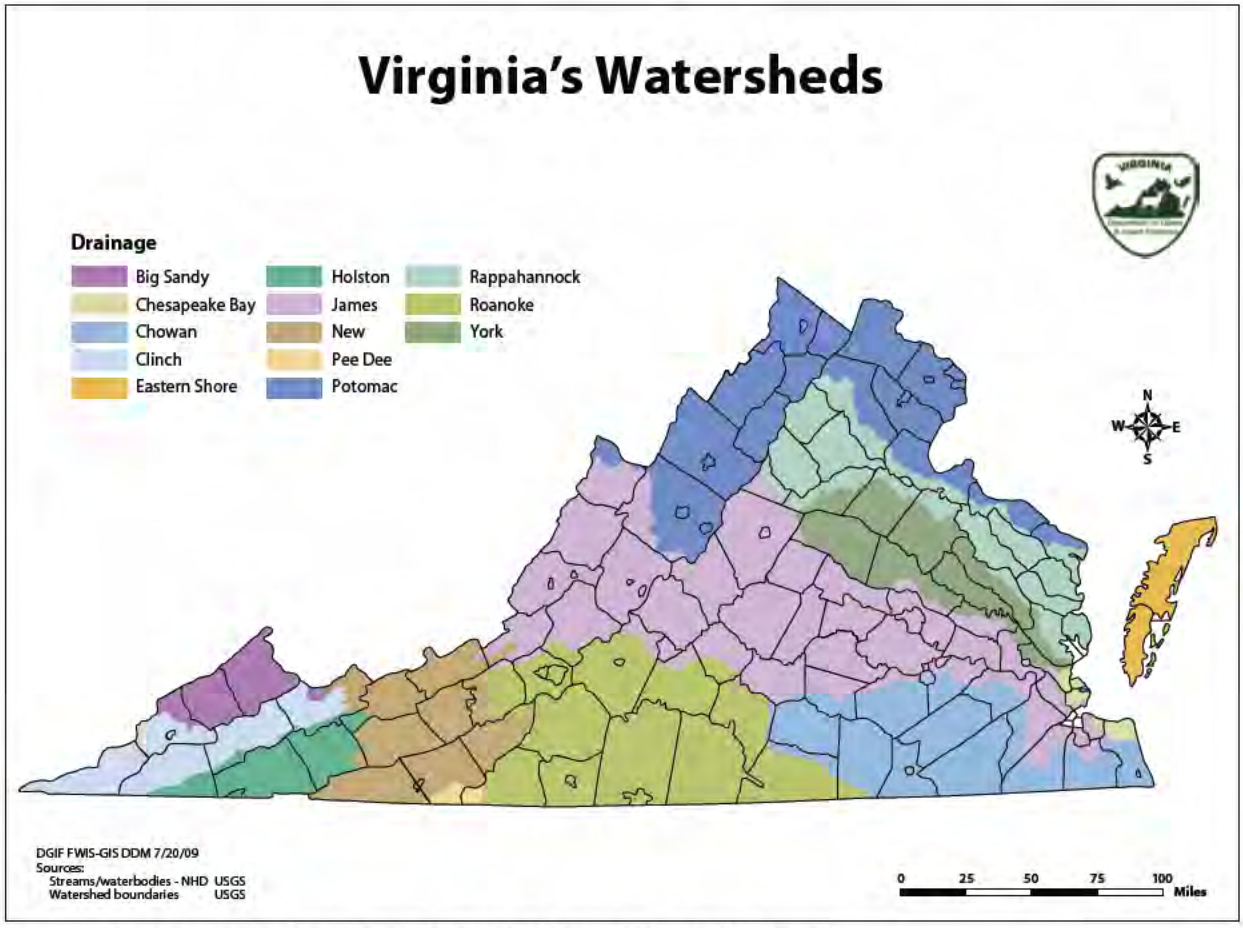



Figure 1-4. Virginia's watersheds. *Source:* VA Dept. of Game and Inland Fisheries.

# 2

# Golf Course Planning, Design and Construction





"The thoughtful use of BMPs during planning, design, and construction should result in an environmentally sustainable golf course that operates efficiently and profitably."

# 2 Golf Course Planning, Design and Construction

Building a new golf course or renovating an existing golf course requires careful consideration of the health of the golf course ecosystem during planning, design, and construction. Designers can draw inspiration and develop a balanced, functional design through intense study of the onsite and neighboring ecological features, habitat documentation, terrain analysis, circulation patterns (such as air, water, wildlife, and traffic), and a variety of other constraints and attributes (Figure 2-1).

The thoughtful use of BMPs during planning, design, and construction should result in an environmentally sustainable golf course that operates efficiently and profitably. Because each golf course project is different, considerable variance in the design process exists. Therefore, the approach outlined in this guidance is general and may not be applicable to all situations. However, this approach provides a framework for good decision making throughout each project phase. Appendix B provides design case studies illustrating the use of design concepts in golf course construction.



Figure 2-1. Golf course design can embrace nature (Ballyhack Golf Club). *Source:* Paul Hundley.

## 2.1 Regulatory Considerations

Regulatory permitting may be necessary during golf course design and construction and can involve federal, state, and occasionally local level regulatory agencies. Regulations can take several forms, including both general and individual permits. Environmental impacts can sometimes be minimized to fall within thresholds for general permits, resulting in a simplified or shortened

### Planning BMPs

**BMP #1**
Assemble a team of qualified professionals.

**BMP #2**
Develop project goals and objectives.

**BMP #3**
Conduct a feasibility study.

**BMP #4**
Identify site opportunities and constraints.

**BMP #5**
Evaluate site data and develop project alternatives.

### Design BMPs

**BMP #1**
Avoid or minimize environmental impacts.

**BMP #2**
Manage stormwater using proper drainage and stormwater management devices.

**BMP #3**
Select appropriate turfgrass species and/or cultivars.

**BMP #4**
Develop a comprehensive master plan.

**BMP #5**
Prepare detailed golf course construction documents.

### Construction BMPs

**BMP #1**
Plan for construction.

**BMP #2**
Implement environmentally sound construction techniques.

**BMP #3**
Implement a construction monitoring program.

permit process. Abbreviated general permits can be activity specific, quantity specific, or both. Activities above general permit thresholds may require individual permits, which can involve a more costly and time consuming application process. Information gathered during the planning phase should be saved for the permit application process.

Permits from local, state, and federal agencies typically include a significant number of general and project specific conditions. During construction, the contractor should be provided with copies of all permits and any specific conditions particularly relevant to the project should be highlighted. In addition, compliance monitoring should be instituted by an owner's representative, such as the course superintendent.

## 2.1.1 Federal

At the federal level, the U.S. Army Corps of Engineers (USACE) regulates encroachment into navigable waters and wetlands under Section 10 of the Rivers and Harbors Act and Section 404 of the Clean Water Act (CWA), respectively. Under federal authority, proposed activities within jurisdictional areas may require an individual, regional, or nationwide permit, depending upon the type of activity and extent of impact. The applicant must demonstrate the sequencing process of avoidance, minimization, and mitigation for proposed impacts to jurisdictional resources as outlined in the Section 404(b)(1) guidelines promulgated by EPA. The CWA provides for state water quality review authority under Section 401 as discussed below.

Permits for impacts to wetlands and streams generally require compensatory mitigation measures such as purchase of credits in a wetland/stream bank, payment of in-lieu fees, or the creation of wetlands or streams onsite or offsite. These permit applications must document that the impacts cannot be avoided, and that the proposed project is the least environmentally damaging alternative.

## 2.1.2 State

Below are regulations and permit requirements typically necessary for golf course construction. Additional state regulations may be applicable, such as Virginia Department of Conservation and Recreation (DCR) dam safety regulations that may apply to larger impoundments such as irrigation lakes (see Section 4.1).

### 2.1.2.1 Water Quality

The CWA provides state water quality review authority under Section 401 for nontidal wetlands (Section 62.1-44.15 of the Code of Virginia). DEQ reviews the terms of nationwide permits, once issued, and can elect to certify water quality under Section 401 of the CWA, certify with conditions, or deny water quality certification.

The Virginia Marine Resources Commission (VMRC) regulates encroachment into, over, and under state-owned submerged lands (Section 28.2-1200 of the Code of Virginia), independent of federal action under the CWA. VMRC also administers Virginia's tidal wetland act (Section 28.2-1300 of the Code of Virginia).

### 2.1.2.2 Stormwater Management

Prior to construction, a Virginia Stormwater Management Program (VSMP) Permit for construction activities from DCR is required. Stormwater permit applications require a Stormwater Pollution Prevention Plan (SWPPP) and permit fee. Stormwater permits require quarterly photo monitoring at all impact sites and semi-annual reporting with photo and narrative documentation. The VSMP permit issued by DCR also requires compliance inspections. Regular inspections of all disturbed areas are required within 48 hours of a runoff-producing rainfall event. Compliance with the SWPPP must be documented on inspection forms and the records kept onsite.

Virginia stormwater regulations remain subject to revision and may impact individual golf courses. Expected changes include a move to a "Runoff Reduction Method" for stormwater runoff calculation that includes additional variables such as changes in land cover, site specific characteristics, and more realistic estimates of real-world runoff conditions.

### 2.1.2.3 Erosion and Sedimentation

Erosion and sediment (E&S) control plans must be prepared by a Virginia Professional Engineer (PE) in accordance with the Virginia Erosion and Sediment Control Handbook (VESCH) (DEQ, 1991)[1] and regulations (4VAC50-30). E&S regulations require a sediment control plan to be submitted, compliance documentation, and onsite recordkeeping.

## 2.1.3 Local and Regional

### 2.1.3.1 Chesapeake Bay Preservation Program

Localities with the Chesapeake Bay watershed are required to conduct a Chesapeake Bay Preservation program

[1] See http://dcr.virginia.gov/stormwater_management/e_and_s-ftp.shtml

pursuant to the Chesapeake Bay Preservation Act and guidance from DCR's Chesapeake Bay Local Assistance Program. Local Chesapeake Bay ordinances provide for regulation of runoff to minimize pollution entering tributaries of the Chesapeake Bay and establish resource protection areas (RPAs). RPAs generally include tidal wetlands, nontidal wetlands connected by surface flow and contiguous to tidal wetlands or surface waters with perennial flow, tidal shores, and a buffer of at least 100 feet along these features.

Only very specific types of development areas are allowed within an RPA, such as water dependent facilities and certain redevelopment. Ordinances typically allow limited clearing to remove dead, diseased, and dying vegetation and to open vistas and site lines on a limited basis. New golf course development would not be allowable in an RPA; however, limited encroachment can sometimes be approved through an exception request process. Similar to the wetland permit application process, the applicant must show no practical alternative to the encroachment, no adverse impacts to water quality, and sufficient proposed mitigation measures. These mitigation measures typically entail enhancement of the RPA buffer through planting or other improvements, such as repair of existing eroded areas. Some localities outside of the Chesapeake Bay watershed have enacted similar ordinances on a voluntary basis.

#### 2.1.3.2 Floodplains

Development within a floodplain is generally regulated at the local government level through a floodplain ordinance based on guidance from the Federal Emergency Management Agency (FEMA).

#### 2.1.3.3 Other Local Regulatory Considerations

A grading or land disturbance permit may also be required for disturbances of generally 2,500 square feet for Chesapeake Bay Protection Area (CBPA) communities and typically 1 acre for others. Localities may also regulate tree preservation and stormwater management, including drainage and design of onsite ponds or other stormwater BMPs. In addition, detailed site plan review is required at the local level for buildings such as the clubhouse and maintenance facility. This review usually involves several local departments to address issues such as zoning, utilities, and fire safety.

## 2.2 Planning Phase

### 2.2.1 Planning Team

Most golf course projects benefit from professional help. The extent of the professional team varies with project size and complexity, but normally begins with the hiring of a qualified golf course architect, such as a member of the American Society of Golf Course Architects (ASGCA) and a certified golf course superintendent. The golf course architect can advise the client of the professional disciplines required for a particular project and can help assemble the team. Experienced professional judgment is crucial when applying BMPs in the planning, design, and construction phases of golf course development. Niche disciplines that may be required include: golf course and clubhouse architects, marketing/economic consultants, ecologists, environmental and civil engineers, soil engineers/scientists, agronomists, geologists, archeologists, irrigation designers, golf course builders, and construction managers.

**Planning BMP #1**
Assemble a team of qualified professionals.

In addition to the hiring of qualified consultants, the process of assembling the team includes permanent staff. The superintendent should be included in the design process and, at a minimum, the construction of the golf course. During construction, a golf course superintendent can be an effective project manager and liaison for the ownership and golf course architect. This expertise and the superintendent's participation in the process can greatly affect the success of the ensuing golf course grow-in and maintenance.

### 2.2.2 Project Goals and Objectives

The professional team can help refine goals and objectives so that they are realistic, achievable, and appropriate for the owner, project setting, economic climate, and current trends in the industry. Although the process of developing goals and objectives varies depending on the complexity of the project and the ownership structure, it must be fully and carefully implemented to ensure success of the project. Clear goals and objectives provide the road map necessary for development of project scope and helps build consensus among project owners and stakeholders.

**Planning BMP #2**
Develop project goals and objectives.

### 2.2.3 Feasibility Study

Environmental, financial, and market factors constrain projects to some extent. A feasibility study should be conducted to analyze a project and is critical for avoiding the waste of time and resources. For example, completing a full golf course design on a site that does not have an adequate irrigation water supply would be a mistake, yet this mistake has been made.

**Planning BMP #3**
Conduct a feasibility study.

The feasibility study for a new golf course project or major renovation project typically analyzes three key project components: marketing/financial, environmental, and design considerations. In addition, a site selection process may be a part of the study if a site has not already been identified. Each of these components is discussed in more detail below.

#### 2.2.3.1 Marketing / Financial Analysis

This study is typically conducted by an expert in golf course marketing and economics and is normally required to obtain project funding from a lending institution, but is also prudent for self-funded projects. The study typically evaluates the existing golf market supply and demand, as well as any other planned projects within proximity of the proposed project, and uses these data to forecast the financial viability of the proposed project.

#### 2.2.3.2 Environmental Analysis

Numerous environmental issues impact the feasibility and design of a golf course. The feasibility study focuses primarily on identifying issues that may be a "fatal flaw" which renders the project infeasible. The study is normally conducted by environmental consultants experienced with golf course projects who typically review a list of site characteristics, such as:

- irrigation water availability
- drainage patterns
- steep slopes
- soils/geology
- vegetation
- stream channels
- floodplains
- wetlands
- Chesapeake Bay or other preservation areas
- habitat for threatened and endangered species
- cultural resources

Although all of these characteristics influence the design of a golf course and some can pose serious constraints, the most common fatal flaw in design is the lack of irrigation water availability.

#### 2.2.3.3 Golf course design feasibility and site selection

Ideally, a golf course architect has had the opportunity to evaluate multiple sites and recommend the one that best meets the project goals and objectives. In practice, however, the site has often already been selected and the architect is limited to evaluating the feasibility of constructing a golf course on the selected site. In a renovation project, the golf course routing may already be established; however, an assessment by a qualified architect is still beneficial and may provide design possibilities that increase the viability or value of the project.

Site selection has an immense impact on all future decision making. A site must meet acreage requirements ranging from approximately 150 to 250 acres or more, depending upon site-specific characteristics such as topography, property line constraints, setbacks, zoning, water, wetlands, buffer zones, soils, steep slopes, and sensitive wildlife habitat. Of these, topography is particularly important. Gently rolling hills of long, broad frequency tend to make up the most ideal terrain from a design perspective. Conversely, severely steep or excessively flat sites may not be suitable. Softly undulating sites provide more natural-looking holes and are easier to construct because less earthmoving is required; these sites increase cost effectiveness and cause less disruption to the native environment.

In the site selection process, consider the use of degraded sites such as landfills, strip mines, and brownfields. In fact, these sites should be embraced as an opportunity to turn an environmental liability into a healthy sustainable site while providing recreational and economic opportunity at the same time. Economic incentives also often exist for redevelopment of these sites. See Appendix B, Case Study #2 as an example of golf course development on a brownfields site.

### 2.2.4 Site Features

Once a site is selected and the project limits and scope are determined, the next planning step is to identify the site opportunities and constraints. By overlaying all of these features onto one map, it becomes evident which areas of the site to avoid and which to consider for development.

This exercise also helps designers understand the site's desirable characteristics (which may provide opportunities for unique and exciting golf holes) and alternatives for locating facilities such as the clubhouse, irrigation supply, and maintenance facility. The site characteristics considered in the environmental analysis (Section 2.2.3.2) are part of the information to be gathered. Other information needed includes zoning, local development regulations and guidelines, site access, adjacent properties, existing buildings and utility infrastructure, prevailing wind conditions, and sun orientation. The information gathering process should also entail a thorough review of public records including site history and context, previous development applications, aerial and site photographs, geographic information system (GIS) data, and boundary surveys. In addition, studies such as groundwater availability, soils, geologic and archeological investigations, habitat surveys, water quality testing and traffic studies may be necessary, depending on the issues that are anticipated and relevance to the site and project.

**Planning BMP #4**
Identify site opportunities and constraints.

## 2.2.5 Site Evaluation

Once the necessary site information has been gathered and mapped, the context and functionality of the site can be assessed. The golf course architect typically develops several concept/routing plans for consideration by the client across multiple sites or entirely on one preferred site. This alternatives analysis ensures that all possibilities are exhausted in the effort to design the best possible golf course consistent with project goals and client expectations. This process is also an important component of the regulatory process, since an alternatives analysis is required as part of a joint permit application for any jurisdictional impacts (Section 2.1). Finally, the alternatives analysis facilitates a re-assessment of the project goals and objectives as well as the project budget before moving into the detailed design phase. Each of these is discussed in more detail below.

**Planning BMP #5**
Evaluate site data and develop project alternatives.

### 2.2.5.1 Context and functionality of the site

A thorough understanding of the site and its relationship to its local watersheds, geology, historical context, and habitat is essential for a successful golf course design. These various facets are often interrelated and help to define a sense of place for the project as well as ensure that the course respects the local environment and culture.

The process of understanding the site should never be considered complete and should continue to improve as the project progresses.

The functionality of the golf course for play is intertwined with the environmental features of the site. Although sensitive environmental areas should be delineated and avoided, designers must understand how these features relate to the remainder of the site and adjacent lands, wildlife, and overall ecologic function in order to protect these systems. Disregard for ecologic functionality can adversely affect course design in less obvious ways as well. The effects of gentle or severe topography clearly affect play, but the design of a golf features may be more complex when factoring in vegetative patterns, sun angles, wind conditions, and relative humidity. For example, a golf green located in a low spot with poor morning sunlight and little air movement requires more intense efforts to maintain than a green on a sunny, breezy, well-drained location. These efforts include increased labor and additional chemical and mechanical inputs that can adversely affect the environment, the efficiency of the golf course operation, and the bottom line over time. Identifying the environmental features at this stage also provides information for the development of an IPM program (see Chapter 8).

In addition to avoiding areas that should be protected, a thorough evaluation of the project site can uncover unique features that the public might not otherwise notice. With foresight and careful planning designers can showcase unique attributes such as rock outcroppings, waterfalls, and remarkable plant configurations, while keeping their sensitivity intact. Moreover, understanding the functionality of the site can assist golf course architects in protecting key habitat connectivity during the golf course routing process. With proper study of these aspects, a more sensitive, ecologically functional, and ultimately more profitable golf course can emerge.

### 2.2.5.2 Water availability analysis

The early identification of an adequate and sustainable irrigation supply should be the foremost priority for any new golf course project (Section 3.2). In addition to ensuring a water supply, this analysis also demonstrates to local officials, agency representatives, and citizens that the project will not burden public water supplies.

#### 2.2.5.3 Re-assessment of project goals and objectives

Once alternatives have been developed and studied, revisiting the project goals and objectives can be helpful. For example, the alternatives analysis may suggest a change in scope from 18 to 36 holes or from a public to a private facility. This re-assessment is also an appropriate time to review any design program developed and to update budget estimates and schedules.

## 2.3 Design Phase

### 2.3.1 Environmental Impact Assessments

The design should avoid or minimize environmental impacts identified during the planning phase and addressed during the regulatory permitting process. In addition, the design can incorporate innovative approaches to address specific site conditions. For example, hydromulches, erosion control matting, and spray-on products not addressed in the Virginia Erosion and Sediment Control Handbook (VESCH) can be used to help control erosion.

**Design BMP #1**
Avoid or minimize environmental impacts.

#### 2.3.1.1 Wetlands and Streams

Wetlands are generally described as lands where saturation with water is the dominant factor determining the nature of soil development and the type of plant and animal communities living in the soil and on the surface. The presence of wetlands should be identified in the field by qualified wetland specialists. Impacts to wetlands and streams generally include activities such as filling, dredging, flooding, or converting areas from one habitat type to another. These activities may require a permit from one or more of the regulatory agencies.

In some instances, construction activities within a wetland boundary or stream can improve the resource. For example, a highly degraded stream or wetland can sometimes be reshaped, rehabilitated, or replaced entirely to meet project goals and improve ecological function. Stream restoration throughout Virginia has taken on added significance in recent years for improving overall water quality by reducing sedimentation. Qualified environmental consultants can evaluate the overall benefit of stream enhancement or restoration and advise how such alternatives may be viewed from an agency perspective.

#### 2.3.1.2 Floodplains

Golf course development is often compatible with floodplains, particularly when compared to other uses such as residential or commercial development. For new projects, minimizing encroachment into the floodplain to the extent possible is prudent (See Appendix B, Case Study #1). 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 the local ordinance. 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 FEMA review along with potential revision to the floodplain mapping.

Finally, construction within the floodplain can cause damage to the golf course and loss of golf play due to periodic flooding. Design key golf course components (such as greens and tees) above the 100 year flood elevation if possible, while considering any effects on the floodplain and floodway and making the required offsetting adjustments in grades or vegetative treatment. An iterative process between the golf course architect and water resources engineer can be critical in ensuring proper water management.

#### 2.3.1.3 Tidal Wetlands

The following features are generally found within RPAs and are regulated by the Chesapeake Bay Preservation program 100-foot wide buffer adjacent to and landward of each:

- tidal wetlands
- nontidal wetlands connected by surface flow and contiguous to tidal wetlands or surface waters with perennial flow
- tidal shores

### 2.3.2 Stormwater Management

Stormwater management planning is required through the regulatory process. Furthermore, proper golf course drainage influences the quality of every aspect of the course and therefore has a profound impact on the long-term quality of the golf course turf, the maintenance requirements, and golf course revenue.

**Design BMP #2**
Manage stormwater using proper drainage and stormwater management devices.

Poorly draining golf courses often fail and are at greater risk for environmental concerns. Erosion can quickly result in a stream that receives poorly defined pipe outlets. A pond will stagnate if it has a poorly shaped edge or cove that does not accept flow from either a significant drainage area or the curvilinear flow within the pond itself. Poor drainage design usually requires retrofit solutions, which result in more maintenance, chemical, and energy inputs than needed for a well-designed course.

Techniques that manage and conserve water, such as Low Impact Development (LID) philosophies, should be adopted whenever possible. LID techniques filter, infiltrate, retain, and detain stormwater runoff near its origin and mimic the natural hydrology of the site to promote infiltration whenever practical. Depending on the intent and need, methods of water management include the selective slowing and speeding of grades to move water which can be used in conjunction with one or more structural water management devices discussed later in this chapter. Existing golf course construction techniques can be smartly modified to assist in water quality and water quantity protection. While tradeoffs in design exist, these effects should be planned for in advance as much as possible.

#### 2.3.2.1 Surface Drainage

Proper surface drainage is the most reliable method for removing water from the golf course play areas. Therefore, understanding natural drainage patterns is critical for planning. From a legal perspective, a drainage system cannot adversely impact neighboring properties.

A successful drainage pattern conveys significant offsite drainage around or through playable areas of the golf course. Drainage design can use existing drainage channels or implement a storm drainage system to capture water above the playable area and safely release it below the playable area. Slope design also affects drainage. Typical playable golf course slopes range from 1%-8% within fairway areas. Although much higher slopes can be played and maintained, in Virginia moderate slopes are recommended. Non-amended surfaces (typically anything outside of greens or tees) should be graded at 3% at minimum in most soils, although 2% can be used on extremely well-draining soil. However, be careful in finishing surfaces near the lower regions of this range, as slopes lower than 3% in turfgrass can degrade over time and result in poor drainage. Over time, these slopes can shift, thatch accumulates, and soils compact due to traffic in ways that alter the functionality of the surface.

Designers must also consider the flow of water as it leaves greens, tees, fairways, and bunkers. Areas of lesser maintenance should not be neglected and are often an important part of the site ecology with their own complex considerations. Surface drainage should be collected to the extent practical and funneled to irrigation storage, as discussed in Chapter 3.

#### 2.3.2.2 Subsurface Drainage

Gravity pipe systems that supplement traditional surface drainage fall into the subsurface drainage category. Subsurface systems often consist of catch basins (Figure 2-2), small diameter high density polyethylene pipe (HDPE), French and gravel drains, and sumps. These methods allow golf course architects to augment or correct the natural drainage processes onsite so that play and maintenance practices can be accommodated properly. Pipes are typically small diameter, 4-6", and remove nuisance residual water from smaller storm events, but are not designed for large volumes of water. Once storm events exceed the capacity of these pipes, runoff reverts back to more traditional, natural drainage patterns. To a lesser extent, large diameter pipes, headwalls, and water control structures can be installed when drainage solutions require a more robust engineering solution. In all cases, the size of the solution must fit the size of the problem.

#### 2.3.2.3 Pipe Outfalls

Small diameter pipe outfalls are not intended to carry large flows and thus typically do not pose major threats to site stability; however, these pipes should still be planned with care. Generally, new pipe outfalls should not discharge directly into the bed or bank of waters. If possible, outfalls should be allowed to buffer diffusely through vegetation. Diffusion is generally accomplished using an enhanced outlet protection system incorporating a level spreader. Diffusing the flow from the pipe slows velocity, promotes infiltration, and improves water quality filtering.

Site constraints can often make diffusion impossible and prevent location of discharge pipes away from the watercourse. Typically, this situation occurs on flat sites where there is only enough elevation at the limit of the stream channel to provide adequate cover over the pipe. Steep areas can also interfere with outfall locations. In these instances, discharging a pipe prior to entry into an incised channel can cause head-cut erosion and instability for the stream and adjacent golf features. Therefore, the priority should always be on long-term stream stability. Unless extenuating circumstances prevail, final outfalls from large diameter pipe, 12" and greater, should adhere

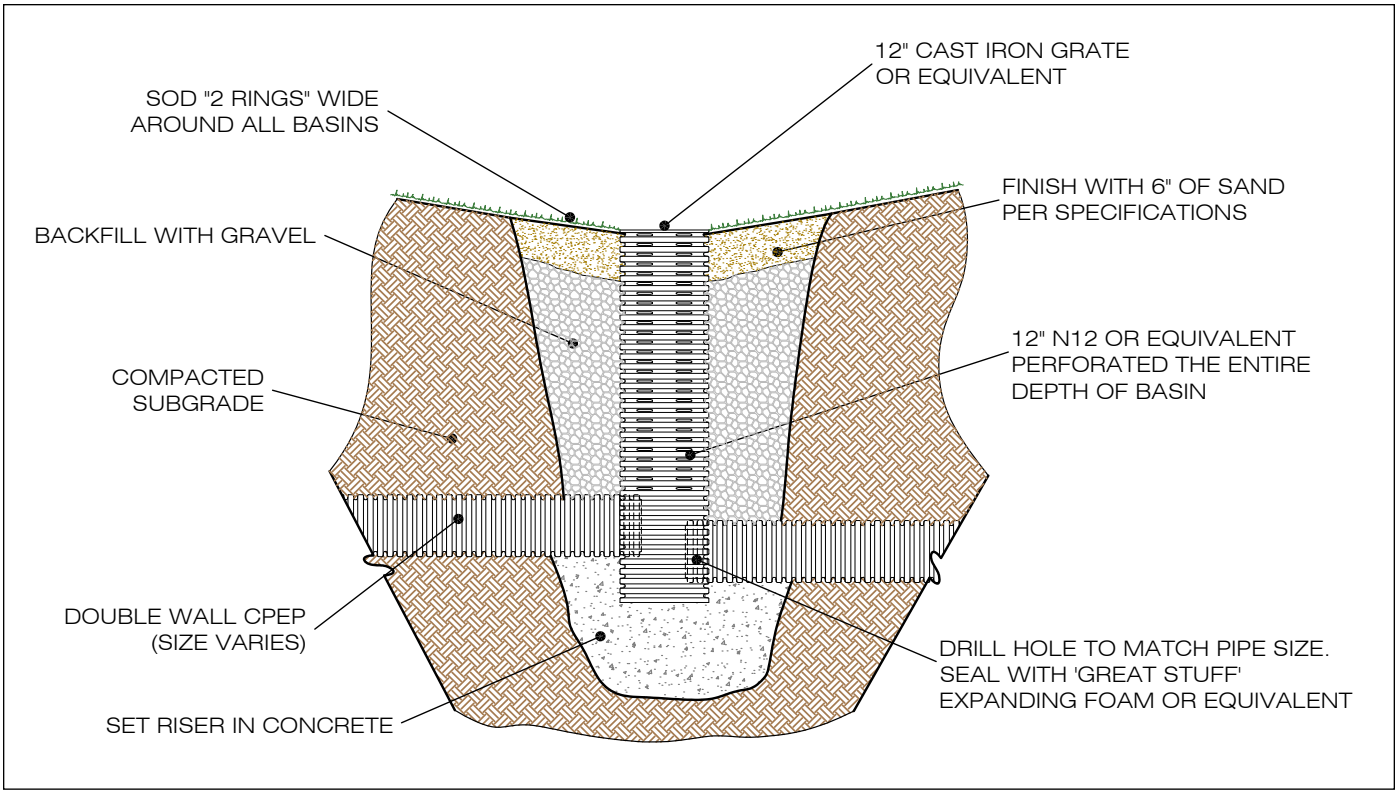



Figure 2-2. Typical catch basin design. *Source:* George Golf Design.

to VESCH Standard & Specification 3.18 entitled Outlet Protection (DCR 1992).

### 2.3.2.4 Stormwater management devices

Intensive runoff management is generally not required for golf courses to the degree and specification applied in residential and commercial areas. Runoff management principles can often be applied in an extremely cost-effective manner in subtle ways to slow water in appropriate areas and encourage infiltration. By incorporating this approach intermittently throughout the site, the collective effect reduces water velocity to non-erosive levels at points of concentration. Often, this approach can be as simple as adjusting grades to speed and slow water at critical areas, but must be done with considerations for playability, agronomy, and maintenance practices.

Grass or other vegetative solutions suitable for use in swales and diversions should be used whenever possible, but when it is necessary to collect water in a pipe, it should be contained until it can be released diffusely in a lower maintenance area with nominal grade (Figure 2-2). The cumulative effects of piping and discharging may be cost effective in the near term, but can create future maintenance problems and potential environmental issues. When working in highly sensitive areas, localities may request additional water quality protections from pipe outfalls. More robust stormwater devices may need to be designed and installed. Possible green solutions include vegetated treatment systems such as filter strips, filtering systems, and bio-retention. More traditional retention and detention structures can be designed where needed (see DCR's *Virginia Stormwater Management Handbook* [DCR 1999]), although the level of detail shown may not be required in a golf context. Several modified structural water management devices are discussed below and include: grassed swales, drywells, infiltration trenches, modified infiltration catch basins, level spreaders, vegetated filter strips and buffers, detention basins, retention basins or ponds, sediment or pretreatment forebays, and constructed wetlands.

*Grassed Swale.* Possibly the most useful passive solution to moving and managing water on a golf course is an appropriately placed grassed swale. Swales have been used for years to keep runoff away from tees and greens, but are now being employed more extensively. Swales can be used in both high and low maintenance areas. In lower maintenance areas, vegetated swales can include taller native grasses to increase water quality treatment. By artfully shaping the bottom of these swales, golf course architects can speed and slow water as needed to move volumes more quickly or more slowly to promote infiltration. A strict

application of a grassed swale with intermittent structural (concrete or rip-rap) ponding sections that stair step down the length of the swale may be required in severe cases where runoff comes off steep slopes towards the golf course areas from out of play. These cases often occur in the mountainous western portions of the state.

*Drywells.* A drywell, or sump, is an excavated pit in the existing soil filled with compacted gravel that provides a subterranean outfall for a small diameter golf course pipe with minimal drainage areas (Figure 2-3). Drywells have historically been used only on flat sites or where dead-end drainage does not permit access to a free outfall due to topographic constraints. In some instances, however, this can be a valuable tool in promoting infiltration. Drywells have great advantages in the golf environment because they can be highly adaptable in size, because they are embedded in the ground, and because they do not require large areas or impinge on the aesthetics of the course. Drywells should be sited in areas of low maintenance, since they can produce soggy conditions in their general vicinity, particularly in clay soils and especially when designed without an overflow mechanism to release water.

*Infiltration Trenches.* An infiltration trench is an excavated void in the soil filled with gravel that intercepts small storm volumes via surface runoff for water quality treatment.

Infiltration trenches can be modified in to meet the goals of stormwater management as well as golf course management. For example, a modified infiltration trench can be used to mark the edge of a maintained area prior to runoff to a highly sensitive system (such as a wetland). The most effective infiltration trench application in a golf environment is a grassed swale with a gravel trench running longitudinally in the bottom of the swale.

Planned wisely, infiltration trenches can be a cost-effective method of assisting golf course drainage while performing additional water quality treatment. The effectiveness of these trenches depends on existing soil percolation rates; if correctly applied, the trenches provide benefits in most environments encountered in Virginia. Within highly maintained areas such as near greens, infiltration trench variations such as French drains (which are small diameter sub-surface pipes encased in the gravel trench) provide healthy turf, reduced damage from residual moisture, firm playing characteristics, and some infiltration.

*Modified Infiltration Catch Basin.* Catch basins can also be modified to promote additional infiltration (Figure 2-4). In appropriate soils, they can be designed with sizeable infiltration storage below the surface without causing adverse impacts to golf course operation. In areas with borderline infiltrative soils, they should be used in areas well out of primary maintenance.

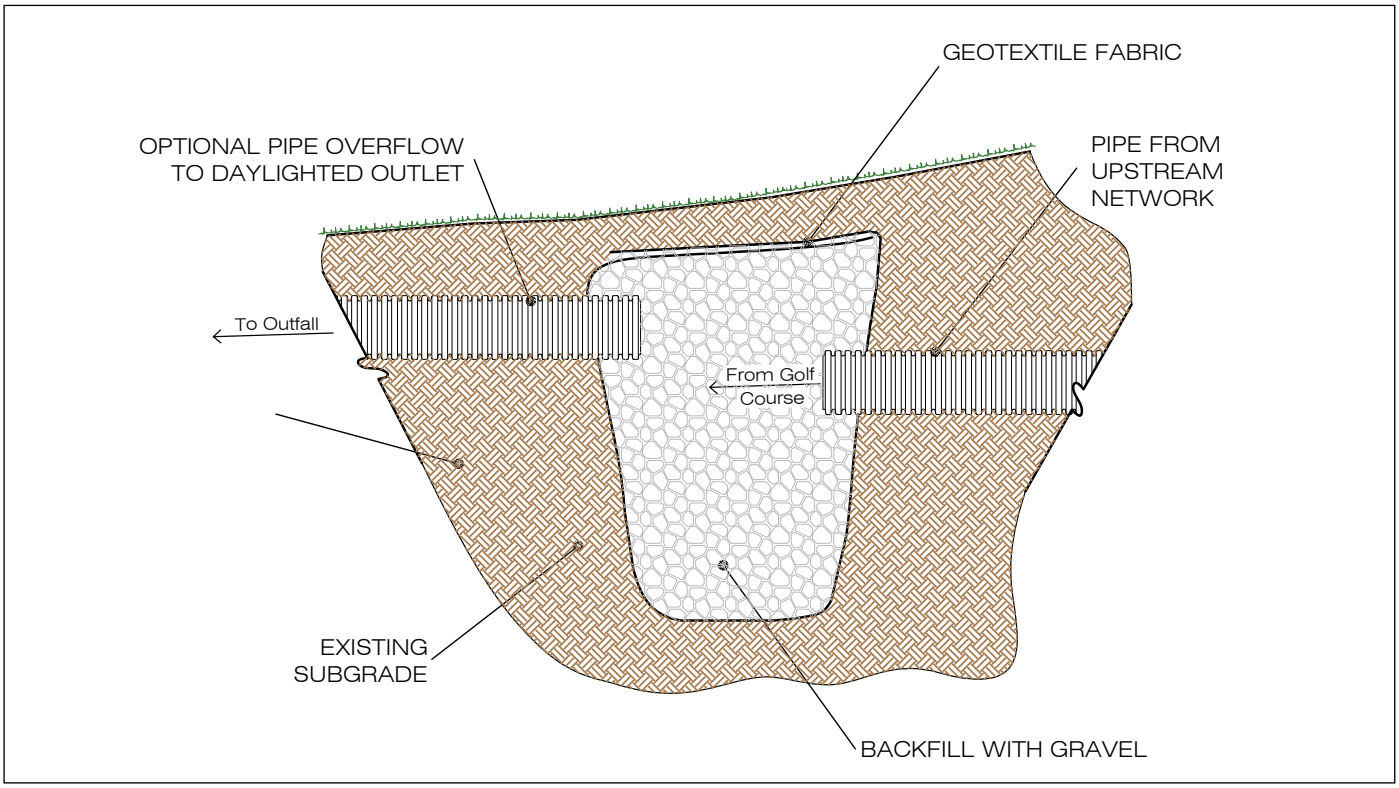



Figure 2-3. Drywell. *Source:* George Golf Design.

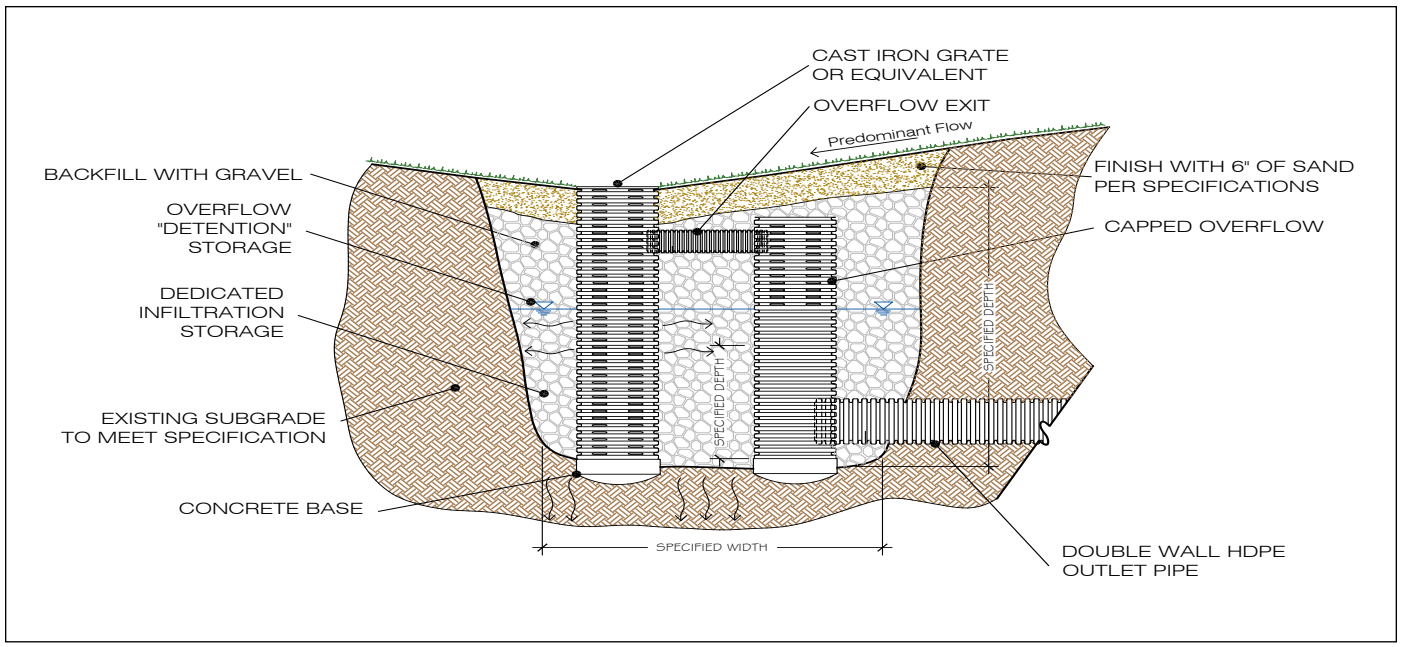



Figure 2-4. Modified infiltration catch basin. *Source:* George Golf Design.

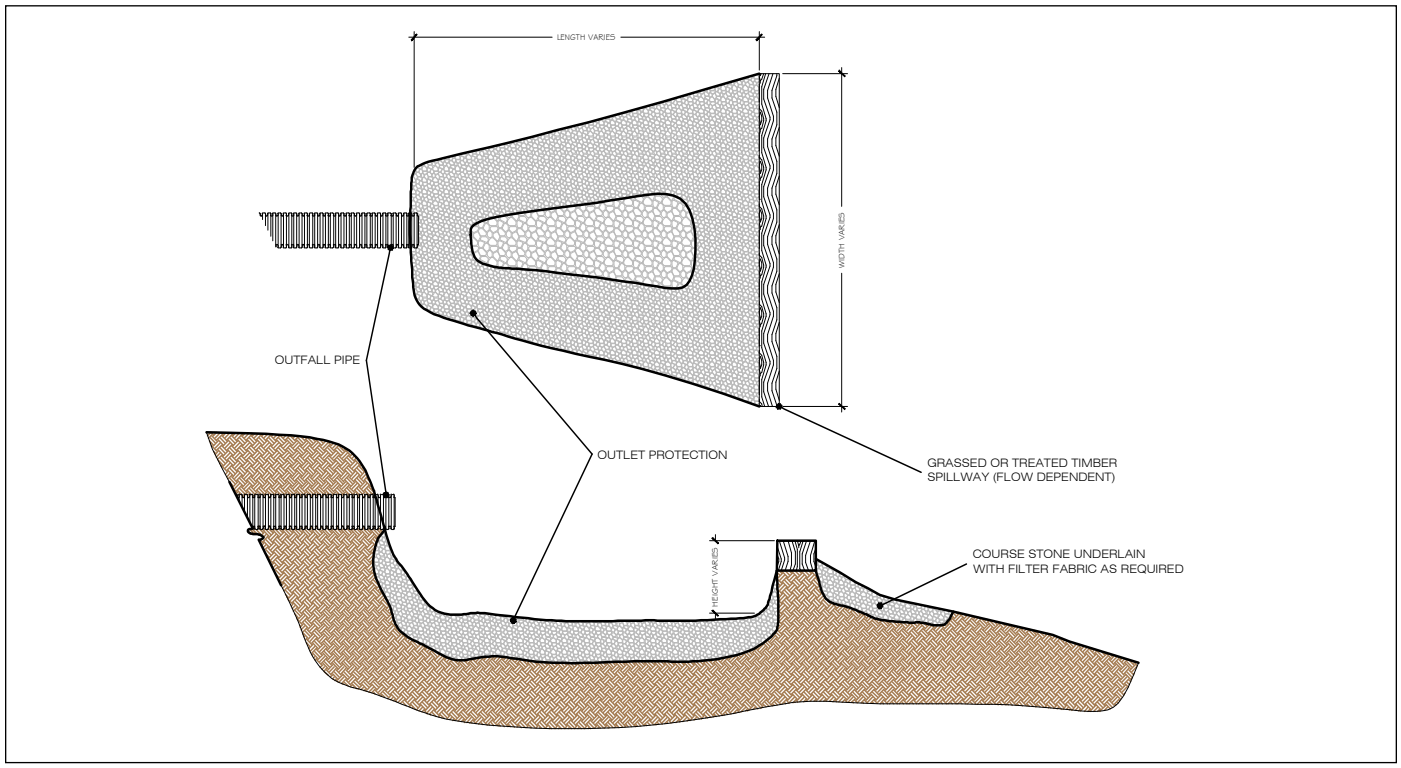



Figure 2-5. Level spreader. *Source:* George Golf Design.

*Level Spreaders.* Level spreaders are rudimentary devices that convert concentrated water flow, such as from pipe outfalls, to less violent sheet flow into areas of existing vegetation (Figure 2-5). Water spreads out over a much wider cross section with a minimal depth, thus reducing water velocity and erosion. Many different styles of level spreaders are available and are most effective at the outfall of larger pipe networks that discharge into or near sensitive areas. Where possible, these outfalls should be placed beyond the boundaries of wetlands and waters allowing the diffuse flow to filter through existing vegetation.

*Vegetated Filter Strips and Buffers.* Whether required or a design feature, vegetated buffers can protect

environmentally sensitive areas. These filter strips allow surface flow to be filtered naturally, prior to entry into wetlands, waters, or other sensitive habitat. Buffer widths are site and project dependent. Long-term planning of buffer areas can be implemented as conservation measures and can also be incorporated in the golf corridor without inhibiting play or routine maintenance.

*Detention Basin.* Detention basins are dry depressions that fill with stormwater and are de-watered over a period of time, allowing pollutants to settle and slowing post-development flows to pre-development levels. Although this level of treatment is rarely required in large traditional existing golf courses, the methodology can be adapted to provide additional small-scale stormwater benefits. For example, designers can include small detention areas (that most golfers will not notice) throughout a golf course. While they can be overused, small diameter pipe networks with catch basins to intercept surface flow have become common. Drainage measures of this type should supplement rather than replace natural surface drainage, but do afford great flexibility in design.

When used in a soft draining swale, small diameter pipe networks can become an effective method of small scale flow detention (Figure 2-6). Catch basins, as shown above,

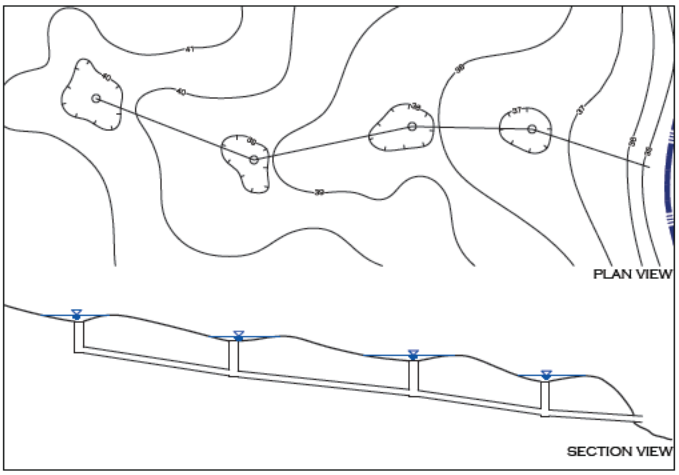



Figure 2-6. Soft draining swale used in combination with a small diameter pipe network. *Source:* George Golf Design.

can be installed in small depressions within a swale creating small ponding areas during storm events that exceed the desired design capability of the subsurface pipe. By effectively choking flows with pipes under-designed for significant rain events (when there is no play), additional detention is obtained. Once the small dry volume is exceeded the water simply overflows safely toward the next basin, down the swale, and eventually to the outfall. As the rain event subsides the basins flow rate can catch back up and function again to remove the residual water prior to the resumption of play. These small detention areas may seem insignificant, but their collective effects in sensitive areas can be substantial.

When instituting this type of design technique, proper pipe sizing calculations ensure that small to moderate storms do not result in wet conditions long after the rain event has passed, since these conditions can impact the resumption of play. For this reason, it is often prudent to locate these features in lesser trafficked, lower maintenance areas. These can also be used effectively during construction as mini de facto "sediment traps", allowing water and sediment to be collected in small areas across the site in a localized fashion. Striking a balance with the various benefits and costs of catch basins is critically important, because the installation expense becomes unnecessary in well-drained soils. In the unlikely event that a larger detention measures are needed, a more formal detention basin can be designed (DCR 1999).

*Retention Basins or Ponds.* Water features are often implemented in golf course design to compliment strategy and aesthetics; however, water features may also be used for stormwater management, wetland mitigation, and irrigation storage. Benefits to using these features include the potential for increasing wildlife habitat and potentially less daily maintenance. However, in some areas within the golf corridor (i.e.,, near landing areas), these features may actually increase the maintenance load. For example, a pond with coves that does not naturally receive flows of water (either from overland flow or flow within the pond) can become stagnant and require intensive maintenance and chemical inputs. Therefore, different design options should be considered in conjunction with other goals and benefits across the site.

*Sediment or Pretreatment Forebays.* Pretreatment forebays are confined pooling areas at key inflow points to lakes and ponds that initially trap pollutants and sediment. Often these structures can be designed to be imperceptible as they help to isolate sediment deposition in a consolidated location, deferring the need for more frequent pond excavation and expense. See Chapter 4 for more information on forebays as a lake management strategy.

*Constructed Wetlands.* Constructed wetlands can increase stormwater treatment efficiency, enhance beauty, increase golf course strategy, and offer additional wildlife habitat.

Whether created as stand-alone wetland or integrated into larger surface waters such as irrigation lakes, opportunities exist on golf courses to integrate wetland creation into golf hole design and to provide wetland mitigation credits, a potential source of revenue. A golf course architect and environmental professional should be consulted to determine the feasibility of constructed wetlands.

### 2.3.2.5 Using stormwater for irrigation

Drainage measures used to manage stormwater can also be used to provide irrigation supply via water harvesting methodology to divert runoff and direct it to an irrigation storage facility. These systems also recycle some portion of existing irrigation volumes. Moderate expense is typically required, although in some situations the expense may be significantly greater and additional networks of pipe may be required. The viability of this approach depends greatly on site specific characteristics. A cost benefit analysis is an important tool in this decision-making process.

### 2.3.2.6 Planning stormwater management with other development

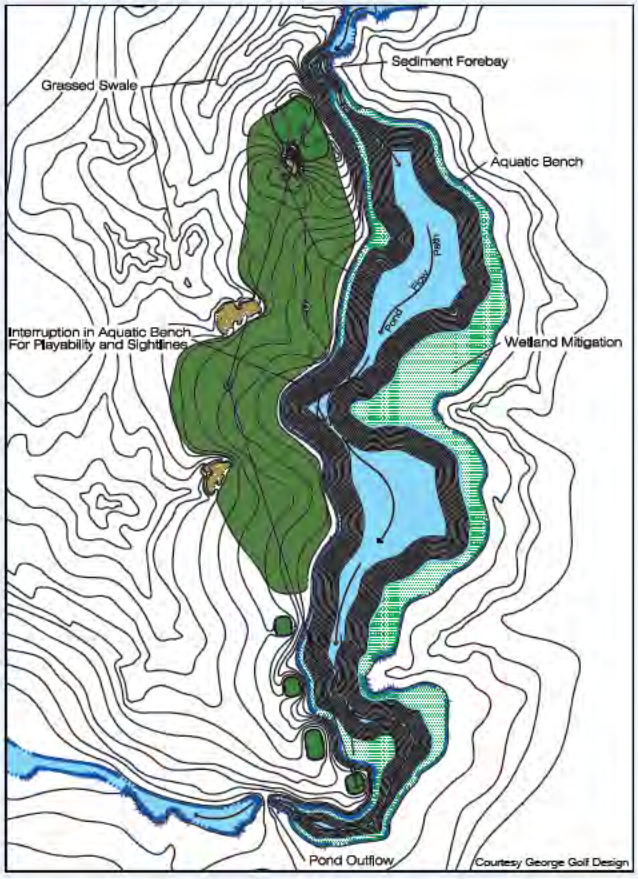
When planned in conjunction with other development (such as associated residential or commercial development, clubhouse, lodging, or maintenance facility), golf course water supply needs can often be integrated with stormwater detention or retention facilities, providing added stormwater treatment for the development and supplementing irrigation supplies. However, the terms of use and withdrawal rights must be clearly defined to protect all parties. Many new courses are forced to implement highly complex irrigation storage transfer systems, requiring intricate negotiations and agreements with other legal entities. Provided the solutions are mutually beneficial, this can be achieved, although simplified solutions work best if possible.

## 2.3.3 Turfgrass Selection

Turf varieties should take into account such variables as drought, cold, heat, and disease resistance; color; fertilization requirements; pesticide requirements; and intended mowing heights. The National Turfgrass Evaluation Program (NTEP) provides information on the testing and adaptation of the major turfgrass species and publishes the results, searchable by state and NTEP test location (see www.ntep.org for recommendations based on Virginia test locations). In addition, the selection of drought resistant turfgrasses for roughs/fairways can decrease irrigation needs significantly (Chapter 3) and disease resistant turfgrasses can decrease pesticide usage

### Integrated Design Example

Many of the concepts and techniques discussed in this section can be combined into an integrated design solution balancing playability, strategy, environmental, and budgetary concerns. The figure below depicts a golf hole that provides interest and playability for various skill levels; irrigation storage; flood storage; a sediment forebay; wildlife habitat and wetland; and a design that reduces maintenance inputs due to water flow design. This is just one example of the many ways in which the goals of golf, the environment, and profitability can be merged. As effective as these components may be, it is not necessary to employ one or all of these characteristics in a golf course design since their inclusion depends on site characteristics. Regardless of whether structural water management devices are employed, there is no substitute for foresight and prudence when designing golf course features so that they are maintenance- and water-friendly.



(Chapter 8). Informed turfgrass selection can greatly affect other aspects of a design, so these decisions should be made as early as possible.

**Design BMP #3**
Select appropriate turfgrass species and/or cultivars.

## 2.3.4 Comprehensive Master Plans

A comprehensive master plan incorporates the design considerations and all other necessary components into a single plan and is essential whether planning a new golf course or renovating an existing golf course. A master plan is particularly helpful when a project is implemented in phases. In addition to the design considerations for avoiding or minimizing environmental impacts, managing stormwater, conserving water, and selecting turfgrass species and/or cultivars as discussed previously, the master plan should take into account maintenance boundaries and considerations for primary, secondary, and tertiary areas.

**Design BMP #4**
Develop a comprehensive master plan.

### 2.3.4.1 Defining maintenance boundaries

The golf course architect and golf course superintendent can work together to determine maintenance boundaries for defining primary, secondary, and tertiary maintenance areas (Figure 2-7). A hierarchical design can incorporate each type of maintenance area into the overall golf course design.

*Primary Maintenance Areas.* The overall program of the golf course facility must be laid out to efficiently accommodate daily maintenance routines. The architect must consider the management needs of each area and deliberately delineate the expected bounds of areas requiring moderate to high maintenance inputs under normal golf course operating conditions, such as greens, tees, bunkers, primary rough, and fairways. These primary maintenance areas are the most critical as they determine the ultimate success of the golf operation and customer satisfaction. While beauty is important, proper playability and turf health should take precedence over aesthetic considerations. These boundary areas have a profound effect on the extent of irrigation and the budgeting of all maintenance requirements, such as mowing equipment needs and annual fertilizer requirements.



Figure 2-7. The fairways and rough at Ballyhack contrast starkly with the tertiary maintenance areas dominated by fine fescues. *Source:* Paul Hundley.

*Secondary Maintenance Areas.* Secondary maintenance areas are those that mimic traditional golf course rough characteristics but may have less traffic and therefore require less (or no) irrigation and less mowing and nutrient input than primary rough. Considerations should be made for these areas to receive less maintenance attention while still providing a playable surface with an acceptable lie. Input and understanding from the golf course superintendent is critical in defining these areas in both the preliminary and final design stages.

*Tertiary Maintenance Areas.* Tertiary maintenance areas have the lowest possible maintenance input and are the least playable surfaces (although they are not 'no maintenance areas') and require some level of maintenance. Golf course architects and superintendents can break down tertiary maintenance areas into multiple tiers of maintenance input, which may change over time. Providing flexibility in these requirements allows smart adaptation for issues like fringe playability concerns and budgetary shortfalls. In addition, opportunities to implement environmental mitigation projects, such as conservation easements, stream restoration, wetland mitigation, habitat creation, and in the future nutrient credit exchange programs, may exist in tertiary maintenance areas. Environmental mitigation projects may compensate for any golf course construction-related impacts or provide mitigation credits for other development projects in the areas, earning additional income for the golf course.

Located well beyond normal golf course play, tertiary maintenance areas may include native grasses, a forested area, or a diverse habitat of plant species. The playability goals of primary and secondary maintenance areas should not apply to tertiary maintenance areas, although the opportunity for a player to locate and advance the golf ball

can be attained. However, many modern golfers consider these areas unplayable and education may be necessary to communicate the value of these tertiary areas.

Many issues should be considered where the tertiary maintenance areas are meant to reflect native environments. Where possible, the areas near high quality waters, sensitive habitat, and drainage features can be incorporated into the design even if they enter into or cross the primary maintenance areas (Figure 2-8). Any clearing required in these areas should be accomplished by hand rather than by mechanized equipment. Care should be taken in these areas to minimize their intrusion into primary maintenance areas ensuring playability for golfers. Densely wooded areas, riparian corridors, wetlands and deep ravines often do not fall within the golf corridor. In these cases, the emphasis shifts even greater to environmental issues such as water quality and wildlife management. Since these areas often have specific restrictions, environmental consultants can develop construction and maintenance plans to ensure that the plan meets regulations and incorporates good environmental stewardship. Resource protection areas and other riparian buffers can often be enhanced with the planting of native vegetation to slow runoff and improve filtering of pollutants. DCR publishes information on riparian buffers and native plantings[1] (DCR 2011).



Figure 2-8. Wetland crossing at Independence Golf Club. *Source:* David Norman.

[1] http://www.dcr.virginia.gov/natural_heritage/documents/riparian_nat_plants.pdf

## Example of Hierarchical Maintenance Design




Wildlife management considerations can also be incorporated into the design of tertiary areas. The environmental analysis, which typically includes include an inventory of existing species and various habitats, should be used during the planning and detailed design of the course to include resource needs such as food, cover, water, and sufficient space for foraging and breeding. To the extent possible, these areas should be as large and as natural as possible. Natural corridors should be used to connect larger natural areas to facilitate wildlife movement. In addition, the introduction of native species and the installation of birdhouses can enhance biodiversity.

### 2.3.4.2 Use of the native and/or non-invasive species

Native plant material can be incorporated outside of the primary maintenance areas. These plantings should be undertaken with experience since some native plants may be complimentary in the golf environment, while others may not be, such as aggressive grasses or shallow rooting trees. For example, the native Eastern Red Cedar

*(Juniperus virginiana)* can be found on many golf courses that transitioned from farm activity or can be the product of planting efforts by members. The cedar's shallow root system spreads widely, robbing moisture from the soil and creating difficulty for even the most basic mowing practices. The extensive root system also discourages grass growth under the trees, decreasing playability. Such ill-advised plantings can increase maintenance concerns and require re-planting. Virginia DCR publishes additional information on native plant materials[1].

#### 2.3.4.3 Communicating the plan

A comprehensive master plan keeps the various members of the project team focused, communicates the project goals to regulators and stakeholders (such as private club members, daily-fee golfing patrons, municipal and county governments, business and community leaders, and homeowner associations), and serves as an important tool for outreach to those outside of the project. The ecological and economic benefits and implementation of BMPs should be effectively communicated to stakeholders and the general public.

Additional input from regulators and other stakeholders may prove beneficial with increased understanding for the duration of the project. Reviewing the master plan with these stakeholders is particularly helpful for phased approach projects. Agency representatives typically appreciate being informed about the overall vision rather than receiving information on a piecemeal basis through a series of phased submittals.

### 2.3.5 Golf Course Construction Plans

Construction plans that clearly communicate the design plan are an invaluable tool for ensuring that all parties understand the project. All critical data from the environmental resource inventory as well as key notes regarding construction processes should be included on the golf course construction plans. Challenges often arise in construction that were not addressed during the design document phase. Proper design is completed in the field and the presence of thorough construction documents, including detailed plans and specifications, assists those involved in responding to any unforeseen challenges, ensuring that a sound framework is in place.

**Design BMP #5**
Prepare detailed golf course construction documents.

[1] www.dcr.virginia.gov/natural_heritage/nativeplants.shtml

## 2.4 Construction Phase

During construction, the site should be kept as stable as possible and erosion minimized. Many creative ways to implement a course design and grassing in the field are available during construction and should be tailored to the site. However, the emphasis during construction must on performing the work properly with care, to minimize the potential for problems during the process and in the future.

### 2.4.1 Construction Planning

Countless problems may be encountered during construction. Although eliminating all risk from the construction process is impossible, proper planning can help to avoid many of the typical pitfalls.

**Construction BMP #1**
Plan for construction.

#### 2.4.1.1 The project team re-visited

A successful construction phase starts with a reassessment of the project team. The golf course architect and other key consultants should stay involved through the construction process. The roles of all consultants should be clearly defined going into the construction phase. The golf course superintendent, ideally on board since the project inception, can often be pointed to as onsite project manager as construction proceeds. On some projects other professionals, such as a construction manager, are brought in to assist the superintendent and owner in this regard. The most important addition to the project team at this point is the construction contractor; it is critical that the contractor be experienced in golf course work in order for the project to stay on time, on budget, and most importantly in accordance with regulations and the construction plans. The Golf Course Builders Association of America can provide more information on golf construction contractors.

#### 2.4.1.2 Project schedule

The project schedule is typically written around meeting acceptable windows for grassing, which varies depending on turf selections. A detailed schedule including key milestones and dates should be required of the contractor prior to scheduling a preconstruction conference.

#### 2.4.1.3 Project staking, flagging, and marking

All project staking, flagging, and marking should be completed prior to the preconstruction conference so that key elements of the project are available for review.

Typically the centerline of all golf holes including tees, greens, and fairway turning points are surveyed and marked as specified by the golf course architect. The following areas are generally flagged:

- sensitive areas (wetlands, streams, buffers, trees to save, conservation areas, and historic resources) including those areas required to be flagged as a condition of issued permits
- property boundaries
- all utilities within the work area, as required by state law

Preconstruction photos are useful as part of the construction documentation process. Photographs of any jurisdictional impact areas are required for monitoring reports associated with a Virginia Water Protection Permit (VWPP).

#### 2.4.1.4 Preconstruction conference

Preparation is the key to a productive preconstruction conference. All project stakeholders, including owner's representatives, key consultants, contractor representatives, local, state and federal regulatory agency representatives, and other stakeholders should be invited. Provide a detailed, comprehensive agenda to all participants in advance of the meeting. Cover each item on the agenda in detail and issue meeting minutes (including an action item list) soon after the meeting date.

### 2.4.2 Construction Techniques

Sound construction techniques include those processes and practices that control soil erosion and stormwater runoff and proper management of the grow-in process. For example, general daily clean up processes at the completion of work or more site specific measures such as additional straw bales in a vulnerable drainage can help prevent erosion. Prior to expected storm events, tracking-in stockpiles and newly formed or transitional slopes with heavy equipment as a form of temporary compaction can greatly reduce the likelihood for rill erosion. On many sites, golf course builders routinely use inlet protection areas as an added measure to slow runoff, adding small treatment area sediment "traps" (Figure 2-9). Inlets for small diameter golf course drainage pipes are intentionally left high above grade in low areas that can encompass sizeable detention volumes, as much as 50 cu. yd. to 100 cu. yd. These columns are typically perforated and encased in stone

**Construction BMP #2**
Implement environmentally sound construction techniques.

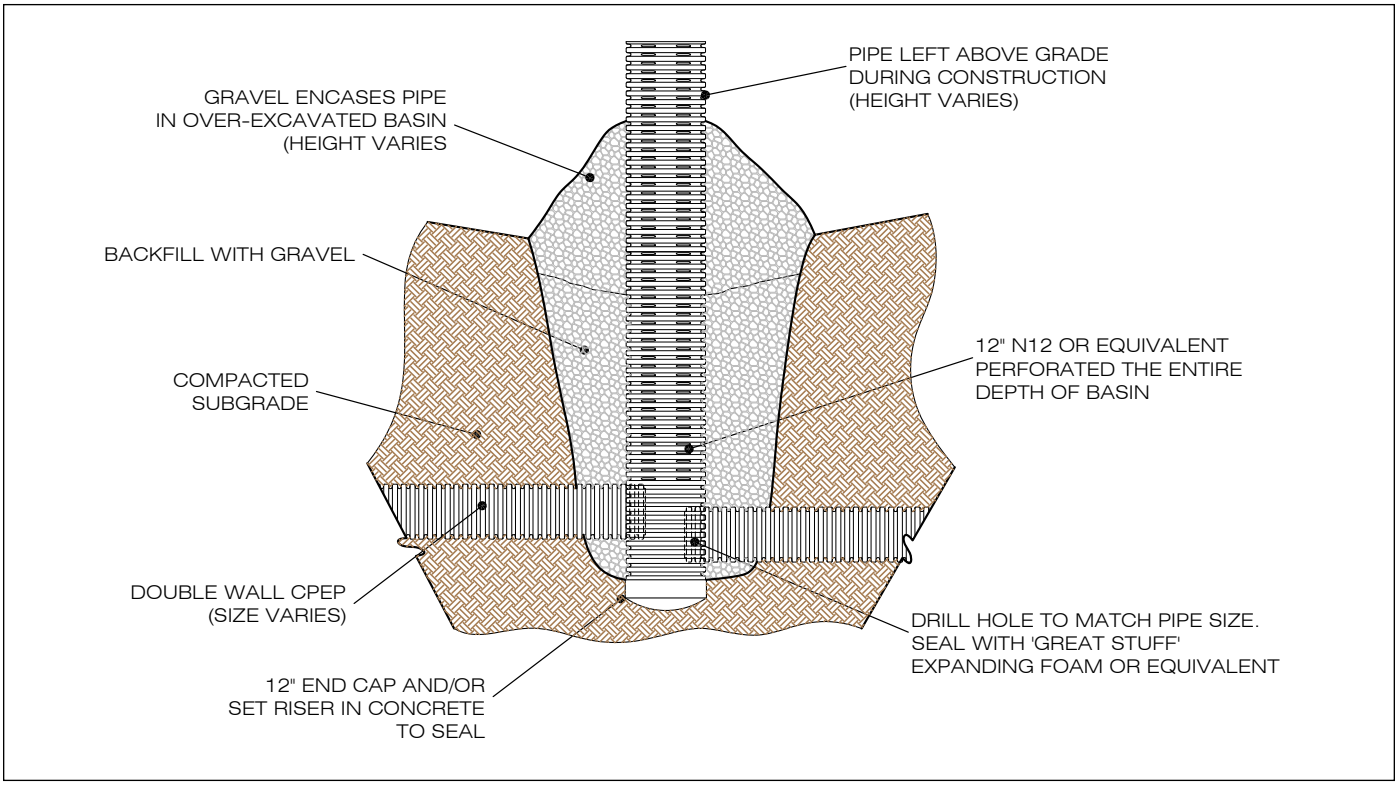



Figure 2-9. Inlet/outlet protection areas can provide an added measure to slow runoff, adding small treatment area sediment "traps". *Source:* George Golf Design.

above existing grade creating slower draining effective dry storage volume at each inlet of one to two feet in depth. Depending on the site, these individual inlets can cumulatively show a larger benefit of treatment. While not meeting the standard for a sediment trap according to the *Virginia Erosion and Sediment Control Handbook* (DCR 1992), these inlets can be implemented to further slow water and promote sediment deposition prior to the water exiting the site. All low cost, practical opportunities should be explored and discussed in golf projects.

#### 2.4.2.1 Dedicated E&S control teams

When working on larger construction projects, it may be advisable to employ a staff dedicated to the routine checking of all E&S control devices to ensure they are current and working properly. After storm events, these team members immediately follow E&S review protocols to ensure proper working conditions and repair any damaged devices, calling on additional staff if larger problems are found.

#### 2.4.2.2 Grassing

The grow-in process begins after the proper irrigation and drainage infrastructure is in place. A golf course can be grassed in many ways, but the methods can primarily be classified by either mature sod, which provides instant cover, or seeding or sprigging of turf, which requires a longer grow-in time and input. Seeding typically refers to the planting of cool-season grasses while sprigging refers to vegetative establishment of warm-season grasses, although some newer hybrid warm-season grasses can be established from seed. The benefits and drawbacks of sodding versus seeding/sprigging must be weighed in regard to cost and the net effect on the local environment, which often varies throughout the site.

Because of the potential for erosion when seeding or sprigging, soil stabilization techniques can be used during the establishment phase if the soils or slopes dictate their need. Hydro-seeding or hydro-mulching are often viewed as an attractive middle ground between seed and sod and may be more cost effective than sodding while providing some of the immediate stabilization benefits that sod provides. Geo-textile erosion blankets are another more structural form of stabilization used in tandem with seeding or sprigging methods and provide some of the moisture retention benefits of hydro-seeding, but can vary in cost. Traditional straw mulching can be effective in some soils on moderate slopes as well. For optimum site stability, a combination of these methods can often be employed so that key features are retained and repetitive re-construction and additional land disturbance is not required. A thorough understanding of the pros and cons of each method should be used to determine where each is applicable across a given site.

### 2.4.3 Construction Monitoring

At a minimum, construction monitoring and reporting is required to comply with project permits and should be reported to stakeholders in some manner, through newsletters or e-mail messages or a project website. In addition, every project must have some level of construction oversight to ensure that the owner's interest is protected and the project is completed in substantial accordance with the plans. The construction progress is typically monitored through a comparison of actual versus scheduled costs to date or a schedule analysis comparing actual and projected completion dates for various tasks. The level of diligence invested in this effort can significantly influence the environmental and financial sustainability of the project.

**Construction BMP #3**
Implement a construction monitoring program.

# 3

# Irrigation



"BMPs for irrigation provide the essential processes and information needed to assure the overall quality of irrigation systems."



# 3 Irrigation

The irrigation system on a golf course is critical for the maintenance of high quality playing conditions. Throughout Virginia, various types of irrigation systems are used, ranging from basic quick connect and hose applications to advanced multi-row sprinkler systems. Advanced systems conserve water, making use of the latest in computerized central control, state of the art pumping systems, sprinklers with highly efficient nozzles, soil sensors, radio communication, and weather data collection devices.

BMPs for irrigation provide the essential processes and information needed to assure the overall quality of irrigation systems. These practices include determining water availability and use requirements, designing a system for efficient use of irrigation water and incorporating water conservation practices and technologies, and operating and maintaining the system. More information on irrigation best practices is available from the Irrigation Association[1].

Because every golf course is different, the requirements, design, and specifications of irrigation systems differ. Therefore, irrigation recommendations should be adapted to fit the needs of a particular system and serve as a basis for determining the course-specific water conservation methods. Furthermore, using BMPs for all facets of design, construction, and maintenance operations aids in the overall conservation of water resources and quality.

## 3.1 Regulatory Considerations

Virginia DEQ regulates water usage in Virginia, as described below. When municipal or public potable water sources are used as a primary or secondary water source for irrigation, local governments regulate cross connection to prevent backflow.

### 3.1.1 Surface Water Withdrawal and Permit Regulations

Under the Virginia Water Protection (VWP) Permit Program Regulation (9VAC 25-210), surface water withdrawals require a permit. The DEQ web site provides more information on permits, including application forms and checklists (http://www.deq.state.va.us/wetlands/permitfees.html)

[1] http://www.irrigation.org/Resources/Design.aspx

### Irrigation Management BMPs

**BMP #1**
Conduct water supply analysis to verify quantity and quality of water supply.

**BMP #2**
Plan for water conservation, integrating practices and technology for precision irrigation control and uniform coverage.

**BMP #3**
Design the irrigation system for the efficient and uniform distribution of water.

**BMP #4**
Program and schedule the irrigation system to conserve water.

**BMP #5**
Know the drought resistance differences between turfgrass species.

**BMP #6**
Conduct an audit of the irrigation system.

### 3.1.2 Groundwater Withdrawal and Permit Regulations

Under the Ground Water Management Act of 1992, Virginia manages groundwater through a program regulating the withdrawals in certain areas called Ground Water Management Areas (GWMA)[2]. Currently, two GWMAs exist in the state (Figure 3-1). Any person or entity wishing to withdraw 300,000 gallons per month or more in a declared management area must obtain a groundwater withdrawal permit.

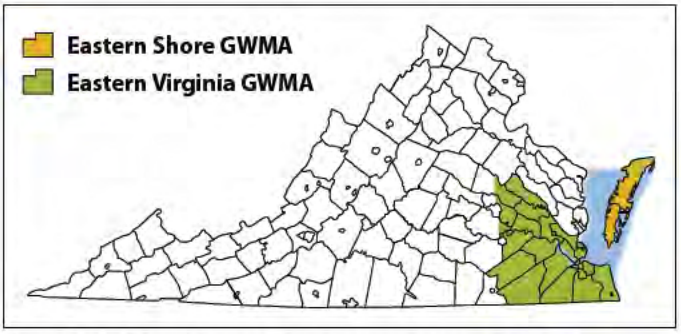



Figure 3-1. Groundwater Management Areas in Virginia.

[2] http://www.deq.virginia.gov/vpa/waterreuse.html

### 3.1.3 Withdrawal Reporting Requirements

Virginia Water Withdrawal Reporting Requirements (9 VAC 25-200-10, et seq.) require reporting for any withdrawal whose daily average withdrawal exceeds 10,000 gallons in any single month. Each withdrawer must report to DEQ surface water or groundwater withdrawals by January 31st in the year following the one in which the withdrawals occurred. The annual monitoring report must contain permit information (the permittee's name and address, permit number) and withdrawal information, such as:

- the source from which water is withdrawn
- the location (latitude and longitude) of each point of water withdrawal
- the cumulative volume (million gallons) of water withdrawn each month of the calendar year
- the largest single day withdrawal volume (million gallons) that occurred in the year and the month in which it occurred
- the method of measuring each withdrawal

An accurate flow meter with a totalizing interface is typically installed at the pump station and communicates to the computerized central controller. This equipment is recommended for effectively and efficiently collecting water use data for reporting and monitoring requirements.

### 3.1.4 Water Reclamation and Reuse Regulations

In Virginia, the Water Reclamation and Reuse Regulation (9 VAC 25-740) governs the reclamation of wastewater (municipal or industrial) and reuse of that water for a variety of purposes, including irrigation. The regulations promote and encourage water reclamation and reuse in a manner protective of the environment and public health. The Virginia Department of Environmental Quality (DEQ), Water Division administers the Water Reclamation and Reuse Regulation and associated programs.

Two sets of treatment standards exist in the regulation: Level 1 and Level 2. Level 1 is the more highly treated and disinfected reclaimed water and is suitable for reuses where there is potential for public contact, such as irrigation on golf courses. Level 2 reclaimed water requires less treatment and disinfection than Level 1 and is suitable for reuses where there is no or minimal potential for public contact, such as irrigation of areas with no public access and limited or protected worker contact.

Facilities that generate and distribute reclaimed water require permits from the DEQ. Most end users of reclaimed water do not require a permit from DEQ, but must enter into a service agreement or contract with a reclaimed water agent. The service agreement or contract includes terms and conditions regarding the proper use and management of reclaimed water by the end user.

Several requirements in the Water Reclamation and Reuse Regulation are specific to irrigation. All irrigation with reclaimed water must be supplemental, defined in the regulation as irrigation in combination with rainfall that meets but does not exceed the water necessary to maximize production or optimize growth of the irrigated vegetation. Supplemental irrigation differs from land treatment of wastewater described in the Sewage Collection and Treatment Regulations (9 VAC 25-790) in that supplemental irrigation is strictly reuse, while land treatment is first and foremost a method of further treating and disposing of wastewater and second a method of planned or unplanned reuse.

Irrigation of an area greater than five acres with reclaimed water, referred to in the regulation as bulk irrigation, requires a nutrient management plan where the following conditions apply:

- The annual average concentrations of total N and total P in the reclaimed water is greater than 8 and 1 mg/l, respectively.
- Independent of the nutrient content of the reclaimed water, the bulk irrigation reuse site is under common ownership or management with facilities that generate or distribute reclaimed water that is applied to the site. In addition to reuse, no option must exist to dispose of reclaimed water through a permitted discharge or there exists a permitted discharge but the permit does not allow discharge of the full nutrient load. The nutrient management plan in this circumstance must be approved by the Virginia Department of Conservation and Recreation.

All bulk irrigation reuse sites must also have a site plan. The site plan must be displayed on the most current USGS topographic map (7.5 minute series) and show the boundaries of the irrigation site, setback areas around the irrigation site that comply with the regulation, and locations of all potable and non-potable water supplies nearby. Items shown on the plan must include wells and

springs; public water supply intakes; occupied dwellings; property lines; areas accessible to the public; outdoor eating, drinking and bathing facilities; surface waters (including wetlands); limestone rock outcrops; and sinkholes within 250' of the irrigation site.

The regulation contains general requirements for all irrigation reuse, as well as general requirements specific to bulk irrigation reuse of reclaimed water. The requirements for bulk irrigation reuse include design, installation and adjustment requirements, labeling requirements, and runoff containment. The regulation also contains setback requirements for irrigation with Level 1 and Level 2 reclaimed water and provides options to reduce some of the setbacks for irrigation reuse of Level 2 reclaimed water.

Many end users of bulk irrigation reuse will also have some form of storage for reclaimed water. Typically, end user storage of reclaimed water uses lakes, ponds, and landscape impoundments. Setbacks are required for nonsystem storage facilities from potable water supply wells and for springs and public water supply intakes. The distance of the setbacks varies and is determined by the level of reclaimed water in the nonsystem storage facility and whether or not the facility is lined. The regulation also describes access control and advisory signage requirements for both nonsystem storage and irrigation reuse sites.

DEQ has a program page specifically for water reclamation and reuse on the agency's website.[1] The program page provides links to the regulation, implementation guidance, permit application forms, and additional resources pertaining to irrigation with reclaimed water.

### 3.1.5 Backflow Prevention and Cross Connection Regulations

Municipal or public potable water sources used as a primary or secondary water source are required to be protected from cross connection that could potentially contaminate the public water supply. In Virginia, local governments regulate the required code and methods of cross connection and backflow prevention. The most common type of backflow prevention device, a reduced pressure zone (RPZ) backflow prevention device (Figure 3-2), must be tested annually by a certified tester.

Local and municipal codes and ordinances relating to cross connection prevention and backflow control should be examined thoroughly prior to planning a potable water source for an irrigation project. The local public utility department or the Virginia Cross Connection Control Association can provide additional information.



Figure 3-2. RPZ backflow prevention device.
*Source:* EC Design Group, LTD.

### 3.1.6 Virginia Drought Response Plan and Golf Courses

In Virginia, the monitoring of current drought conditions is facilitated by the Virginia Drought Monitoring Task Force, an interagency group of technical representatives from state and federal agencies. In coordination with the National Oceanic and Atmospheric Administration (NOAA) and Virginia DEQ, current drought reporting information is made available online for Virginia[2]. Included in the online information is a graphical map of the current status of Virginia drought regions and drought indicators. Thirteen drought evaluation regions have been defined to address specific drought responses within the state.

Drought conditions are monitored using four indicators to evaluate the severity of the drought based on the amount of precipitation and effective precipitation on Virginia's hydrologic system as follows: precipitation deficits, stream flows, groundwater levels, and reservoir storage levels.

These drought indicators are used for recommending the declaration of a particular drought stage. The drought stages include: Drought Emergency, Drought Warning, Drought Watch, and Normal. Unrestricted irrigation of golf courses is prohibited during a declared Drought Emergency. The following is a list of exceptions

[1] http://www.deq.virginia.gov/vpa/waterreuse.html
[2] http://www.deq.state.va.us/waterresources/drought/homepage.html

specifically applying to golf courses for all sources of water and are only in effect when the governor of Virginia declares a Drought Emergency through the issuance of an executive order:

- Tees and greens may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. at the minimum rate necessary.
- Localized dry areas may be irrigated with a handheld container or handheld hose equipped with an automatic shutoff device at the minimum rate necessary.
- Greens may be cooled by syringing or by the application of water with a handheld hose equipped with an automatic shutoff device at the minimum rate necessary.
- Fairways may be irrigated between the hours of 9:00 p.m. and 10:00 a.m. at the minimum rate necessary not to exceed 1" of application in any ten day period.
- Fairways, tees, and greens may be irrigated during necessary overseeding or re-sodding operations in September and October at the minimum rate necessary. Irrigation rates during this restoration period may not exceed 1" of applied water in any seven day period.

Localities in Virginia have also adopted water reducing measures that may apply to golf courses during drought. These measures were adopted to comply with the Local and Regional Water Supply Planning Regulation (9 VAC 25-780). These ordinances are expected to be activated consistent with determinations of drought stage by the Drought Monitoring Task Force. Drought Watch and Drought Warning stages anticipate voluntary water reductions.

## 3.2 Water Supply Analysis



Figure 3-3. Surface water storage pond. *Source:* David Norman.

**BMP #1**
Conduct water supply analysis to verify quantity and quality of water supply.

An adequate water supply is essential for any planned or proposed golf course irrigation system and is necessary to the irrigation system design process. The water availability analysis should consider a number of water sources, including existing surface water from ponds and lakes, stormwater detention ponds, wells, reclaimed water sources, effluent sources and any combined supplemental sources from rainwater and stormwater collection (Figure 3-3). When available, use effluent or other non-potable water for golf course irrigation.

For a water source to serve as an irrigation source, it must be dependable, reliable, and offer sufficient resources to accommodate turf grow-in needs and ongoing maintenance. Determine water requirements using a seasonal and maximum bulk water requirement analysis. Water quality must be suitable for plant growth and pose no threat to public health.

### 3.2.1 Determining Seasonal Bulk Water Requirement

Estimating the seasonal bulk water requirement verifies water source suitability for supplying irrigation water. The seasonal bulk water requirement allows for effective rainfall and determines the typical consumptive use of an irrigation system under normal conditions. The following information is needed to calculate the seasonal bulk water requirement:

- *Irrigated area measured in acres.* An estimate of the irrigated area may be obtained by GPS, golf course architect information, or archived field measurements.
- *Length of irrigation season.* The irrigation season in Virginia is typically 8 months (35 weeks), beginning in March and ending in October.
- *Effective precipitation data.* Historical precipitation data can be obtained from local weather sources, weather stations within the area, and the Southeast Regional Climate Center[1]. Historical precipitation data must be multiplied by a factor of 0.70 to determine effective precipitation data (which does not include losses as a result of surface runoff or percolation below the root zone).

[1] http://www.sercc.com/climateinfo/historical/historical_va.html

- *Estimated irrigation system efficiency*. Most irrigation systems fall into three primary categories regarding efficiency: 80% (newer systems using latest technology); 70% (average irrigation systems); 55% (older systems with poor coverage and dated technology).
- *Plant water requirement*. This figure is based on local potential evapotranspiration (PET), which is the environmental demand for ET of a short green crop, completely shading the ground, of uniform height and with adequate water in the soil. PET is multiplied by a coefficient for the specific type of grass used. Crop coefficients must be based on the turfgrass species, and local crop coefficients are used because of regional climate variances. In general, two primary crop coefficients are used in Virginia: one for cool-season species (0.8) and another for warm-season species (0.6). PET data for Virginia is available from the University of Virginia Climatology Office[1]. Additional detailed and specific crop coefficient data may be obtained from Virginia Tech's Department of Crop and Soil Environmental Science[2]. Formulas and conversion data for calculating PET are provided in Appendix C.

The resulting seasonal bulk water requirement value is the starting point when estimating demands of a new irrigation system. Throughout the process of design and evaluation, this figure may be adjusted as the process evolves and more data becomes available. The seasonal bulk water requirement may also be used as preliminary demand data for the purpose of permitting applications and feasibility studies.

### 3.2.2 Determining Maximum Seasonal Bulk Water Requirement

The maximum seasonal bulk water requirement does not allow for effective rainfall and determines the worst case demand of an irrigation system under extended drought conditions. This usage amount is often the basis for determining mainline pipe size, pump station capacities, etc. To calculate the maximum seasonal bulk water requirement, the allocation of effective rainfall is eliminated.

### 3.2.3 Water Quality

The water quality of the source is as important as water quantity. Due to the constantly changing environment on a golf course, water quality analysis should be performed regularly to check for potential problems due to changes in pH, salinity, bicarbonates, micronutrients, and suspended solids. Virginia Cooperative Extension (VCE) provides additional information on irrigation and agronomic concerns with reclaimed water[3] (VCE 2009a).

#### Seasonal Bulk Water Requirement Calculation Example

**Data**

- 80 acres of irrigated turf
- 35 week (8 month) irrigation season
- 31 in. of historical precipitation
- 70% system efficiency
- 1.56 in. per week peak PET
- Cool-season grasses (crop coefficient = 0.80)

**Plant water requirement (peak PET x crop coefficient)**

1.56 in./week x .80 = 1.25 in./week

**Effective precipitation (historical precipitation x loss factor)**

31 in. x .70 = 21.70 in.

**Preliminary net water requirement (plant water requirement over season, minus effective precipitation)**

(1.25 in./week x 35 weeks) – 21.70 in. = 22.05 in.

**Preliminary gross water requirement (preliminary net water requirement divided by system efficiency)**

22.05 ÷ .7 (70% system efficiency) = 31.5 inches

**Seasonal bulk water requirement (preliminary gross water requirement x acreage)**

31.5 in. x 80 acres = 2520 acre in.

2520 acre in. x 27,154 gallons/acre in. = 68,428,080 gallons

[1] http://climate.virginia.edu/va_pet_prec_diff.htm
[2] http://www.turf.cses.vt.edu/Ervin/et_display.html
[3] http://pubs.ext.vt.edu/452/452-014/452-014_pdf.pdf

### Maximum Bulk Water Requirement Calculation Example

Using the same data as the seasonal bulk water requirement example, plant water requirement of 1.25 in./week, and no effective precipitation (0 inches):

**Preliminary net water requirement**

- (1.25 in./week x 35 weeks) - 0 = 43.75 in.

**Preliminary gross water requirement**

- 43.75 in. ÷ .7 (70% system efficiency) = 62.5 in.

**Maximum seasonal bulk water requirement**

- 62.5 in. x 80 acres = 5,000 acre in.
- 5,000 acre in. x 27,154 gal/acre in. = 135,770,000 gal

## 3.3 Water Conservation Planning

Water management is a critical component of the overall design of a golf course and of a management plan. Irrigation system planning should incorporate practices and technologies that conserve water as well as ensure the efficient and uniform distribution of water.

**BMP #2**
Plan for water conservation, integrating practices and technology for precision irrigation control and uniform coverage.

### 3.3.1 Practices and Technologies for Precision Irrigation Control

Practices and technologies that allow for precision control and uniform coverage are the foundation of an efficient irrigation system. Golf course superintendents should investigate irrigation products that have earned the WaterSense label. A WaterSense product has been certified to be at least 20% more efficient without sacrificing performance. WaterSense is a partnership program developed by EPA http://www.epa.gov/watersense/). Additional examples of equipment and practices that promote precision control and uniform coverage include the following:

- individual sprinkler control throughout the entire golf course
- flow management of the irrigation system
- handheld radio control
- handheld computerized control (such as smart phone or tablet applications)
- soil moisture sensors throughout the system (Figures 3-4 and 3-5)
- onsite weather station (Figure 3-6)
- computerized central control
- sufficient quick coupling valves
- monthly area audits to evaluate sprinkler performance
- solid state timing



Figure 3-4. Underground wireless soil sensor providing soil profile feedback to irrigation central control. *Source:* EC Design Group, LTD.



Figure 3-5. Wired soil sensor. *Source:* Rainbird Corporation.

Significant advances have been made in inground soil sensor technology that can monitor soil moisture, salinity levels, and soil temperature levels in real time. Wireless and wired versions interface with computer irrigation control systems. Wireless sensor systems (Figure 3-4) allow hundreds of sensors to be strategically installed throughout the golf course and can be accessed from the internet. Wired sensor systems (Figure 3-5) provide critical soil profile data in specific locations. Groups of sprinklers may be associated within these defined areas, which allows for microclimate-specific watering applications. When integrated with the irrigation central control computer software, this highly accurate data collection method provides excellent water resource conservation.

Onsite weather stations (Figure 3-6) provide an effective method of collecting data that can be used to determine actual site ET rates. This data is logged and interfaced with the irrigation central control software to aid in determining water applications. The weather station location can limit the reliability of this data, since the area of an average golf course ranges from 150–200 acres and the placement of the weather station must represent a typical irrigated area. In general, ET values provided by the weather station are for reference purposes only.



Figure 3-6. Onsite weather station. *Source:* David Norman.

### 3.3.2 Practices and Technologies for Uniform Irrigation Coverage

Practices and technology applications that offer uniform coverage include the following:

- using the proper sprinkler for the proper application
- using sprinkler application rates that do not exceed soil infiltration rates
- providing pressure regulation at each valve in head sprinkler and each remote control valve
- using lower angle nozzles and/or trajectory adjustment for each sprinkler in windy areas
- using sprinklers that use lower base pressure for windy areas
- providing continuous and proper irrigation system maintenance
- installing consistent sprinkler patterns: rectangular, square, and/or triangular

## 3.4 Irrigation System Design

Irrigation systems should be designed to be efficient, distribute water uniformly, conserve and protect water resources, and meet state and local code and site requirements. Site-specific characteristics and incorporation of water conservation practices and technologies should be evaluated in the design. In addition, the Irrigation Association lists 25 design-oriented BMPs[1] that should be reviewed during the design phase.

**BMP #3**
Design the irrigation system for the efficient and uniform distribution of water.

[1] http://www.irrigation.org/Resources/Design.aspx

### 3.4.1 Site Specific Information Needs

Collecting accurate site data is critical to the irrigation design process. A wide number of site-specific conditions affect the planning and efficiency of an irrigation system. During this preliminary planning stage, the golf course superintendent should seek assistance from Certified Golf Course Irrigation System designers, professional irrigation consultants, and professionals certified through WaterSense labeled programs. Prior to designing an irrigation system, the following site-specific information should be considered:

- environmental characteristics, such as local climate and weather data patterns; soil structure in various areas throughout golf course; topography; and exposure to wind, sun, and shade throughout golf course
- applicable regulations and restrictions
- base map information, such as property boundaries, utility easements, and aerial photos
- design elements, such as design features and concepts, planned or existing turfgrass varieties, and planned or existing drainage systems
- planned or existing golf course management procedures, such as fertilization and/or fertigation practices and available and desired "water window" or time of operation
- electric power considerations, such as locations and type of available electric power, power rates, and resistance to ground readings measured in ohms
- water source information, such as water analysis results and static pressure data from municipal sources
- available budget

### 3.4.2 Irrigation System Plan Components

The irrigation system design plan requires an accurate base map in addition to the installation details. Because computer aided design (CAD) software is typically used for irrigation system design, digital data layers of existing base map information (such as utility easements) should be supplemented with data collected onsite using global positioning system (GPS). For additional accuracy and reference in the base map, current aerial photography (recommended print scale of 1" = 100') is recommended if available. When printed, base maps should include the project name, printed scale, contour interval, complete title block with page numbering, and north arrow.

In addition to the base map, the irrigation system plan should include complete installation details such as a specific detail sheet for pipe trenching and thrust blocking, valve installation, electrical grounding, electrical splice preparation, swing joint and sprinkler installation, pump station installation, concrete slab construction, pump station intake and wet well installation, field satellite controller installation, and any other specific or unique installation requirement.

### 3.4.3 Design Considerations

Important design considerations include sprinkler and piping placement, sprinkler coverage and spacing, and communication options and serviceability.

#### 3.4.3.1 Sprinkler / Piping placement

Sprinkler and piping placement should consider play and maintenance. These placement issues include the following:

- placement of sprinklers away from the putting surface or collar to avoid interference with the putting performance of the turf
- placement of sprinklers away from the approach area and flight line of an incoming golf shot
- installation of irrigation pipe away from the green surface to avoid substantial increases in repairs should the pipe break

#### 3.4.3.2 Sprinkler coverage and spacing

Designers must incorporate special considerations when designing the irrigation system for golf greens. Early systems typically used four full circle sprinklers that irrigated the playing surface, collar, partial approach, and green surrounds, with the run time for all sprinklers based on the watering needs of the putting surface. The evolution of sprinkler technology has provided the golf course irrigation system designer the opportunity to design a sprinkler layout specific to each unique constructed green. Examples of sprinkler layout designs include the following:

- Part circle sprinklers can be arranged and spaced to apply water only to the green surface.
- A separate row of part circle sprinklers can be arranged and spaced to irrigate the green surround areas.
- An additional group of part circle sprinklers can be included to provide specific and unique water application to the heavy traffic areas of the greens approach.

- Block system spray zones may be incorporated into the greens surround bunker faces to provide specific management of water application to these severely sloped areas'
- Subsurface drip irrigation can also prove an excellent and efficient choice for bunker face irrigation.

A two-row layout addressing the tee surface only is the most efficient design for tees. This layout uses sprinklers spaced at 25 to 35 foot and larger radius to apply water to the tee surrounds. Both sets of sprinklers must be able to operate independently of each other for the efficient use of water and increased control. Other options can waste water, reduce the area available for the placement of tee markers, or do not provide adequate precipitation to some parts of the tee surface.

Irrigation of golf course fairways has historically used manual and/or single-row coverage, which does not provide uniform irrigation. Double-row sprinklers offer an improvement, but multi-row sprinkler coverage offers the best method to control and conserve water (Table 3-1). Additionally, individual sprinkler head control should be applied whenever possible.

### 3.4.3.3 Communication Options

Reliable irrigation control systems allow the user to take advantage of highly efficient control. Two primary methods of communication for golf course central/satellite control systems are available: direct burial multi-conductor communication cable or wireless communication. During the design and planning phase, the course and irrigation designer must decide the best communication option for the golf course. Virginia experiences moderate to high numbers of lightning strikes per year, especially in the central and southern portions of the state (Figure 3-7). Specify and select communication equipment with lightning damage concerns in mind.




Figure 3-7. Lightning flash density map.

Decoder systems are the most susceptible to lightning damage because the entire system is installed underground, requiring increased lifetime cost of ownership and service maintenance. However, these systems are ideally suited for areas that are prone to flooding and vandalism or areas where the installation of aboveground field controllers is not possible. Field satellite controllers require grounding, which should meet current American Society of Irrigation Consultants (ASIC) standards[1]. Communication cables used with conventional field satellite controllers or decoder systems are typically installed in an open trench underneath the irrigation mainline for increased protection. The communication wire path is a direct line into the most critical of the irrigation control system and therefore it is essential that substantial surge protection be incorporated into the system.

Wireless communication systems for irrigation use either UHF narrow band radio (requires an FCC

## Table 3-1. Sprinkler coverage and spacing considerations

| Sprinkler Spacing | Advantages/Disadvantages |
|---|---|
| **Manual and/or single row sprinkler coverage**<br>Typically use long radius sprinkler spacing > 90 ft. | Scheduling coefficient (SC) values are high and distribution uniformity (DU) values low. Overall, this type of fairway coverage results in inefficient irrigation. |
| **Double row sprinkler coverage**<br>Sprinkler throw distances range from 80–90 ft., increasing the effective width of coverage and allowing for individual sprinkler control based on the terrain of the fairway area. | Offers an improvement of efficiency over single row coverage. However, manual hand watering or other types of supplemental watering may be needed outside the fairway area and into the extended rough. |
| **Multi-row sprinkler coverage**<br>Incorporates three to five rows. Typically, the spacing of sprinklers ranges from 55–75 ft. | Offers the best method to control and conserve water and provides the user the best ability to respond to specific moisture requirements of a given fairway area. |

license) or paging technology. Wireless communication systems typically cost more than wired systems due to the additional radio components, such as antenna equipment, and repeaters if needed to provide stable communication. Some systems use hybrids of both the wired communication path and wireless communications. A fully wireless system allows the user to add satellite controllers easily without the need to install additional communication wiring. For a new golf course construction project, a wireless system can be installed and communicating as the irrigation system construction is completed to provide efficient control of water during the grow-in period.

## 3.5 Irrigation Pumping Systems

Irrigation pumping systems play a key role in water management and life cycle management of any irrigation system. Modern pumping systems are complex arrangements of hydraulics, electronics, and communications that keep water flowing at specific rates and pressures. Properly designed and maintained, these systems can assure the user of quality service and production. Poorly designed and maintained pump systems can increase maintenance costs, create service issues, and waste energy and water. The most commonly used pump type for golf course irrigation is the vertical turbine configuration, which offers greater efficiency, less overall maintenance, and fewer loss-of-suction issues than other pump types. Major system components include a pump station (Figure 3-8), irrigation pumping station control, and intake and discharge piping networks.

Irrigation pumping system control can best be achieved by programmable logic controllers (PLC) in conjunction with variable frequency drives (VFD) to efficiently determine the proper speed of the pump motor based on demand. Hydraulic system pressures can also ramp up and down relative to system flows to ensure the piping network is not compromised. These systems provide advantages over regulating valves and limit switches, which do not vary based on demand and produce non-uniform pressure strain on the piping network. Computerized irrigation central control systems and PLC also allow remote monitoring of the operation of the pump station. Pump station control software that integrates with the irrigation central control software allows remote monitoring of pump station operation and provides water use and consumption data.

[1] http://www.asic.org/Design_Guides.aspx

## 3.6 Irrigation System Programming and Scheduling

Designers must understand turf needs in order to program and schedule the irrigation system appropriately. The principle of "deep and infrequent" delivery of water promotes deep rooting, gas exchange, and soil temperature moderation, while discouraging surface soil compaction. Enhanced soil gas exchange also promotes increased rooting density, improving water and nutrient absorption efficiency. In practice, for unobstructed soils of 12-18" in depth, the irrigation system applies water to fill soil pores to the depth of roots and then does not irrigate again until surface soil moisture has been depleted to near the wilting point. Soil type, effective root zone depth, and estimated ET demand determine irrigation frequency and soak cycle needs. Turfgrass species also affects irrigation frequency, since some turfgrasses more effectively resist drought than others (Section 3.7). Appendix E provides example irrigation schedules.



Figure 3-8. Vertical turbine pump station installation. *Source:* EC Design Group, LTD.

Irrigation programming also affects surface runoff. Prolonged irrigation on saturated soils can cause excess water to remain on the soil surface, increasing the potential for surface runoff containing fertilizer or pesticides.

**BMP #4**
Program and schedule the irrigation system to conserve water.

### 3.6.1 Plant Available Water Based on Soil Type

The infiltration rrate for heavier soils such as silts and clays is 0.25–1" per hour, while the infiltration rate of sandy soils can be 2–20" per hour. Soil type also determines how much water per inch can be held at field capacity

(Table 3-2). Soil compaction restricts permeability, but can be enhanced with regular core aerification (see Section 7.3).

### 3.6.2 Effective Root Zone Depth

Effective root zone depth is defined as the depth to which 90% of the root system penetrates and must be determined onsite with a soil probe or spade. The soil type and effective root zone depth together are used to estimate the soil water-holding reservoir available to the root system.

### 3.6.3 ET Demand

ET is a combination of the transpirational water needs of the plant and water lost from the soil surface via evaporation. As temperatures increase and the relative humidity decreases, ET demand rises. ET requirements vary based on turfgrass species, maintenance conditions (such as intensity of use, soil type, microenvironment, and mowing height), and time of year.

Table 3-3 provides weekly estimates of irrigation required on Virginia golf course playing surfaces for warm- and cool-season grasses to replace moisture lost to ET. ET demand decreases in correlation with decreases in typical mowing heights (for example, greens are mowed lower than roughs or fairways) because lower cutting heights reduce leaf area resulting in less overall leaf transpiration. However, water cannot be conserved by mowing all areas lower because of the trade-offs associated with lower mowing heights (see Section 7.2).

Examples of the influence of ET demand on irrigation needs include the following:

- Warm-season species (bermudagrass and zoysiagrass) require significantly less irrigation than most cool-season grasses because they use water and carbon dioxide more efficiently. This increased efficiency, coupled with their

**Table 3-2. Estimated plant available water (PAW) between field capacity and wilting of various soil textural classes**

| Soil Textural Class | Field Capacity | Wilting Point | PAW |
|---|---|---|---|
| | Inch of Water per Inch of Soil | | |
| Sand | 0.14 | 0.06 | 0.08 |
| Sandy Loam | 0.24 | 0.09 | 0.15 |
| Loam | 0.34 | 0.13 | 0.21 |
| Silty Clay Loam | 0.40 | 0.18 | 0.22 |
| Clay | 0.41 | 0.28 | 0.13 |

**Table 3-3. Estimated ET replacement requirement of various turf surfaces in Virginia**

| Type of Turf | | May | June | July | Aug | Sept |
|---|---|---|---|---|---|---|
| | | Estimated ET Requirement (inches per week[1]) | | | | |
| Cool Season | Rough | 0.60″ | 1.20″ | 1.50″ | 1.30″ | 0.80″ |
| | Shaded Area | 0.30″ | 0.60″ | 0.75″ | 0.65″ | 0.40″ |
| | Fairway | 0.55″ | 1.10″ | 1.35″ | 1.20″ | 0.75″ |
| | Green | 0.50″ | 1.00″ | 1.10″ | 1.10″ | 0.80″ |
| Warm Season | Rough | 0.45″ | 0.85″ | 1.05″ | 1.00″ | 0.55″ |
| | Fairway | 0.35″ | 0.75″ | 0.90″ | 0.90″ | 0.50″ |
| | Green | 0.30″ | 0.70″ | 0.80″ | 0.80″ | 0.70″ |

[1]These estimates assume that only 50% of monthly rainfall is effectively soil absorbed and becomes available for plant uptake.

deep-rooting nature, imply the need for 30-50% less irrigation than cool-season grasses during the summer.

- Heavily used turf surfaces tend to have more compact soil that restricts rooting and therefore need slightly more irrigation, applied more frequently and in smaller amounts to promote wear recovery.
- Shaded grasses exhibit 30-50% less ET demand than turfgrasses in full sun, but often have shallower roots due to low light intensity. Therefore, shaded grasses should be watered approximately half as much and half as often as turf in full sun.

### 3.6.4 Irrigation System Precipitation Rates

Once irrigation needs are known, the precipitation rate of the irrigation system or zone must be determined. This rate is most accurately determined by conducting an irrigation audit using a catch can test (Appendix D).

#### Example Irrigation Recommendation

**Description:** Tall fescue rough with one irrigation zone in the sun and one in moderate shade.

**Recommendation:** Irrigate the sunny area every 3rd or 4th day with 0.7" of water. Irrigate the shaded area every 7th or 8th day without measurable rain with 0.35" of water.

## 3.7 Turfgrass Drought Resistance

Some of the areas of the golf course may be irrigated sparingly or not at all. Planning for these areas and restricting their irrigation requires knowledge of the most drought resistant turfgrass species (Figures 3-9 and 3-10) and maximizing this resistance. Drought resistance encompasses two facets: avoidance and tolerance. Drought avoidance is preferred, since it is the ability to stay green and growing as surface soil dries and drought progresses. Drought tolerance is the ability to keep growing points alive, though not necessarily green, as drought progresses.

**BMP #5**
Know the drought resistance differences between species.

### 3.7.1 Cool-Season Grasses

Among cool-season grasses, tall fescue (TF) has the best genetic potential to grow deep roots and avoid drought as surface soil moisture becomes limited. Perennial ryegrass (PR), a close genetic relation to TF, also avoids drought a few days longer than others. However, the ability of PR to tolerate drought after exhausting accessible soil moisture is relatively poor; PR often exhausts all energy reserves and dies in an extended summer drought of 3 to 5 weeks. TF tolerates drought a little longer than PR, but also succumbs to an extended summer drought of 4 to 6 weeks. Irrigation to replace 25 to 50% of ET once weekly prevents widespread loss of TF and PR. This approach conserves water and money while reducing the need for extensive fall renovation (although the turf appearance may suffer).

Kentucky bluegrass (KBG) and the fine fescues (FF) respond differently to the onset of drought. These grasses are more shallow-rooted than TF and PR and therefore respond much sooner to dryness in the upper soil profile by stopping leaf growth and allowing leaves to brown and senesce. The subsequent lack of leaf transpiration allows the limited root moisture uptake to be used to maintain hydration of growing points at the crown and on rhizome and stolon nodes. Undeveloped tillers can thus remain viable and arise from these nodes once drought subsides. During extended summer drought these brown grasses are said to be in drought dormancy. KBG and FF can usually recover from up to 6 weeks of drought dormancy. If these areas are subjected to wear during dormancy, this survival limit is shortened. Unlike TF and PR, KBG and FF do not respond well to small irrigation events that do not effectively return soil moisture to field capacity. Such a minimalist approach brings some nodes out of dormancy and sends out a few new tillers, but with the quick return of dry soil much of this new growth will perish, leaving fewer potential tillers for full recovery at the real cessation of drought. With KBG and FF the approach has to be all or nothing: a robust and continued use of irrigation or no irrigation at all.

Creeping bentgrass (CBG), when grown on native soils on golf fairways, is most often shallow-rooted, since it lacks thick roots to penetrate heavy soils. This root structure, combined with a growth habit that partitions considerable energy to stolon development, results in a species that is not able to mine deeper soil moisture and avoid drought. While CBG's extensive stolon network provides many growing points for potential recovery from drought, this tolerance mechanism is grossly inadequate for maintaining a functional golf playing surface. Do not attempt to maintain CBG in Virginia without irrigation. Figure 3-9 provides ratings of drought avoidance and tolerance for common cool-season turfgrasses.

### 3.7.2 Warm-Season Grasses

The water use efficiency of warm-season grasses is often 50% greater than cool-season grasses. This means that they can develop 50% more biomass with an equivalent amount of water. Such a photosynthetic advantage also often translates into plants that are deeper rooted than cool-season grasses. This is especially true for buffalograss (Buff) as it primarily uses photosynthetic energy to grow deep roots rather than heavy shoot biomass. While this growth habit makes buffalograss susceptible to wear and weeds, it also makes it the most drought resistant turfgrass used in the U.S. Bermudagrass, a more commonly used species in Virginia, rates only slightly behind buffalograss as it tends to allocate more energy to shoot growth during drought, which can result in some shoot death in prolonged summer drought (over 8 weeks). Zoysiagrass, St. Augustine, and centipedegrass are three grasses that originate from high rainfall climates and are progressively more shallow-rooted and therefore of decreasing drought resistance. Figure 3-10 provides ratings of drought avoidance and tolerance for common warm-season turf grasses.

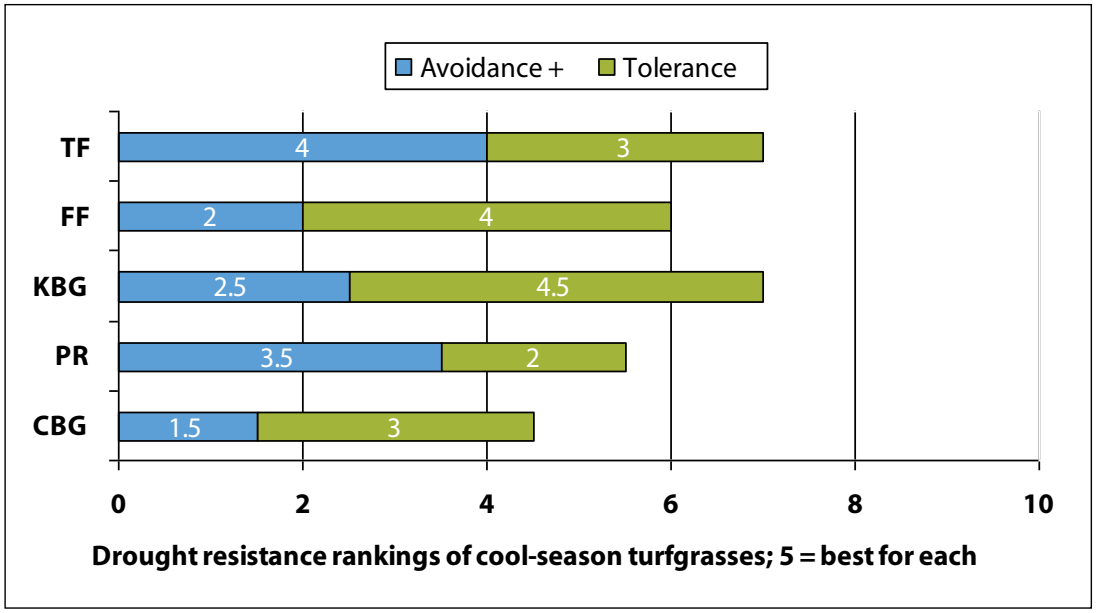



Figure 3-9. Drought resistance rankings of cool-season turfgrasses. Based on a scale of 1 to 5 for avoidance and tolerance; 5 = best ranking for each.

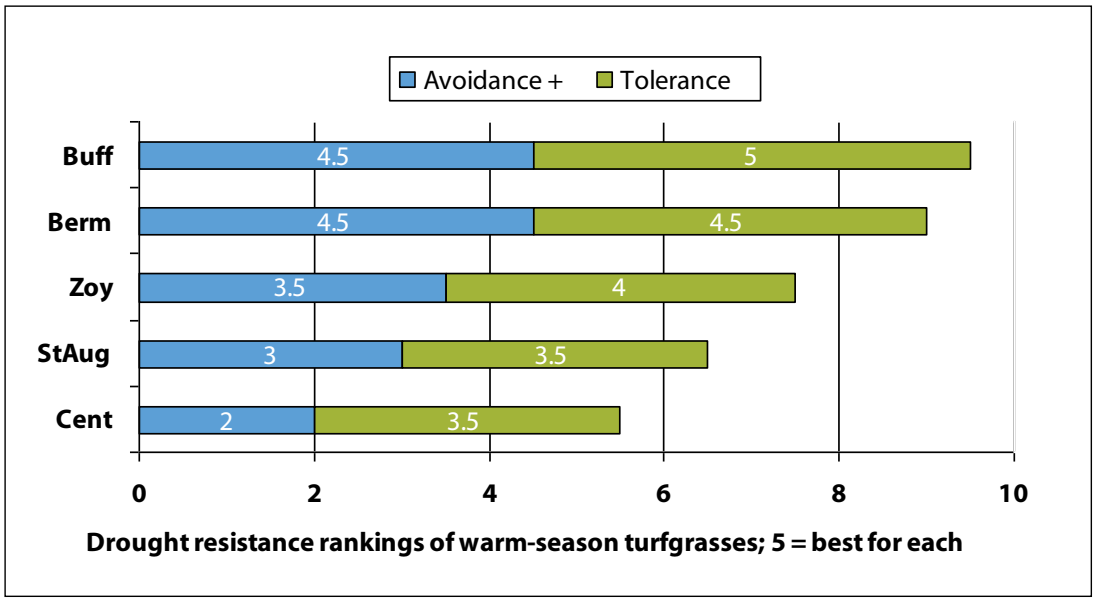



Figure 3-10. Drought resistance rankings of warm-season turfgrasses. Based on a scale of 1 to 5 for avoidance and tolerance; 5 = best ranking for each.

## 3.8 Irrigation System Quality

All existing underground irrigation systems are designed and installed to perform their watering function with few visible portions of the system aboveground. Therefore, visual inspections and analysis are required to assess the efficiency of an irrigation system. Inspection and auditing tasks may be accomplished initially by the golf course superintendent, but for a complete and thorough analysis including assessment of irrigation system longevity and lifespan, a professional irrigation consultant specializing in golf course irrigation systems should be contacted. The Irrigation Association (www.irrigation.org) offers the Certified Golf Irrigation Auditor program.

**BMP #6**
Conduct an audit of the irrigation system.

### 3.8.1 Cool-Season Grasses

Prior to performing a system audit, a thorough visual inspection of the system should be performed and become a routine part of the golf course irrigation system preventative maintenance program. This inspection should include the following:

- *Damaged sprinklers.* Identify any sprinklers that may have been damaged as a result of turf maintenance or other causes. This damage typically affects the riser and nozzle assembly of the sprinkler and typically impairs application performance and efficiency. Maintain a spare parts inventory including nozzle turrets and caps for quick replacement.
- *Plugged nozzles.* Depending on available water quality and filtration methods, debris may clog nozzles. Clogged nozzles should be cleared or replaced.
- *Improper arc alignment*. Sprinklers may have had their arc altered as a result of tampering, damage from maintenance equipment, or sprinkler mechanism failure. Sprinklers should be inspected during operation to determine if readjustment is necessary.
- *Leveling sprinklers.* All sprinklers should be level to finished grade with the body of the sprinkler and splice completely buried. Adjustments are necessary if the sprinklers are tilted, below the finished grade, or higher than finished grade. Settling of soil may also impact sprinklers in relation to finished grade (Figure 3-11). Sprinklers that are not level unintentionally alter the original performance of the trajectory arc, impacting efficiency and potentially damaging turf. If possible, the sprinkler splice should be inspected and replaced if necessary. Splices should be free of corrosion and be completely waterproof.
- *Non-rotating sprinklers.* As a result of mechanical failure, age, or damage, some sprinklers may not be rotating. These sprinklers should be identified and replaced immediately. If the gear drive of the sprinkler is the cause, most sprinklers allow for easy and inexpensive replacement of the internal gear drive assembly. Sprinkler manufacturers also offer complete drive assembly conversion kits that include nozzles for easy retrofit and upgrade without digging up the entire sprinkler. These kits allow users to upgrade from older sprinkler technology to new sprinkler technology for improved efficiency and performance.
- *Closed isolation valves.* Develop a routine checklist of frequently and infrequently used valves and inspect each one to determine if any are unintentionally closed. Closed valves impact the overall design flow characteristics of the irrigation system, likely impacting sprinkler base pressures and altering or eliminating portions of the piping network, thereby increasing velocities throughout the remainder of the system. Finally, all areas of the system should be included in the overnight watering program.



Figure 3-11. Poor sprinkler installation. The soil was not properly backfilled and compacted. *Source:* EC Design Group, LTD.

### 3.8.2 Irrigation System Audit Procedures

Uniform application of water to golf courses can be difficult to assess through visual observation of sprinkler operation. However, extended dry weather periods and limits on the frequency and duration of irrigation system operation may highlight deficiencies in uniformity. The degree of uniformity of a group of sprinklers can be determined by measuring the irrigation efficiency within a given area, defined as the ratio of dry areas to wet areas and referred to as DU. Efficiency is defined as the ratio between the amount of water applied and the amount of water the plant beneficially receives and uses. Uniformity is defined as how uniformly water is made available to plants over a given area.

The most common method for determining the DU of an irrigation system is to perform a catch can test (Figure 3-12). It is strongly recommended that the irrigation system inspection and preventive maintenance items are corrected prior to applying this test. Testing should be performed during conditions that best represent actual operating conditions. For example, tests should be conducted on a day when wind speeds are similar to those during the scheduled irrigation time. Green, tee, and fairway surfaces should be tested separately and individually. The procedures and recommendations for an irrigation audit using catch can tests are provided in Appendix D.



Figure 3-12. Catch can test layout in fairway.
*Source:* EC Design Group, LTD.

# 4

# Surface Water Management



“Proper surface water management preserves the environmental quality of the water features.”



# 4 Surface Water Management

Whether natural or manmade, lakes, ponds, and streams have long been associated with golf courses. Lakes and ponds are usually associated with existing water sources, such as wetland areas. Historically, draining wetlands created these lakes and ponds while creating more dry land for the course. Draining wetlands also mitigated insects such as mosquitoes and black flies, which need wetlands for reliable reproduction, as well as eliminated foul odors often associated with decaying organic matter in wetlands. However, impacts to wetlands and streams are now regulated, restricting these activities (Section 2.1).

Golf course ponds and lakes vary in size, depth, and purpose. They can range in size from quite small to a number of acres and in depth from a few feet to tens of feet. Shallow ponds provide aesthetic benefits and present a water hazard challenge (Figure 4-1). Lakes, particularly those that are man-made, typically serve as irrigation reservoirs, stormwater catchment basins, or some combination thereof. In addition to lakes and ponds, many golf courses situated along natural lakes or rivers often have aquatic inclusions. Regulated stormwater impoundments differ from lakes, ponds, and other surface waters in that they are designed to remain dry except following significant rain events and have the primary purpose of capturing sediments and nutrients from runoff.

Most aquatic areas require their own management plan and regular attention. Organic material and nutrients can lead to eutrophication and to DO depletion. Pesticides in stormwater runoff may be sufficient to harm both vertebrate and invertebrate populations. Therefore, surface water management strategies involve the following efforts:

- reduce sedimentation and nutrient enrichment of surface waters through the use of appropriate design BMPs, appropriately maintained
- reduce chemical runoff (i.e.,, fertilizers, pesticides) in stormwater runoff
- maintain DO levels
- manage algae and aquatic plant populations
- maintain and improve aquatic habitat

Surface water management incorporates many of the issues discussed in this document, including design considerations such as the use of vegetated buffers (Chapter 2), fertilization strategies near surface waters (Chapters 3 and 6), pesticide usage (Chapters 8 and 9), and water quality monitoring (Chapter 5). Proper surface water management as discussed in this chapter and referenced in other chapters preserves the environmental quality of these water features, protects water quality downstream of the golf course, and conserves water.



Figure 4-1. Water hazard. *Source:* David Norman.

## 4.1 Regulatory Considerations

Regulatory issues associated with surface water management vary based on the status of the surface water, the use of pesticides, or biological practices.

### Surface Water Management BMPs

**BMP #1**

Reduce sedimentation and nutrient enrichment to surface waters.

**BMP #2**

Reduce chemical runoff near surface waters.

**BMP #3**

Maintain dissolved oxygen levels.

**BMP #4**

Use native aquatic plants.

**BMP #5**

Manage aquatic plants by implementing an IPM strategy, considering non-chemical means of control first.

### 4.1.1 Dam Safety Regulations

Impounding Structure Regulations (Dam Safety) (4 VAC 50-20) regulates dams in Virginia unless a dam is specifically excluded from the regulations[1]. These regulations cover construction, alteration of an existing impoundment structure, and operation and maintenance of the impoundments. A six-year Regular Operation and Maintenance Certificate is required for an impounding structure. Depending upon the classification of the impoundment, an Emergency Action Plan or Emergency Preparedness Plan and annual Inspection Report are required.

### 4.1.2 Stormwater Regulations

Stormwater regulations apply to impoundments constructed to retain stormwater as discussed in Section 2.1.2.2. These regulations include the use of construction BMPs such as sediment forebays, grassed swales, and vegetative filter strips. Design features that protect aquatic habitats and maintenance issues for these design features are discussed in this chapter.

### 4.1.3 Pesticide Regulations

Any herbicide used must be labeled for aquatic sites and registered with the VDACS for use in Virginia. See Section 9.1 for more information on pesticide regulations.

In addition, a Virginia Pollutant Discharge Elimination System (VPDES) permit is required for the direct application of pesticides to surface waters. A general permit issued by the DEQ is available to operators who discharge pesticides to surface waters from the application of either biological pesticides or chemical pesticides that leave a residue, including pesticides used for weed and algae control. Finally, applicators must be certified by the VDACS Office of Pesticide Services (OPS).

### 4.1.4 Grass Carp Regulations

Biological practices such as the introduction of triploid (sterile) grass carp can be a useful component of a lake management strategy. Under state regulations (4 VAC 15-30-40) the introduction of grass carp requires a permit from the Virginia Department of Game and Inland Fisheries (VDGIF), Triploid Grass Carp Program, which typically involves an onsite inspection following submission of an application and fee[1]. Impoundments are usually approved if little chance exists for the fish to escape.

## 4.2 Water Quality Protection

Sedimentation and nutrient enrichment can promote excessive growth of aquatic plant populations. The flow of sediments such as clay colloids, organic matter, and nutrients into surface waters is difficult, if not impossible, to completely stem. The use of BMPs as described in this section significantly reduces these inputs and protects water quality of surface waters on the golf and downstream, protects irrigation sources, and protects aquatic organisms.

**BMP #1**

Reduce sedimentation and nutrient enrichment to surface waters.

### 4.2.1 Design Considerations

Golf course design can include stormwater management structures to reduce sedimentation to surface waters. Structures that can be incorporated into the design of aquatic areas include the following:

- grassed swales
- vegetated filter strips and
- buffers (Figure 4-2)
- detention basins
- retention basins or ponds
- sediment or pretreatment forebays
- constructed wetlands



Figure 4-2. Vegetated filter strips. *Source:* George Golf Design.

These structures decrease the speed of stormwater runoff, filter runoff, and can store water for irrigation. Each structure is discussed in greater detail in Section 2.3.2.4 and is included in the design BMP "Manage stormwater appropriately through proper drainage and stormwater management devices."

[1] http://www.dgif.virginia.gov/forms/PERM/PERM-001.pdf



Figure 4-3. Riparian buffers. *Source:* George Golf Design.

Depending upon site-specific conditions, including the amount of available space and in-play versus out-of-play considerations, a range of buffer widths can be considered. Buffer widths from 10 to 656 feet have been shown to be effective. In most cases, a buffer of at least 100 feet is necessary to fully protect aquatic resources. Smaller buffers (toward the lower end of this range) still afford some level of protection to the surface waters and are preferable to no buffer at all. Protection of the biological components of wetlands and streams typically requires buffer widths toward the upper end of the range.

For vegetated buffer zones, the installation of ornamental grasses, wetland plants, or emergent vegetation around the perimeter and edges of surface waters serves as both a buffer and wildlife habitat for many aquatic organisms, as well as being aesthetically pleasing (Figures 4-2 and 4-3). Use native plants for these plantings whenever possible (DCR 2011)[1]. A thorough discussion of the selection, installation, and management of other vegetative buffer systems used in golf turf management is presented by Lyman et al. (2005).

### 4.2.2 Maintenance Practices

Maintenance considerations for water quality include the following:

- Maintain healthy turf cover adjacent to surface waters to slow sediment accretion and reduce runoff flow rates.
- Plant shrubs and trees far enough from water edges so that leaves stay out of the water.
- Mow and clip vegetated filter strips, buffers, and riparian shrubs to avoid contributing nutrient inputs into surface waters. Return clippings away from the water or collect them (such as for composting in a designated area) so that runoff does not carry vegetation into the water.
- Mow buffers on in-play areas in riparian areas to heights up to 4 inches.
- Use imaginative plant selection to help reduce nutrient content, such as small floating hydroponic rafts of plants whose roots draw nutrients from the water. These plants can be periodically harvested and composted, which removes nutrients from the water permanently.
- Periodically clean small basins, ponds, and forebays to remove sediments. Be aware that the effort, disruption, and financial outlay for this effort is less than that for dredging an entire body of water.
- Use native plants for riparian buffer zones.

#### Buffer Zone Maintenance Examples

**Example 1:** An approximately 5' wide perimeter to the water's edge is designated as 'zero maintenance' (no fertility or weed control) area, which is cut with a sickle bar mower 1 to 2 times per year. Specific weed pressures are addressed by spot treating. Periodic mowing with a sickle bar is required to prevent undesirable woody plants. The taller vegetation also deters geese because tall vegetation can harbor predators.

**Example 2:** Maintain mowed turf to the water's edge, but raise the cutting heights of the turf as the water's edge is approached. Oklahoma research that simulated intensively managed golf fairway turf bordering water sources showed that a graduated buffer system where turf cutting heights were raised from 1" to 2" as the slope approached the water significantly reduced total runoff volume as well as N and P movement (Moss et al., 2006). This graduated buffer approach improved water quality protection and met the playability expectations of most golfers.

### 4.2.3 Chemical Runoff

Application of chemicals such as fertilizers, dressings, dyes, herbicides, fungicides, insecticides, algaecides, and plant growth regulators can impact aquatic ecosystems. Some pesticides can lead to the loss of certain aquatic organisms and disrupt the food chain. Other products can contribute nutrients causing excessive aquatic plant growth and algal blooms.

[1] Riparian buffer zone plants: www.dcr.virginia.gov/natural_heritage/documents/riparian_nat_plants.pdf.

The BMPs outlined in this document can minimize runoff and prevent stormwater runoff from carrying contaminants into golf course surface waters. Relevant BMPs include the design considerations discussed above and in Chapter 5, appropriate fertilizer applications (Chapter 7), IPM strategies (Chapter 8) and appropriate pesticide application (Chapter 9). Establishing tertiary maintenance buffer zones on the perimeter of all streams and lakes is the most important strategy for avoiding pesticide and fertilizer runoff into surface waters. As a general practice, all chemical applications should be kept 10 to 15 feet away from the water's edge when using rotary spreaders and/or boom sprayer applications. When fertilizers or pesticides are needed, spot treat weeds or use drop spreaders or shielded rotary spreaders and boom sprayers to minimize the potential for direct deposition of chemicals into the water.

**BMP #2**
Reduce chemical runoff near surface waters.

### 4.2.4 Wildlife

Another sedimentation and nutrient source is wildlife, particularly large masses of waterfowl. Not only do waterfowl contribute to the overall decline of many surface waters, they destroy turf and leave unwelcomed droppings. Some waterfowl species, notably Canada geese, have become a serious problem on Virginia golf courses. These birds can thin grass cover and soil greens, fairways, and lounge areas, as well as contribute significantly to the nutrient and sedimentation load of surface waters. Efforts to control unwanted wildfowl have met with mixed success. Some golf courses use unusual, loud sounds to deter waterfowl, others use dogs, while some accommodate hunters for the first hour or two on designated mornings. Unfortunately, many of these efforts do not lend themselves to all golf courses, particularly in more urban areas.

Water also attracts certain rodents. Muskrats, beavers, and nutria tend to cause the most harm. Muskrats burrowing into dams can cause severe leakage and possible dam failure. Beavers damage trees growing near ponds and lakes and cause significant obstruction to water flow. Nutria (an exotic species) not only burrow but also consume the roots and rhizomes of wetland plants. Consult a vertebrate pest control specialist if any of these species cause serious problems.

## 4.3 Dissolved Oxygen

The life of all fishes, most invertebrates, many amphibians, and some reptiles depends on adequate levels of DO. The amount of DO an aquatic organism needs depends upon its species, the temperature of the water, presence of pollutants, and the state of the organism itself (adult or young, active or dormant). Warm water fish species can survive at levels as low as 3-4 ppm, but are severely stressed and some will die. DO deficits can also impact other vertebrate and invertebrate species inhabiting the lake or pond.

### 4.3.1 DO Capacity

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. Temperature determines the amount of oxygen that can dissolve in water. Colder water has higher DO levels than warmer water; DO levels will differ by time of day and by season as water temperatures fluctuate. Similarly, a difference in DO levels may be seen at different depths in deeper surface waters if the water stratifies into thermal layers. Flow rates also influence DO levels; for example, fast-flowing streams hold more oxygen than impounded water. At best, impoundments in Virginia can attain about 25 ppm of DO, but levels of 8-12 ppm for impoundments are more typical.

Gas exchange with the atmosphere also influences DO levels. For example, oxygen can be lost when exposure to the atmosphere is impeded. In warmer weather, impoundments can become covered with vegetation, restricting atmospheric gas exchange and increasing microorganism activity. A series of overcast days can so severely limit photosynthesis that oxygen is not replenished as fast as it is used. Respiring plants will use much of the DO while failing to photosynthesize. When the increased numbers of aquatic plants eventually die, they support increasing amounts of bacteria which in turn use large amounts of DO for decomposition of the organic material.

Aquatic plants and algae photosynthesize, producing and using oxygen in water. During the day, photosynthesizing algae and plants constantly release oxygen. At night, photosynthesis slows down considerably or even stops and algae and plants pull oxygen from the water. Excessive growth is called eutrophication. Eutrophic impoundments can become stressed quickly and the potential for a fish kill increases, especially following several days of cloudy weather or low light as discussed above.

### 4.3.2 DO Levels

DO levels are seldom a problem in cold weather. Maintaining sufficient DO in an impoundment in warmer weather often presents a challenge but is necessary to help maintain ecological balance and, therefore, a healthy lake or pond.

Preventing nutrient enrichment to surface waters from stormwater runoff containing fertilizers, soil amendments, mulches, and vegetation, (management of aquatic plant populations) helps to prevent eutrophication. In particular, P in one of two anionic forms, $HPO_4^{2-}$ or $H_2PO_4^-$ is highly leachable and is a nutrient of concern with respect to eutrophication (see Section 6.6.1).

Mechanical aeration increases oxygen exchange with the atmosphere and accelerates decomposition of organic materials. Bottom diffusion aeration is typically the most efficient and economical method. Air is pumped from a quiet rotary vane compressor to a self-cleaning diffuser on the bottom of the lake. The column of rising bubbles circulates water continuously to the surface as it is oxygenated. Aerators that move the water into the air (such as fountains) require a great deal more power to operate and do not get as much oxygen into the water as bottom diffusion. Bottom diffusion aeration can also prevent turnover in stratified lakes. In stratified lakes, the colder bottom layer of water may become deficient in DO due to microbial decomposition of organic matter on or near the bottom. A sudden cold rain or wind can break down stratification and bring the cold, oxygen-depleted water to the surface very quickly. This sudden change in oxygen availability can stress or even kill organisms that normally inhabit the upper water. Bottom-up aeration prevents stratification and therefore the potential for turnovers.

**BMP #3**
Maintain adequate dissolved oxygen levels in surface waters.

## 4.4 Aquatic Plants

Aquatic plants include algae and vascular plants. Many non-native plants can become invasive and therefore the use of native plants is encouraged. The excessive growth of any plants can require plant management since plant populations can shift dramatically from one growing season to the next. Water clarity may change slightly, nutrient loads in the sediment may increase, and temperature change may stress one species more than another. Unseen predators or diseases may take a toll on one species, thus releasing another species to expand its niche.

### 4.4.1 Aquatic Plant Classification

Aquatic plants are classified, in general, as either algae or vascular (higher) plants. Algae are further classified as planktonic, filamentous, or erect. Vascular plants are further classified as submersed, emersed, or floating.

#### 4.4.1.1 Algae

Planktonic algae exist as either single cells or small conglomerations of cells. Their physical attributes usually are not discernable with the naked eye. Under normal conditions, planktonic algae are a primary part of the food chain. They tend to give water a green cast, which can be intense under heavy bloom conditions in warm weather. Under eutrophic conditions, planktonic populations can expand rapidly and can produce extraordinary amounts of oxygen during the day, thus depleting DO during the night. Die off may occur just as quickly, causing cause severe DO depletion as microorganisms decompose the dead algae. While planktonic algae are found in virtually all impoundments, it is the boom-bust cycle that requires attention. In addition to DO concerns, this type of algae may become malodorous.

Filamentous algae form long strings of cells that can often resemble hair. Most begin to grow from the bottom of a pond in water shallow or clear enough to allow light penetration. They form delicate, light green masses. As the growing season progresses, portions of these masses break loose from the bottom and float to the surface. As the floating material dies it becomes unsightly and is often referred to as “pond scum”. Ultimately, the algae falls to the bottom and decomposes. This type of algae may also become malodorous.

Erect algae grow on the bottom of impoundments and resemble vascular plants, but do not possess roots or a vascular system. For the most part, erect algae cause few problems, although in relatively shallow water they can cover a large percentage of the water. These algae provide habitat for a host of vertebrate and invertebrate organisms.

#### 4.4.1.2 Vascular Plants

Submersed vascular plants are rooted in the bottom of a body of water and grow towards the surface. They grow to just below the surface and remain covered by water, although some send flower stalks above the surface. Provided sufficient light is available, they can grow in water of significant depth. In Virginia, some of the most noxious

invasive plants, such as hydrilla and curly-leafed pondweed, fall into this category.

Emersed vascular plants are rooted on the bottom of the body of water and grow up through the water and past the surface. Some have leaves that float on the surface of the water while others are more erect and may grow from inches to feet above the surface. Some, such as cattails, sedges, and reeds, may grow out onto the riparian margins of the impoundment. Most provide excellent habitat for animals, though not all may be considered desirable. One emersed plant that has become extremely noxious is common reed *(Phragmites)*, which tends to form vast monocultures.

Floating plants have no roots extending into the soil. At least one fern falls into this category in Virginia. As unattached plants, they are easily blown about an impoundment by the wind. At low population levels, these plants are of little consequence. However, at high population levels, they can literally cover the surface and leave no water visible. Under these circumstances, these plants form a barrier that severely limits atmospheric gas exchange. Unfortunately this type of growth occurs during the warmer part of the season when the water's ability to hold DO is significantly reduced. One particularly noxious floating invasive plant present in Virginia is giant Salvinia, a native of South America.

### 4.4.2 Native Aquatic Plants

Few lakes naturally occur in Virginia, limiting the selection of native aquatic species. However, aquatic plants found along slow moving streams often lend themselves to golf course lakes and ponds. Using native species helps new impoundments provide the proper environment and habitat for native animals, which in turn establishes efficient interspecies relationships. This arrangement then provides naturally occurring checks and balances to growth that cannot be achieved using non-native plant material.

Non-native plant material can be used to create certain aesthetically pleasing views but can also be problematic. When used terrestrially, most of these plants can be controlled. However, non-native aquatic plants often have a competitive edge over native plants and can become invasive. Invasive plants are characterized as follows:

- grow and mature rapidly
- reproduce prolifically
- have highly successful seed dispersal, germination and colonization strategies
- are capable of rampant vegetative spread
- can outcompete native species
- can be expensive to remove or control

DCR publishes lists of invasive alien plant species that includes aquatic plant species[1] (DCR 1999). Certain plants are considered so invasive that federal law prohibits their transport across state lines. In addition to invasive non-native species, some native species can be very aggressive. Their use should be delayed (or avoided) until the more delicate species are well established. Some native plants, such as watershield *(Brasenia)*, can interfere with irrigation water intakes.

To avoid introducing invasive species, carefully establish vegetation around a new impoundment. Only purchase plants after inspecting the source and assure that the plants are not contaminated with non-natives. Non-native species can also be introduced via the feathers of waterfowl as vegetative fragments or pass through the digestive system as unharmed seeds, tubers, or turions. In addition, humans can introduce invasive species into a golf course aquatic environment, such as through dumping of aquarium vegetation.

**BMP #4**
Use native, non-invasive aquatic plants.

### 4.4.3 Aquatic Plant Management

Additional information on aquatic pest management and recommendations for aquatic vegetation management in Virginia may be found in the following references:

- *Horticultural and Forest Crops Pest Management Guide, Low-Management Crops and Areas:* Aquatic Weeds section (VCE)
- *Aquatic Pest Control: A Guide for Aquatic Pest Managers in Virginia* (VCE, 2003; in revision)
- *Pesticides and Aquatic Animals: A Guide to Reducing Impacts on Aquatic Systems* (VCE 2009b)

In addition, the National Invasive Species Information Center maintains a web site on aquatic plant management, including additional references and management plans by species[2]. The control of aquatic weeds should be achieved using an IPM strategy (Chapter 8). Prevention, cultural practices, mechanical removal, and chemical control should be part of this strategy. Although these management

[1] http://www.dcr.virginia.gov/natural_heritage/documents/invlist.pdf
[2] http://www.invasivespeciesinfo.gov/aquatics/main.shtml

efforts can control existing aquatic plant species populations, even the best efforts can be thwarted by wildlife, which can reintroduce undesirable species.

**BMP #5**
Manage aquatic plants by implementing an IPM strategy, considering non-chemical means of control first.

#### 4.4.3.1 Prevention
The first line of defense is prevention. Educating golfers and adjacent residents about the environmental and financial cost of aquatic vegetation management may help. Managing waterfowl to reduce sedimentation, reduce nutrient enrichment, and avoid the introduction of invasive species may help prevent excessive or unwanted aquatic plant populations.

#### 4.4.3.2 Cultural practices
In addition to the design and management considerations discussed in Section 4.1 to decrease sedimentation and nutrient enrichment, cultural practices are available to manage aquatic plant populations. For example, dyes and colorants can be used to reduce sunlight penetration. Most work well, except in very shallow waters. As another example, benthic barriers are available that provide a cover for the bottom of an impoundment to prevent vascular plant growth.

#### 4.4.3.3 Biological practices
Biological practices such as the introduction of triploid (sterile) grass carp can be a useful component for the control of a significant number of submersed species, particularly hydrilla. As discussed in Section 4.1, a permit is required VDGIF before introducing grass carp. VDGIF personnel can recommend the number and size of the fish to be used based on site-specific characteristics. Additional fish should be added each year to allow for mortality and consumption by larger carp. Smaller carp are the most voracious eaters, but care must be taken in size selection. If the impoundment contains predatory fish such as bass, larger carp must be stocked.

#### 4.4.3.4 Mechanical removal
Mechanical removal of troublesome vegetation is an option, but can be expensive. Furthermore, the process of removing vegetation often results in vegetative fragments being left behind which can float to other areas of the impoundment, take root, and create new problems. Mechanical removal does not preclude manual removal of algae or other organic detritus. Mechanical skimmers can be used to remove small floating plants such as watermeal and duckweed.

#### 4.4.3.5 Chemical control
Chemical control is an option often selected because results are soon evident. Products are now available that are both efficacious and selective, but may be expensive and limit irrigation for varying periods of time. Algae can be controlled by a variety of copper products, with spot treatments possible using granular products. Selective and nonselective products are available for the control of vascular plants. Section 7 of *Pest Management Guide: Horticultural and Forest Crops* (VCE) provides information on aquatic herbicides. Information provided in this publication includes relative effectiveness for different aquatic species, water use restrictions, and application rates.

Treatment of aquatic weeds should take place in the spring as the weeds begin active growth. Later in the season, weed density and maturity make control more difficult. Sampling the lake bottom in the late spring or early summer in areas heavily infested the year before should show when the growth begins. It may be necessary to treat only a third to half of the impoundment at a time.

The control of aquatic weeds should follow an IPM strategy (Chapter 8). If chemical control is necessary, application of aquatic herbicides should follow pesticide management regulations (Section 9.1), pesticide selection, application, storage, and handling BMPs (Chapters 9 and 10).

## 4.5 Human Health Concerns
Standing bodies of water, particularly small ones, tend to attract insects. While most are harmless, even desirable, others are both a nuisance and a health hazard. Mosquitoes, black flies, and deer flies all require small bodies of water for reproduction, such as small puddles or wet tree knotholes often associated with small impoundments. While spraying the adult insects with an insecticide is usually not practical or efficacious, the use of larvacides is common in Virginia. See Chapter 8, Integrated Pest Management, for more guidance on managing insects to protect human health.

# 5

# Water Quality Monitoring





"Regularly scheduled water quality monitoring can be both preventive and curative in terms of environmental impact."

# 5 Water Quality Monitoring

Regularly scheduled water quality monitoring can be both preventive and curative in terms of environmental impact. The public perceives that water sources on golf courses are contaminated with nutrients and chemicals applied in turf management. However, as demonstrated in a high-profile research project conducted at Purdue University's North Golf Course, a properly designed and managed golf course can actually improve the quality of the water entering golf courses from stormwater runoff originating from neighboring farmland and residential development (Kohler et al. 2004).

Water quality monitoring measures the likely origin and extent of sedimentation and nutrient inputs and impacts to surface water and groundwater. Using monitoring data, management strategies can be altered if the need for corrective action is identified. In addition, water quality monitoring of irrigation sources (particularly water supply wells and storage lakes) provides valuable agronomic information that can inform nutrient and liming programs.

If budgetary concerns limit the scope or frequency of sampling, water quality monitoring should concentrate on the water sources with the most significant impacts on the surrounding environment. In addition, a group of area golf courses can purchase water sampling equipment to share among their facilities.

### Water Quality Monitoring BMPs

**BMP #1**
Conduct periodic water quality sampling.

**BMP #2**
Follow recommended sample collection and analytical procedures.

**BMP #3**
Interpret water quality reports and take corrective action as needed.

## 5.1 Regulatory Considerations

Statewide water quality monitoring requirements do not currently exist for Virginia golf courses, although regulatory agencies such as Virginia Department of Environmental Quality (DEQ) have occasionally required water quality monitoring programs for some new golf course construction projects depending on site-specific concerns and project components. Except for these cases, water quality testing in Virginia is voluntary and is expected to remain voluntary in the immediate future.

Although water quality monitoring programs for golf courses are voluntary, they are based on regulations that reflect water quality concerns in Virginia. In order to understand these concerns and develop effective monitoring programs, golf course managers should establish working relationships with local and state regulatory agencies involved in water quality assurance and share monitoring data with them. Monitoring data can also be used to document water quality and educate the public about water quality issues. Finally, impaired waters and the Chesapeake Bay are affected by specific regulations. Golf course managers in these watersheds should be aware of the impact of current and potential future requirements on golf course management.

### 5.1.1 Total Maximum Daily Load Requirements

The goal of all water quality protection programs is to ensure that waters meet water quality standards and are thereby 'fishable and swimmable'. EPA lists impaired waters throughout the state (303(d) list of impaired waters); consult this list to identify any TMDL requirements for water sources in a watershed[1]. TMDLs are developed based on targeted levels of potential pollutants such as excessive nutrients, fecal coliform bacteria, sediment, metals, and toxic chemicals. State, federal, and local water quality regulations can change and therefore it is critical to remain informed on local, regional, and national policies and regulations.

### 5.1.2 Chesapeake Bay Watershed Considerations

Protecting water quality in the Chesapeake Bay watershed is a key interest in Virginia for the area of the state within the watershed boundaries (see Figure 1-1). EPA has mandated improvements in the Bay's water quality and enacted what was originally termed the 'Chesapeake Bay TMDL' but is now being called 'the Chesapeake Bay pollution diet'. The Bay pollution diet identifies the necessary reductions of nitrogen, phosphorus, and sediment for the Bay on a state-by-state basis. In formulating the 'pollution diet', each state submitted a

[1] water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/

final Phase I watershed implementation plan (WIP) to EPA. Although golf turf management is not specifically mentioned in the WIP or in EPA's overall 'pollution diet', EPA's review of Virginia's final WIP details three key areas of particular interest to golf turf as a component of urban stormwater management:

- Virginia finalized a stormwater rule in 2011 to improve new and redevelopment performance standards.
- Virginia requests individual wasteload allocations for Phase I Municipal Separate Storm Sewer Systems to more explicitly demonstrate the amount of urban runoff load that each permitted jurisdiction is expected to achieve.
- Virginia commits to implement a Bay-wide and possibly statewide regulatory program to limit fertilizer application on urban lands.

Each of these components has potential golf turf management implications. Addressing these three areas of concern will play a large part in achieving designated milestones in nitrogen, phosphorus, and sediment reductions. Phase II WIPs are currently being developed by states for review by EPA. By 2017, Phase III WIPs will be considered and implemented. The EPA can further modify TMDLs between 2017 and 2025 to achieve stated goals in pollution reduction by 2025.

## 5.2 Water Quality Sampling Program Design and Implementation

The design and implementation of a water quality monitoring program requires an understanding of the following:

- watershed dynamics, both on the golf course and surrounding the course
- discharge levels
- site characteristics, such as soil characteristics and topography
- size and depth of standing water sources and their potential uses
- turfgrass and vegetation selection
- any future plans for development in and around the course

For new golf courses, baseline water quality levels should be measured prior to construction at points of entry and exit of flowing water sources on or surrounding the golf course, as well as in any existing lakes or ponds on the site. Golf courses sited near residential areas should also include upgradient and downgradient sampling in the monitoring program. As in new golf course scenarios, monitoring programs for existing golf courses should establish baseline flow and nutrient/chemical levels. Water quality monitoring efforts should be prioritized on the water sources with the most significant impacts on the surrounding environment.

### 5.2.1 Periodic Water Quality Sampling

Periodic sampling identifies trends in water quality changes due to the environment and/or management programs. Monthly sampling is ideal, but time, labor, and budget constraints for sampling and sample analyses may make this unachievable. Therefore, a seasonal sampling program (i.e., 4 samples per year) is recommended. At a minimum, semi-annual testing is acceptable once baseline data are established.

**BMP #1**
Conduct periodic water quality sampling.

### 5.2.2 Number and Location of Sampling Points

The number of samples per site is highly variable and depends on the size, location, and number of water sources on or near the golf course. The entry and exit points of golf course water sources are logical sampling points. However, sampling and analysis of standing water sources (ponds and lakes), springs, and any other irrigation sources should also be conducted. State and local regulatory agencies, nonprofit environmental groups, schools, and the local extension service can be consulted for assistance in developing an effective sampling program.

## 5.3 Sampling Parameters, Collection, and Analysis

Water quality monitoring with properly collected samples that measure the recommended sampling parameters provides the information necessary to conduct a detailed assessment of golf course water quality. This level of testing is one of many important steps required for golf courses seeking Audubon Cooperative Sanctuary Certification by Audubon International. This program helps golf courses protect the environment and preserve the natural heritage of the game of golf. While not required, the Audubon program can serve as a valuable resource for many golf courses.

### 5.3.1 Sampling Parameters

A number of common parameters can be used to assess water quality (Table 5-1; see also *Virginia Citizen Water Quality Monitoring Program Methods Manual* [DEQ 2007]). Additional references for water quality parameters include the following:

- *Environmental Stewardship Guidelines* includes a highly detailed chapter on water quality monitoring specific to golf turf (Oregon GCSA 2009).
- *Best Management Practices for the Enhancement of Environmental Quality on Florida Golf Courses* contains extensive discussions on water quality monitoring and appropriate sampling parameters (FL DEP 2007).
- *A Guide to Environmental Stewardship on the Golf Course* discusses water quality monitoring as an important component of the Audubon International certification program (Audubon Intl. 2002).



Figure 5-1. Benthic macroinvertebrate collection and identification. *Source:* Williamsburg Environmental Group, Inc.

Identification and general assessments of the populations of benthic macroinvertebrates (bottom-dwelling aquatic invertebrates larger than ¼ mm, such as insects, worms, and larvae) can also be a component of a water quality monitoring program and is recommended by Audubon International (Figure 5-1). As water quality indicators, benthic macroinvertebrates reflect current ecological conditions and cumulative impacts from multiple environmental stressors over time. Macroinvertebrates are collected using a multi-habitat approach consistent with the EPA's *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers*[1] (Barbour et al. 1999). Sample collection and taxa identification guidelines are available (MD DNR 2003[2]; WV DEP[3]), but often require trained biologists. It may be feasible to supplement the services of a professional biologist with the help of local volunteers such as environmental advocacy groups and the biology/ecology classes from area schools. Local or state regulatory agencies may also be able to help establish a testing program.

### 5.3.2 Sample Analysis

Standard sampling parameters for a golf course include pH, DO, electrical conductivity, and water temperature. These data must be measured on site because the parameters are dynamic and subject to change during transport to the laboratory. A portable, handheld multi-probe water quality instrument (such as a Hydrolab[4]) should be used for monitoring these parameters and typically costs $2,000–$3,000 (Figure 5-2). If the cost of the multi-probe is a deterrent to developing a testing program, a group of area golf courses can purchase a unit to share among their facilities.

If water quality monitoring is specifically targeting nutrient management (Chapter 6), the most essential data are measurements of N (both nitrate [$NO_3$-N] and ammonium [$NH_4$-N]) and phosphate. Numerous testing kits are commercially available to assay these nutrients, but their reliability and accuracy can be suspect. Therefore, the use of accredited laboratories that specialize in water quality assessments is recommended. Prior to sample collection, an accredited laboratory can also provide detailed instructions on proper sample collection and handling methods. Following analysis, laboratories should provide N data as both $NO_3$-N and $NH_4$-N measurements, sometimes presented in reports as $NO_3$- and $NH_{4+}$. Water quality reports also include an interpretation of data results as they apply to parameter thresholds.

**BMP #2**
Follow recommended sample collection and analytical procedures.

Accredited laboratories can also provide pesticide concentration analyses. Pesticide tests are expensive and are typically only performed every 3–4 years as part of a regularly scheduled monitoring program. But, similar to nutrient management, the data can be instrumental in validating the performance and precision of pest control at a well-maintained golf facility (Chapters 8 and 9).

[1]water.epa.gov/scitech/monitoring/rsl/bioassessment/upload/2001_03_21_rbp_wp61pdf_rbp_main.pdf
[2]http://dnr.maryland.gov/streams/pdfs/ea-99-2_rev2003.pdf
[3]http://www.dep.wv.gov/WWE/getinvolved/sos/Documents/Benthic/AquaticInvertGuide.pdf
[4]www.hydrolab.com

## Table 5-1. Common water quality parameters

| Parameter | VA Water Quality Standard (9 VAC 25-260) | Importance |
|---|---|---|
| Dissolved Oxygen (DO) | Most Waters: min. 4 mg/l<br>Stockable Trout Waters: min. 5 mg/l<br>Natural Trout Waters: min. 6 mg/l | Essential for aquatic organisms. |
| pH | Most Waters: 6.0 – 9.0 (the exception is swamp waters with a pH standard of 3.7-8.0). | Affects chemical and biological processes; organisms can only survive within a specified range. |
| Nitrogen | Nitrate as N in public drinking water supplies: 10,000 µg/l; other nitrate standards to be developed. | Essential for plant growth; necessary for metabolism and growth of aquatic organisms. |
| Phosphorus | In saltwater as elemental phosphorus: 0.1µg/l. Screening value for total phosphorus to be developed. | Essential for plant growth; necessary for metabolism and growth of aquatic organisms. |
| Benthic Macroinvertebrates | Narrative standard based on type and abundance of observed organisms. | Good indicators of water quality. |
| Bacteria | Standards for the protection of aquatic life (see 9 VAC 25-260-170). | Indicator of fecal contamination; can cause illness. |
| Chlorophyll A | Screening values for Chlorophyll a in Chesapeake Bay and tidal tributaries. | Estimates the abundance of algae. |
| Submerged Aquatic Vegetation (SAV) | No | Food and habitat for aquatic organisms. |
| Temperature | Nontidal Waters (coastal and piedmont zones): 32°C<br>Mountainous zones waters: 31°C<br>Stockable Trout Waters: 21°C<br>Natural Trout Waters: 20°C | Affects chemical and biological processes. |
| Turbidity/Transparency or Total Solids | No | Turbidity is a measure of water clarity and an indirect indicator of sedimentation and nutrient enrichment. Excessive turbidity impacts aquatic habitat and can impair photosynthesis. |
| Salinity | No | Affect the distribution of plants and animals in estuarine environments. |
| Conductivity | No | Useful measure of general water quality. Significant changes may indicate a discharge or another source of pollution. |

Sources: *Virginia Citizen Water Quality Monitoring Program Methods Manual* (DEQ 2007) and Virginia Water Quality Standards 9 VAC 25-260, www.deq.state.va.us/wqs/documents/WQS_eff_6JAN2011.pdf.

## 5.4 Water Quality Reports

**BMP #3**
Interpret water quality reports and take corrective action as needed.

Water quality monitoring data must be carefully analyzed to ensure reaching proper conclusions and taking appropriate action. In order to implement a successful water quality monitoring program, the definition and significance of each parameter and acceptable range of results should be understood. Regulatory standards exist for some, but not all, of the parameters relevant to a golf course water quality monitoring program (Table 5-1). Audubon International has also developed a list of water quality parameters with descriptions and acceptable ranges. Published information sources should provide sufficient guidance for most monitoring programs.

Interpretation and use of the data depends to a large extent on the goal of the monitoring program. For example, data can be evaluated in any of the following ways:

- comparison with baseline data before construction of a new or renovated golf course or prior to implementing maintenance program changes, such as IPM
- comparison of monitoring points entering the site with those leaving the site to determine if golf course maintenance practices are having any impact on water quality (either positive or negative)
- comparison of results over a period of time to determine trends, such as comparing particular monitoring point data collected at the same time of year
- comparison of results with an acceptable range of values as determined by DEQ standards or those suggested by Audubon International



Figure 5-2 Water quality monitoring using a Hydrolab at the Country Club of Virginia. *Source:* Erik Ervin.

Use good judgment and common sense when interpreting test results and be wary of basing management decisions on single data points. Individual test results depend on many variables, such as time of day, weather, season, and stream flow conditions. For example, DO results are affected by these variables and also by salinity. DO concentrations of surface samples are typically highest around mid-day due to photosynthetic activity of aquatic plants and lowest in the early morning due to the overnight consumption of DO. Additionally, lower DO concentrations are expected during the summer because warm water cannot hold as much DO as cold water. Lower DO concentrations are also anticipated during low flow conditions due to less oxygen exchange with the environment.

Stream flow also has an impact on water quality and macroinvertebrate populations and should be considered when interpreting these results. For example, high flow conditions following a storm event may show higher sediment levels due to stream erosion and particulate matter suspension resulting from greater water velocity. Therefore, decisions based on just one sample can sometimes be faulty and comparative trends over time may provide the most insight regarding water quality.

Simply collecting water quality data is of little to no value without using those results to identify strengths and weaknesses in the golf turf management program. Periodic review, comparisons, and contrasts of current test results with results from previous seasons help to identify potential 'problem spots' on the course and to develop management strategies to specifically address these concerns. If a spike in nutrient levels is observed, possible causes include:

- a recent fertilizer application or perhaps 'misapplication' due to operator error
- an extreme weather event
- some combination of these or other factors

Most often, water quality problems can be addressed by simple changes in management strategies to a course's existing nutrient management program (see Chapter 6 and Appendix F).

## Example Water Quality Monitoring Report

Appendix A includes a sample test report from the water quality monitoring program at the Keswick Club. This program was initiated as part of an Audubon Cooperative Sanctuary Program certification and therefore the test parameters are based on Audubon recommendations.

Five monitoring stations were located where streams enter and leave the golf course property. DO, temperature, conductivity, and pH were measured using a water quality probe. Flow was calculated using a flow velocity meter. Water depth was measured at 6" intervals across the stream. Samples were collected and taken to a laboratory for testing of nitrates, Total Kjeldahl Nitrogen (TKN), and phosphorus. Benthic macroinvertebrate sampling and sorting was also conducted.

The report indicates that water temperature was normal for the time of year and fluctuated slightly due to differences in tree canopy. DO levels were much higher than the DEQ recommended minimum, as might be expected for a winter monitoring. Conductivity was found to be within a normal range for these streams. The stream pH was also found to be normal and within the middle of the allowable range per DEQ standards. Laboratory test results indicated that nitrates, TKN, and phosphorus were acceptable and negligible differences were found between upstream and downstream stations.

The report has a detailed description of the benthic macroinvertebrate sampling and sorting process used to determine water quality value. The Virginia DEQ biomonitoring protocols were used for this project. The sampling indicated that water quality declined somewhat downstream. What caused this decline? A single test result may not be sufficient to determine the cause and make management decisions for the golf course. Furthermore, the cause may not be related to golf course activities. In this case, for instance, the degradation could be due to offsite construction activity rather than golf course management practices.

# 6

# Nutrient Management



"The nutrient requirements of turfgrasses are met by properly choosing fertilizer sources and application strategies to optimize turfgrass performance and protect the environment."



# 6 Nutrient Management

Millions of turfgrass plants live on a golf course, each with its own nutrient requirement. These plants have a variety of performance expectations and nutrient needs depending on how they are used and maintained, where they are located, and what type of soil they are grown on. The nutrient requirements of turfgrasses are met by properly choosing from a myriad of fertilizer sources and application strategies that not only optimize turfgrass performance for a specific use, but also protect the environment. A healthy, actively growing grass with an extensive root system optimizes the turf's ability to protect water quality by minimizing the potential movement of nutrients and sediments through runoff and leaching. This chapter details the successful strategies used in developing fertility programs, choosing appropriate nutrient sources, and properly applying the materials.

Additional considerations for fertilization management depend on site-specific characteristics within each golf course. For example, irrigation provides the necessary soil moisture required to grow a healthy turf (Chapter 3). Cultural practices such as returning clippings to recycle nutrients can improve turf health while other practices such as core aerification can increase the efficiency of nutrient and lime applications, which helps to reduce the potential for surface runoff (Chapter 7). Surface water management strategies (Chapter 4), such as using low input vegetated buffers around surface waters, are also part of nutrient management programs that can improve water quality. Maintenance operations for the storage and handling of fertilizers prevent unintended releases of fertilizers (Chapter 10). Appendix F provides additional information on nutrient management planning and preparing a nutrient management plan.

### Nutrient Management BMPs

**BMP #1**
Base all fertilization practices other than standard N fertility needs on a soil test.

**BMP #2**
Supplement soil tests with plant tissue tests when necessary.

**BMP #3**
Optimize nutrient use efficiency and reduce leaching potential of readily available nitrogen sources.

**BMP #4**
Use Enhanced Efficiency (slow release or stabilized) N sources to optimize nutrient use efficiency and reduce nutrient leaching potential.

**BMP #5**
Use iron as a supplement to standard nitrogen programs to promote turfgrass greening without flushes of shoot growth.

**BMP #6**
Maintain appropriate soil pH in order to optimize nutrient availability.

**BMP #7**
Apply nitrogen during periods of optimal turfgrass growth.

**BMP #8**
Consider site-specific conditions before making a fertilizer application.

## 6.1 Regulatory Considerations

Virginia regulations (4 VAC 5-15) serve as the basis for developing certified Nutrient Management Plans (NMPs) to limit nutrient (primarily N and P) and sediment pollutants from reaching water and entering watersheds. DCR certifies individuals to write NMPs for turf and landscape. These regulations provide the basis for developing environmentally responsible NMPs that consider both warm-season and cool-season grasses, the turf use, soil type, and nutrient application levels and frequencies for both grow-in and general management purposes. A certified nutrient management planner uses these recommendations in developing a site-specific NMP. DCR and VGCSA have set a goal for all golf courses in Virginia to have a NMP in place before 2017. DCR provides a list of certified planners and information about the certification program[1]. Appendix F provides more information on nutrient management planning and a sample NMP.

[1] www.dcr.virginia.gov/stormwater_management/nutmgt.shtml

## 6.2 Soil Testing

Soil testing provides the basis for sound nutrient management and water quality protection programs in golf turf management, especially given the dynamic nature of the sandy soils of many putting greens and tees. A standard soil test provides information on soil pH and the levels of the macronutrients phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) and typical micronutrients iron (Fe), zinc (Zn), copper (Cu), and boron (B). Soil test results do not provide nitrogen (N) levels because N constantly fluctuates between plant available and unavailable forms. However, soil test results typically provide a recommendation for N levels and timing of applications.

No single 'best' soil testing protocol for golf turf soils exists. Two general approaches to basic soil testing are the sufficiency level of available nutrients (SLAN) and the basic cation saturation ratio (BCSR). In general, the SLAN testing procedure provides the most accurate assessment of plant-available nutrients in the soil. The BCSR method is considered to be a 'maintenance level' approach that considers a soil's cation exchange capacity (CEC) in its determination of soil nutrient status.

Chemical extraction is also needed to predict nutrient needs and amounts required to avoid deficiencies. In the mid-Atlantic states, the Mehlich-1 extractant is typically used, while other laboratories use the newer Mehlich-3, which requires new calibration data to relate soil test levels to field performance. In addition to standard nutrient extraction procedures, other techniques are available such as the Saturated Paste Extraction method, which is highly effective in measuring sodium adsorption ratios (SAR) and total soluble salts (TSS). This procedure provides very different standard nutrient extraction levels than Mehlich-1 or -3 extractions. Chemical extract data must be calibrated, which means it must be tested and proven under actual growing conditions using replicated nutrient response field trials with the plant species of interest under a wide range of soil, water regimes, and climatic conditions. The quality of the calibration data determines the accuracy of the resulting recommendations.

**BMP #1**
Base all fertilization practices other than standard nitrogen fertility needs on a soil test.

A series of articles on soil testing from a golf turf management perspective (Carrow et al. 2003, 2004a, 2004b) offers guidance on the differences in testing procedures and the types of questions to ask a soil test provider. Although soil test results and recommendations may vary depending upon the chemical extraction procedures used, results should be similar when performed using the same procedures. Working with a single accredited laboratory will help to achieve consistent results.

### 6.2.1 Frequency and Timing of Soil Tests

Native soils require testing only once every three years. Sand-based greens and tees require testing once a year, however, because of their specific characteristics. Sand-based systems, which are often completely modified soils designed for rapid drainage and resistance to compaction, have reduced nutrient and water holding capacity compared to heavier textured soils. Furthermore, frequent removal of clippings from golf greens (and sometimes tees) increases the need for supplemental fertilization. Nutrient and pH levels on heavier textured native soils are highly buffered against rapid change due to much greater nutrient and water holding capacity. If testing indicates additional nutrient or lime needs, large quantities of amendments are typically required to affect the change. Once desired levels have been achieved, further changes in nutrient levels and pH occur slowly.

Soil samples can be taken at any time of the year, but sampling is usually recommended in advance of planting or of regular fertilization. Fall sampling is most common and allows time to review results and apply lime and nutrients in advance of spring growth. Limestone takes months to fully react with soil, so liming should be done well in advance of spring growth. Nutrients, on the other, are more reactive and should be applied closer to the onset of plant growth. Do not perform soil sampling for at least two months after fertilization or liming.

### 6.2.2 Soil Sample Collection

The quality of the soil test data received depends on the quality of the samples collected. A soil test of a 'problem site' (such as a fertilizer or chemical spill) can provide valuable information for specific problems and guide remediation efforts, but this soil sample should not be included with other soil samples that represent typical course conditions. Make sure that samples represent conditions in the area of concern.

When planning sample collection, divide the golf course into its logical components for sampling (greens, tees, fairways, and rough) on a hole-by-hole basis. Each green should have its own sample collected while each tee is usually represented by a sample of a hole's tee complex.

Golf course fairways and roughs are usually sampled as individual units, but the nature of the soil and the lower management required for roughs typically means the area sampled might well exceed an acre.

A stainless steel soil probe (standard diameter of 0.6") is an ideal tool for sampling and is a standard piece of equipment at most golf courses. Samples should be collected in a random pattern across the area, removing the grass mat from the top of the sample. Typically, 10 to 15 samples per area provide both a representative sample of the soil and enough material for the testing procedure (approximately ½ pint). The samples should be mixed together in a plastic bucket and placed in the testing box or bag provided by the soil testing lab.

All soil test sample submission forms request additional information that improves the value of the test, such as soil description (sand, clay, modified, native) and a brief history of recent fertility and liming (if known). In addition to standard pH and nutrient information, additional soil test data, such as cation exchange capacity, soil organic matter content, and total soluble salts, can be requested and may prove valuable in the management of putting green soils in particular.

### 6.2.3 Interpreting Soil Test Results

Labs report results as either parts per million (ppm), pounds per acre (lbs/A), or as a predictive index. Most laboratories report a rating indicating the relative status for each nutrient, such as:

- **Very Low** A plant response is most likely if the indicated nutrient is applied. A large portion of the nutrient requirement must come from fertilization.
- **Low** A plant response is likely if the indicated nutrient is applied. A portion of the nutrient requirement must come from fertilization.
- **Medium** A plant response may or may not occur if the indicated nutrient is applied. A small portion of the nutrient requirement must come from fertilization.
- **High** Plant response is not expected. No additional fertilizer is needed.
- **Very High** Plant response is not expected. The soil can supply much more than the turf requires. Additional fertilizer should not be added to avoid nutritional problems and adverse environmental consequences.

Test results provide recommend nutrient (including N) and lime application levels and frequency of application. The results form the basis for nutrient management planning (Section 6.1 and Appendix D) for selection of nutrient sources, rates of application, and appropriate timing to meet site specific needs for greens, tees, fairways, and roughs.

### 6.2.4 Importance of pH Test Results

Soil pH levels may be the most important data in the test results. Soil pH is an assessment of the total amount of hydrogen ions (H+) in soil solution ('active acidity') and those ions attracted to soil colloids ('reserve acidity'). Nutrients may be present in the soil but not available to plants because nutrient availability to plants is governed primarily by pH. Figure 6-1 shows that slightly acidic soils are optimal for nutrient availability (typically 6.2 to 6.8 for golf turf management). Extremes in soil pH result in nutrient deficiency or toxicity, both of which can cause suboptimal growth conditions and ultimately lead to turf loss.

## 6.3 Plant Tissue Analysis

Visible plant symptoms can offer helpful clues in diagnosing nutrient deficiencies, but can also be easily confused and misinterpreted, especially where micronutrients or sulfur compounds are involved. Tissue testing can help to adjust nutrient management programs:

- to confirm a suspected nutrient element deficiency when visual symptoms are present
- to monitor plant nutrient element status in order to determine whether each tested nutrient is in sufficient concentration for optimum performance

Recent soil test results should be used to assist in the interpretation of the results of a plant tissue analysis. If none are available, a soil sample should be submitted along with the tissue sample.

**BMP #2**
Supplement soil tests with plant tissue tests when necessary.

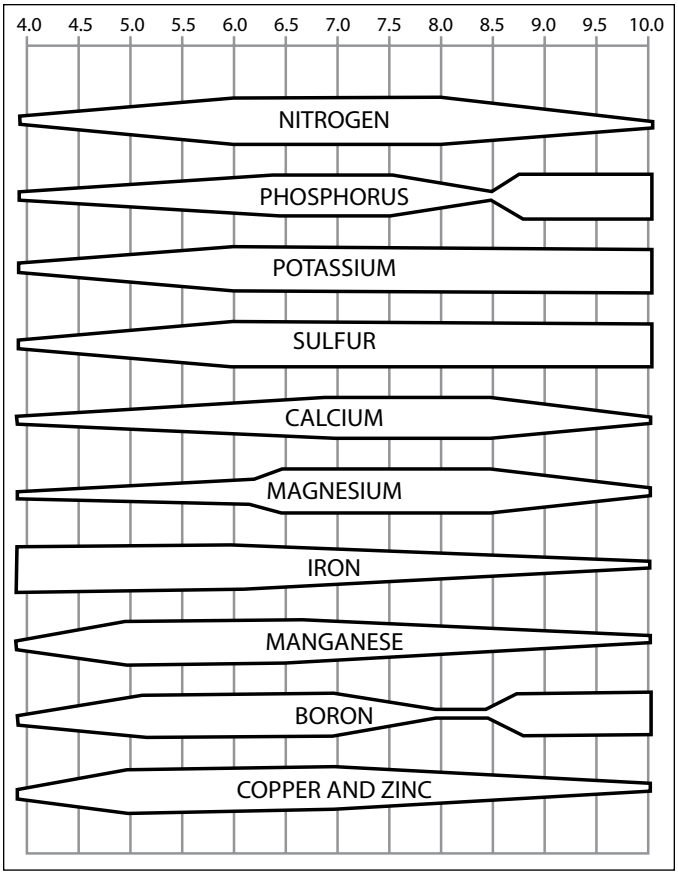


Figure 6-1. Relative soil nutrient availability as influenced by pH.

### 6.3.1 Nutrient Monitoring

Tissue sufficiency ranges used by most labs are based on values common in turfgrasses with acceptable quality under a wide range of growing conditions and management levels, and not specifically 'golf turf'. Knowing the percentage of nutrients in tissues for various grasses over different seasons, however, allows a golf turf manager to formulate a stronger nutrient management program. The value of a tissue test is enhanced when this information is combined with the results of a soil test. Tissue tests can indicate ranges in possible nutrient excesses or deficiencies, but the data does not explain the cause of the nutrient deficiency (such as unsuitable pH, or deficiency or excess in nutrient application).

A routine monitoring program and the resulting recommendations provide a basis for effective nutrient management practices. Some golf course superintendents submit samples to testing labs bi-monthly or monthly, especially for creeping bentgrass grown on completely modified sand-based putting greens. Trends in tissue nutrient status can be observed, and in conjunction with soil test data, can be used to make adjustments in lime and fertilizer treatments before deficiencies or excesses develop. In addition, by comparing plant analysis results with turf quality, nutrient applications, and soil test data over time, the nutrient sufficiency ranges and nutrient management practices required to maintain site-specific turf quality under varying climatic conditions and management constraints can be refined. If regular sampling is cost prohibitive, then prioritized sampling is recommended and should include areas that are representative of the turf quality, use, composition, and soils.

### 6.3.2 Plant Sampling Considerations

Plant samples should be taken at regular intervals from each representative area prior to and during growth cycles. Turf quality (clipping yields if available), weather conditions, and any known problems at the time of sampling should be recorded. Nutrient additions on each monitored site should be documented and routine soil samples collected at least once a year (prior to P and K fertilization) to supplement nutrient management records.

For diagnostic samples, plant tissue samples should be collected as soon as symptoms appear. Plants showing severe deficiency symptoms are often the most difficult to interpret correctly, since a deficiency of one element may result in deficiencies or excess accumulation of other elements if uncorrected. Plants under prolonged stress of any kind (temperature or moisture extremes, pests, flooding, mechanical damage, etc.) can have unexpectedly high or low nutrient levels due to the stress.

Comparative sampling can improve the accuracy of diagnosis by collecting both plant and soil samples from "good" and "bad" areas that are close to each other. Both areas should have similar soil types, similar species composition, and similar management (mowing height, irrigation, etc.). Since the recommended ranges of plant nutrient content are general, a sample should represent general site and management conditions. Differences in nutrient concentrations can then be compared with soil samples to determine if the problem is related to fertility management or is an uptake problem (such as disease, water, compaction, or root damage). For example, differences in Mg and Mn between plants could be related to differences in soil pH.

Samples should be collected from the aboveground portion of the plant, clipped just aboveground level no more than two days after mowing. As a general rule, monitoring samples can be taken from turfgrass clippings collected in buckets, as long as the bucket is clean and the clippings are not contaminated from chemical applications (fertilizers or pesticides, reel-sharpening compounds, etc.). When whole

plants are sampled, the roots should be cut off and discarded and shoots washed to remove soil particles. Under normal conditions, rainfall is frequent enough to keep leaf surfaces fairly free from dust and soil particles. If recently sprayed, or if Fe is of primary interest, a quick wash in a dilute (0.3%) detergent solution followed by a quick rinse in a strainer or colander removes residues and soil particles that could bias the sample. To prevent decay during transport to the lab, excess moisture should be reduced by partially air drying plant tissue samples before shipment to the laboratory. Fresh samples should not be put in a tightly sealed or plastic bag unless they will be kept cold during transport.

### 6.3.3 Interpreting Plant Analysis Results

Plant analysis indicates only what the root and internal transport system is able to deliver to the sampled tissue. Tissue analysis is excellent for determining nutrient deficiencies, but as previously discussed, this analysis does not explain why the deficiency occurs. Submitting a soil sample along with a tissue sample will provide additional information needed for addressing the problem. Levels below the sufficiency range can result from low or excessive soil nutrient levels, inadequate or excessive fertilization, and improper pH. Even where soil fertility levels are correctly managed, biotic factors (such as nematodes, disease, or herbicide injury), and physical conditions (compaction, flooding, drought, root injury, incorrect mowing) can limit nutrient uptake and distribution in the plant. In other cases, visible symptoms may not be nutrient related (for example, pesticide injury).

The effects of time of sampling, turf species, stage and character of growth, traffic and use, and environmental factors (such as soil moisture, temperature, and light quality and intensity), should also be considered during interpretation. These conditions may significantly affect the relationship between nutrient concentration and turf quality.

## 6.4 Defining Fertilizers

In Virginia, the Virginia Department of Agriculture and Consumer Services (VDACS) analyzes samples of fertilizer and agricultural lime sources to ensure that labeling guarantees are met and that the product is safe for the environment. A fertilizer label (Figure 6-2) must include five criteria based on standards established by the Association of American Plant Food Control Officials (AAPFCO):

- brand
- grade
- guaranteed analysis
- net weight
- name and address of the registrant and licensee

Fertilizers are also often classified as either organic (containing carbon) or inorganic (containing no carbon). Organic fertilizer sources can be a naturally occurring animal or plant byproducts or a synthetic product such as urea and any urea-based compound (ureaformaldehyde, methylene urea, isobutyraldehyde urea, etc.). However, 'organic fertilizer programs' are likely using naturally occurring organic sources and not synthetics.




Figure 6-2. The five components required on a fertilizer label. *Source:* American Plant Food Control Officials.

The grade (19-19-19) and the guaranteed analysis are typically most important for fertilizer selection. The grade presents the percentages by weight of N, phosphate ($P_2O_5$), and potash ($K_2O$). Note that the grade is not N, P, and K; the percentages of the actual (or elemental) P and K nutrients can be determined by multiplying the $P_2O_5$ level by a constant of 0.44 and the $K_2O$ level by 0.83. While most soil test recommendations for these nutrients are provided in units of $P_2O_5$ and $K_2O$ per 1,000 ft², levels are sometimes provided in pounds of the actual nutrient instead. The guaranteed analysis details all nutrients in the product (in addition to N, $P_2O_5$, and $K_2O$) on a percent by weight basis.

Complete fertilizers contain N, $P_2O_5$, and $K_2O$, while incomplete fertilizers contain only one or two specific nutrient needs (such as 45-0-0, 0-20-0, 0-0-50, 18-46-0). Balanced fertilizers contain equal amounts of N, $P_2O_5$, and $K_2O$ (8-8-8, 10-10-10, or 19-19-19, etc.). Balanced fertilizers are often referred to as 'garden fertilizers' because of their use in gardening applications to optimize bloom or fruit yield with phosphate and potassium. The wide-scale

use of balanced fertilizers is often discouraged because of the emphasis placed on applying P only when indicated by a soil test. Unbalanced fertilizers have varying levels of nutrients (such as 29-3-7, common in many turf-specific products).

## 6.5 Nitrogen

Nitrogen sources get the most scrutiny in a management program because of the intensity of golf turf management and the highly variable grass requirements, based on the turfgrass species, turf use, maintenance requirements, and soil type. A wide variety of N sources are available, but only two forms of N are plant available: the ammonium cation ($NH_{4+}$) and the nitrate anion ($NO_{3-}$). Regardless of the source, N must be transformed into one of these two forms to become plant available. Given its positive charge, $NH_{4+}$ can be temporarily bound in the soil by CEC reactions. $NO_{3-}$ is highly prone to leaching and can quickly contribute to water quality issues, particularly for sand-based soils with very low CEC.

The first selection criterion in choosing an N fertilizer source is often its water solubility. Readily available N sources, such as water soluble N (WSN), provide rapid turfgrass growth and color responses and are more prone to leaching, particularly in sand-based soils often used for golf putting greens or tees. Slowly available N (SAN) sources, often referred to as water insoluble N (WIN) or controlled release N (CRN), are highly variable in N content and release characteristics.

The latest generation of 'stabilized' N sources cannot be adequately described on the basis of N solubility. The Association of American Plant Food Control Officials (AAPFCO) adopted the term "enhanced efficiency" (EE) to better describe fertilizer products that minimize the potential of nutrient losses to the environment, as compared to a 'reference soluble' product such as WSN or SAN. This term distinguishes between two categories of EE fertilizer products:

- 'Slow release' fertilizer sources release or convert nutrients to a plant-available form at a slower rate relative to a 'reference soluble' product. For these products, the release of soluble nutrients is governed by either a coating or occluded materials (such as polymer or sulfur-coating, urea form and derivatives, and isobutyraldehyde diurea).
- 'Stabilized' N sources are amended with an additive that reduces the rate of transformation of fertilizer compounds, resulting in extended time of availability in the soil, such as nitrification inhibitors, nitrogen stabilizers, and urease inhibitors.

Both categories of products improve nutrient use efficiency and minimize the potential of nutrient losses to the environment. AAPFCO is refining the definition of these products and their labeling characteristics as technologies evolve.

Nitrogen solubility and stabilization are highly variable, depending on the source and possible combinations with readily available materials. While SAN and stabilized sources are significantly more expensive on a cost per pound of N basis as compared to WSN materials, their release characteristics fit well given the precision required in golf turf management and their use is encouraged whenever possible.

### 6.5.1 Nitrogen Application

As a rule of thumb, no more than 1 lb of readily available N per 1,000 $ft^2$ per growing month is applied in a single application; when possible, this addition should be split into two or more applications. This strategy meets both turfgrass nutritional needs and minimizes potential water quality concerns. Restricting N application levels is especially important on sand-based putting greens and is easily adapted into green management programs, where it is commonplace for superintendents to "spoonfeed" (0.05 to 0.4 lb N/1,000 $ft^2$) the turf, making numerous light applications of nutrients on a frequent basis. This strategy balances turfgrass growth and color with requirements for turf health, recovery, and playability, in addition to reducing nutrient leaching potential.

Spoonfeeding can be accomplished with both granular and liquid applications. The practice of liquid feeding or foliar feeding is popular for facilities with spraying equipment. Liquid feeding uses greater than 45 gal/A of water and most nutrient uptake occurs at the root system. Foliar feeding uses less than 45 gal/A water carrier in order to keep the majority of the nutrients on the leaf surface for foliar absorption.

Applying fertilizer in water improves the uniformity of distribution and allows small amounts of nutrients to be accurately applied with water as the carrier. Fertigation (delivery through an irrigation system) is another specialized means of delivering nutrients and is especially effective during a grow-in when wet soils are not conducive to spreader and/or sprayer operation. Fertigation performance is only as good as the distribution and uniformity capabilities of the irrigation system. Dispersible granule fertilizer formulations are now available that provide enhanced turf coverage that

mimics foliar or liquid feeding. Upon contact with water, a single fertilizer granule separates into several thousand particles, thus coating the turfgrass foliage. This formulation technology is expected to become more widespread.

### 6.5.2 Readily Available Nitrogen

Readily-available sources of N quickly become plant available following application. While all N sources gradually lower soil pH, readily-available N sources typically reduce soil pH and increase soluble salt levels much quicker than SAN materials. While not a typical problem, higher than optimal applications of readily-available N sources can result in excessive salt accumulations in the soil that can damage roots and reduce their function; however, since most areas of the mid-Atlantic receive periodic rainfall, concerns from salt accumulations in the soil from quickly-available fertilizers are limited. The primary concern with turf damage from quickly-available, high salt content fertilizers is the potential for "foliar burn", caused by tissue desiccation. Water soluble, high-salt fertilizers that remain on the turfgrass leaves attract water from the leaf cells, resulting in cell and tissue desiccation in localized areas.

Some of the most common forms of inorganic, readily-available N sources used in golf turf management are ammonium nitrate, ammonium sulfate, potassium nitrate, calcium nitrate, diammonium phosphate, and monoammonium phosphate. The sources with the highest water solubilities (ammonium nitrate, urea, and ammonium sulfate) are often dissolved in water and are foliar applied. The water solubilities and salt indices for these sources are provided in Table 6-1.

**BMP #3**
Optimize nutrient use efficiency and reduce leaching potential of readily available nitrogen sources.

Ammonium nitrate is the most soluble of the quickly-available N sources, providing the fastest growth and color response potential due to its rapid conversion to plant-available $NH_{4+}$ and $NO_3$. This compound also has the greatest potential for foliar burn and leaching because of its high water solubility. Ammonium nitrate supplies for the golf market are restricted due to its high chemical reactivity, but calcium ammonium nitrate (27-0-0) is becoming more widespread in the mid-Atlantic.

Ammonium sulfate is significantly less water soluble than ammonium nitrate, and therefore exhibits less potential for foliar burn. This compound provides a rapid growth and color response from two macronutrients, N and S. Because of its high S content (24%) and the ammoniacal form of N, ammonium sulfate causes the quickest decline in soil pH of the readily-available N sources.

Potassium nitrate is a popular golf turf fertilizer due to its combination of N and K nutrients and is particularly useful in sand-based soils where K leaching is a concern. This source is frequently applied in spring and fall as a

### Table 6-1. Grade, salt index, and water solubility of the most common readily-available nitrogen sources used in turf and landscape management fertility programs

| Fertilizer | Grade | Salt Index[1] | Water solubility[2] g/liter (lb/gal) |
|---|---|---|---|
| Ammonium nitrate | 34-0-0 | 3.2 | 1810 (15) |
| Ammonium sulfate | 21-0-0 | 3.3 | 710 (5.9) |
| Potassium nitrate | 13-0-44 | 5.3 | 130 (1.1) |
| Monoammonium phosphate | 11-48-0 | 2.7 | 230 (1.9) |
| Diammonium phosphate | 20-50-0 | 1.7 | 430 (3.6) |
| Urea | 45-0-0 | 1.7 | 780 (6.5) |

[1] The salt index scale is <1 = low, 1 to 2.5 = moderate, and >2.5 = high.
[2] Water solubility expressed in grams per liter (pounds per gallon in parentheses).

*Source:* Turgeon 1985.

treatment to increase K levels in plant material. Potassium is the second highest nutrient content in plant tissues that is typically supplemented by fertilizer applications. Potassium regulates water movement into and out of cells. Its function is often described as the 'summer coolant' and 'winter antifreeze' of plants because of its ability to improve environmental stress tolerance. Potassium's low water solubility results in much less foliar burn and leaching potential, but it is also difficult to dissolve and apply as a liquid.

Monoammonium phosphate (commonly called MAP) and diammonium phosphate (commonly called DAP) are popular sources for blended fertilizers and are also used as relatively inexpensive sources for N and P application in golf turf. These compounds are particularly useful for establishing and maintaining fairways and roughs when P deficiencies are indicated by soil testing. DAP has the greater water solubility of the two, but this water solubility is so low that it is not a concern for fertilizer burn.

Urea is a synthetic organic (carbon-containing) N source with a low salt index. It is a major component of numerous SAN sources in which it is either coated or chemically reacted with other compounds in order to slow its N release characteristics. Urea is available in granular and prilled forms that have the same chemical composition, but the granular forms are larger and harder, while the prilled forms are softer and easier to blend with other fertilizers. While urea is classified as a readily-available N source, its N release is not immediate because it requires the presence of the enzyme urease (commonly present on leaves and dead plant residues) to be converted to $NH_{4+}$. When applied, some volatile losses may occur under windy or hot and dry conditions if the fertilizer is not promptly watered into the soil. Approximately 60% of the application is converted to plant available N on the day of application (under desirable moisture conditions) and the remainder converted within a week.

There is great interest in the previously mentioned 'stabilized' forms of urea. Manufacturers have developed chemical additives to urea that reduce its conversion rate to plant available N (nitrification inhibitors) or gaseous loss (volatilization). The additives are effective in laboratory settings, but their level of effectiveness in the field is variable and the factors affecting response are not yet clearly understood. Research in this area continues in order to better understand chemical approaches to improve N-use efficiency of urea. While these products affect the rate of conversion to plant-available N, they do not alter the water solubility of the urea.

### 6.5.3 Slow Release and Enhanced Efficiency N Sources

In 2011, AAPFCO recommended that EE be adopted to describe fertilizer products with characteristics that minimize the potential of nutrient losses to the environment. Under the EE umbrella are the categories of the traditional 'slow release' fertilizers and 'stabilized' products (described in Section 6.5). This chapter primarily discusses slow release fertilizers as these sources are the most researched and widely available products in EE materials. Within the category of 'slow release' products are a wide variety of N sources defined as slowly available N (SAN). Virginia regulations define SAN as:

**BMP #4**

Use Enhanced Efficiency (slow release or stabilized) N sources to optimize nutrient use efficiency and reduce nutrient leaching potential.

> N sources that have delayed plant availability involving compounds which dissolve slowly, materials that must be microbially decomposed, or soluble compounds coated with substances highly impermeable to water such as polymer coated products, methylene urea, isobutylidene diurea (IBDU), urea formaldehyde based (UF), sulfur coated urea, and natural organics. (4 VAC 5-15).

The primary SAN sources used in turf management systems are listed in Table 6-2 and further described below.

The stabilized products included under the category of EE products that are of the most interest in golf turf management at present contain urea. Manufacturers have developed chemical additives to urea that reduce its conversion rate to plant available N (nitrification inhibitors) or gaseous loss (volatilization). To date, the additives are extremely effective in laboratory settings, but their level of effectiveness in the field is variable and the factors affecting response are not yet clearly understood. Research in this area continues in order to better understand chemical approaches to improve N-use efficiency of urea. While these products affect the rate of conversion to plant available N, they do not alter the water solubility of the urea and for the purposes turfgrass management, stabilized N sources are treated as water soluble, readily available N. As the science and technology of stabilized N evolves, AAPFCO's inclusion of these materials under EE products will provide the flexibility to accurately consider their possible economic and environmental advantages as turf nutrient sources.

## Table 6-2. Common SAN[1] sources

| N Source | Typical Analysis | General Comments about the Fertilizer |
|---|---|---|
| Natural organics | 6-2-0[2] | Derived from waste byproducts; very low N analyses, usually contain some phosphate and other micronutrients; very controlled release that is dependent on microbial activity. |
| Sulfur coated urea (SCU) | 32-0-0[3] | Urea granules coated with molten S; analyses and release rate varies depending on amount of coating; N release due to osmosis, so moisture and temperature govern release rate; relatively inexpensive compared to other SAN sources; reduces soil pH; handling is important because scratching the coat removes the controlled release characteristic. |
| Polymer coated urea (PCU) | 32-0-0[3] | Polymer coating of urea (sometimes also combined with S); N analyses variable depending on coating thickness; noted for very predictable release characteristics and handling is not as much of a concern as for SCU. |
| IBDU | 31-0-0 | Synthetic organic with N release rates primarily governed by particle size and adequate soil moisture. |
| Methylene urea | 30-0-0[4] | Synthetic organic that can have varying levels of SAN that are defined by their solubility in hot or cold water; N release rates are depending on the chain length of the carbon polymers (higher percentage of short chains increases water solubility); N availability based on microbial activity. |
| UF | 38-0-0 | Synthetic organic with predominantly long chain carbon polymers and very controlled N release; N availability based on microbial activity; very limited response in cold temperatures. |

[1] SAN is used as a comprehensive term regarding N availability and includes sources also identified as water insoluble N (WIN) or controlled release N (CRN)
[2] N analyses variable depending on the source.
[3] N analyses variable depending on the coating thickness.
[4] The percentage of SAN varies depending on the source.

### 6.5.3.1 Natural Organic

Natural organic fertilizer sources are by-products of plant and animal industries or waste products such as municipal sewage sludge; hoof, horn, seed, bone, and feather meal; or chicken and cow manures. These fertilizers are characterized by their low (typically <10%) N content and presence of mostly WIN and are highly dependent upon microbial activity for breakdown and release of N. For this reason, neutral pH, adequate moisture and oxygen, and temperatures above 55 degrees enhance release.

### 6.5.3.2 Ureaformaldehyde and methylene urea

UF and methylene urea (MU) are made by reacting urea with formaldehyde-based products. This process develops N fertilizers with highly variable N release rates dependent on the carbon chain lengths and relative numbers of long-chain (very slow release) and short-chain (rapid release) polymers in the end product. UF products, like natural organic fertilizers, are dependent upon microbial activity and subject to similar environmental conditions.

While traditional UF products remain in use in golf turf management because of their extremely controlled release, MU products made with higher ratios of urea to formaldehyde have gained in popularity because they provide both initial and extended response. These products contain 35 to 40% N and are classified as 'slowly available' by the AAPFCO, but are labeled as 'other water soluble N' on the guaranteed analysis due to the portion of N that is either unreacted urea or has only a short carbon chain and is therefore water soluble. Some products are available in liquid formulation as flowable products, which require tank agitation.

#### 6.5.3.3 Isobutyraldhyde diurea

IBDU is made by reacting isobutyraldehyde and urea and is slowly soluble in water. Approximately 90% of the N is in the WIN form. Higher soil moisture and smaller particle size result in a more rapid release. N release is somewhat depressed in alkaline soils and is independent of microbial activity. For this reason, IBDU releases more readily during cooler temperatures than UF products, but it is still considered to be a controlled release material.

#### 6.5.3.4 Sulfur-coated urea

These products are made by spraying molten sulfur on urea particles. A sealant (wax or oil) is usually added to seal the imperfections followed by a conditioner to reduce stickiness. Particles often contain a 2N:1S ratio. N is released by the microbial degradation of the coating and/or diffusion through the coating. SCU products without sealants often release slower because of the thicker sulfur coating. Release rate increases as coating thickness decreases and temperature increases. The variability in coating thickness and particle size differences allows for initial greening residual response. Breaking of particles (with a spreader, traffic, or mower) results in the immediate release of N. A 7-day dissolution rate in water (lab procedure) is commonly used to characterize the quickly available fraction of SCU products. Most products have dissolution rates in the range of 25–35%. Controlled release soluble urea nitrogen (CRSUN) is a term used on certain SCU labels and refers to the total %N as SCU in the product. CRN refers to the amount or %SCU particles that are not broken and at least covered with a sealant.

#### 6.5.3.5 Polymer-coated nitrogen

These products are coated with a synthetic, plastic-like polymer coating. The polymer coating is sometimes also supplemented with sulfur coating. Polymer-coated urea products are not microbially dependent since they have no wax sealant. N is released through cracks in the sulfur and diffusion through the plastic. In plastic coated urea, N dissolves in water absorbed through the coating and is then gradually released by osmosis. Release increases with temperature and is influenced little by soil moisture content, irrigation, soil pH, or microbes. Coating thickness determines the release rate for polymer-coated products.

#### 6.5.3.6 Practical considerations in interpreting fertilizer labels and applying SAN sources

The SAN sources offer advantages from both an environmental perspective and from reductions in application frequency and controlled plant response. In cooperation with Virginia DCR, the following application criteria were developed for SAN sources (all categories and combinations of WIN, CRN, etc., apply) to optimize plant nutrient use efficiency and environmental responses:

- Fertilizer is ≥ 50% SAN: up to 1.5 lb N/1,000 $ft^2$ is acceptable in a single application during optimal growing periods.
- Fertilizer is 25–49% SAN: up to 1.25 lbs N/1,000 $ft^2$ is acceptable in a single application during optimal growing periods.
- Fertilizer is < 25% SAN: no more than 1 lb N/1,000 $ft^2$ should be applied in a single application during optimal growing periods.

### 6.5.4 Combinations of Readily- and Slowly-available N

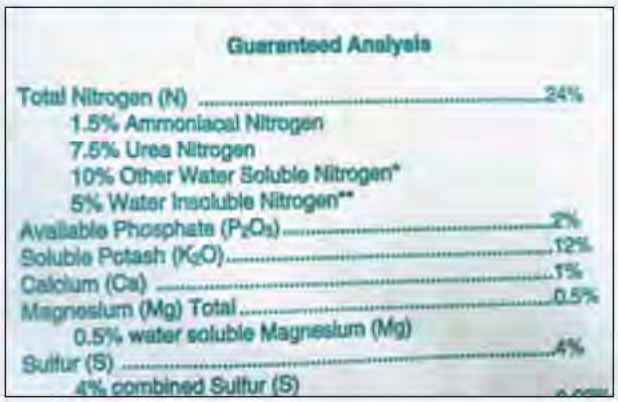
Many manufacturers combine readily-available and slow release sources of N to take advantage of both strengths. The quick-release source provides quick green up but is at a sufficiently low rate to prevent salt injury or reduce the potential for leaching. The slow-release source is available to provide a greening response for a longer duration.

## Determining the %SAN in a Fertilizer Example

Determining the %SAN in a fertilizer source that contains varying forms of water soluble and slowly available N can be tricky. As an example, the guaranteed analysis of a complete, balanced fertilizer as shown below can be used to determine its %SAN and its maximum recommended application rate.

The material is 32-4-4 with the two forms of readily available (water soluble) N being ammoniacal (3.5%) and urea (17.2%) for a total of 20.7% of the total N being readily available. For the SAN sources, 5.7% is clearly defined as WIN. The remaining 5.6% is classified as 'other water soluble N', and here the analysis can be confusing. The footnote says that the 'other water soluble N' is derived from methylene urea. This SAN source contains highly variable percentages of N solubilities, ranging from very slowly available to readily available (which, since it contains readily available N, is why it is classified as 'other water soluble N').

Therefore, the total SAN in this source is 5.7% + 5.6% = 11.3% SAN. The %SAN is 11.3% ÷ 32% = 35% SAN. According to the ranges given above, in the 25–49% range the product can be applied up to 1.25 lbs/1,000 ft$^2$ in a single application.




## 6.6 Phosphorus

Phosphorus is a critical nutrient for turfgrass growth and development, playing important roles in energy transformations in plant cells and root development. P enhances turfgrass establishment and is the most important nutrient in 'starter fertilizers'. On the fertilizer label, the middle number of the analysis represents the percent by weight of $P_2O_5$, which can be converted to %P by multiplying by 0.44 (10-10-10 is actually 4.4% by weight P). In the soil, P is generally in complex with other elements and is an insoluble (plant unavailable) nutrient.

Phosphorus is slowly made available to plants on an 'as needed' basis by chemical reactions in the soil that convert it to either of two anionic forms, $HPO_4^{2-}$ or $H_2PO_4^-$. In these anionic forms, phosphorus is highly leachable and is a concern for water quality issues since it contributes to eutrophication (see Section 4.3). However, the complexing of P with other elements greatly minimizes P leaching as compared to $NO_3^-$ leaching potential. Phosphates are a potential leaching concern during the grow-in of turfgrasses on sand-based systems that inherently have very low nutrient holding capacity and are subject to frequent irrigation. Leaching can also be a concern where P is over applied to established turf, especially on sand-based systems. In native soils, P leaching is typically of minimal concern unless P has been overapplied for many seasons. P leaching potential is best managed by applying it on the basis of a soil test. Applying fertilizers near water resources and/or hardscapes that move stormwater contribute to water quality concerns and should be avoided.

The standard P fertilizer sources are provided in Table 6-3. Recent changes in fertilizer manufacturing include the production of 'P-free' fertilizer sources. In addition, interest in natural organic fertilizers has grown, but these are not 'P-free' and are typically 0.5 -2% $P_2O_5$ by weight. Phosphonate (phosphite) is a unique form of P used in the golf turf industry primarily for its activity on Pythium-induced turf diseases (Landschoot and Cook, 2005). Numerous labeled phosphonate fungicides have been shown to be low cost, extremely effective *Pythium* control products when used on a preventative basis. Phosphonates are most often referred to in the golf turf industry as 'plant health products' since they have such low nutrient value, but can be converted to plant available phosphate by soil-borne bacteria over time (3-12 months). Hence, their use warrants some consideration by golf turf managers and nutrient management planners. The normal use rates for *Pythiuim* disease suppression are so low compared to

## Table 6-3. Typical grade, salt index, and water solubility of the most common P sources used in turf and landscape management programs

| Fertilizer | Grade | Salt Index[1] | Cold Water Solubility in g/l (lb/gal) |
|---|---|---|---|
| Superphosphate | 0-20-0 | 0.4 | 20 (0.16) |
| Treblesuperphosphate | 0-45-0 | 0.2 | 40 (0.32) |
| Monammonium phosphate | 11-48-0 | 3.2 | 230 (1.8) |
| Diammonium phosphate | 20-50-0 | 1.7 | 430 (3.4) |
| Rock phosphate | 0-30-0[3] | N/A[2] | N/A |
| Bone meal | 4-12-0 | N/A | N/A |

[1] The salt index scale is <1 = low, 1 to 2.5 = moderate, and >2.5 = high
[2] N/A= not applicable
[3] Rock phosphate levels of $P^2O^5$ can range from 27-41%

*Source:* Turgeon 1985.

standard phosphate-containing fertilizers that they would not be anticipated to contribute to excessive soil loading of P that might ultimately lead to phosphate leaching.

## 6.7 Potassium

Potassium is not a direct component of any organic compound within a plant but is heavily involved in many biochemical responses. In particular, K is the nutrient that most impacts water relations within the plant, sometimes referred to as the 'antifreeze' and 'coolant' nutrient of the plant world. The most common forms of potassium fertilizer sources are presented in Table 6-4. Because the last of the three numbers that appear in the fertilizer grade represents potash ($K_2O$), this value must be converted to elemental K by multiplying by 0.83.

Although many unrefined and manufactured sources of potassium exist, plants always absorb potassium in the same form, the K+ cation. K is required in the second highest quantities by plants after N. As a cation, K+ can be temporarily bound and exchanged for other cations (i.e.,, cation exchange) in soils that contain significant anionic (negatively charged) exchange sites (i.e.,, soils with significant amounts of clay and/or organic matter). Even as a cation, K+ can still leach depending on soil type (especially sand-based soils) and under heavy rainfall or irrigation. Potassium is not considered to be an environmental concern that negatively impacts water quality and therefore does not receive as much attention as N and P from this perspective.

## 6.8 Calcium, Magnesium and Sulfur

While much time is spent on N, P, and K, when it comes to nutrient management programs for golf turf, Ca, Mg, and sulfur (S) are equally important for plant growth and development. In addition to the common sources provided in Table 6-5, other materials such as bone meal, wood ash, manures, and sludge can contain significant amounts of these elements.

## Table 6-4. Typical grade, salt index, and water solubility of the most common K sources used in turf and landscape management programs

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

[1] The salt index scale is <1 = low, 1 to 2.5 = moderate, and >2.5 =high

## Table 6-5. Common inorganic sources of calcium, magnesium, and sulfur

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

Many of these sources also alter pH (i.e.,, liming materials that raise pH, sulfur-based materials that lower pH). Therefore, if Ca, Mg, or S is limiting in the soil, but a pH change is not desired, standard liming sources and elemental S should be avoided and gypsum ($CaSO_4$), magnesium sulfate, or potassium-magnesium-sulfate used to supply these nutrients.

Calcium and magnesium both have important activities in the plant. Calcium serves as a primary component of cell walls and magnesium serves as the central atom of the chlorophyll molecule. These elements behave much the same in the soil due to similar chemical properties, but Mg is typically found in much lower quantities in soils than Ca. Both are divalent cations ($Ca^{2+}$ and $Mg^{2+}$) and are of similar size. The emphasis placed on the ratios of Ca, Mg, and K in the soil depends on whether the soil test result recommendations were made on the basis of the previously mentioned SLAN or BCSR philosophies. A complete discussion of the interpretation and implementation of soil test data in regards to the percentages and ratios of these nutrients can be found in the book *Turfgrass soil fertility and chemical problems: Assessment and management* (Carrow et al., 2002). The mobility of both Ca and Mg is relatively low, especially compared to anions or even other cations such as sodium or potassium. Therefore, loss of these two cations through leaching is relatively low, especially when applied in the form of lime. Leaching is primarily limited to sandy soils with low CEC, and is enhanced by low pH. Applications of these nutrients to soils does not result in any known water quality problems, but mismanagement that leads to a weaker turf can indirectly alter water quality.

Similar to N, S is highly mobile in the soil in its plant available form, the sulfate ($SO_4^{2-}$) anion. However, sulfate leaching is not a significant water quality concern. Sulfur deficiency is rather unusual, but it is very possible in

sand-based, low organic matter soils in particular. The symptoms of S deficiency are very similar to those of N deficiency and can be diagnosed by tissue sampling.

## 6.9 Micronutrients

Micronutrients are required in very small quantities but are just as important to plant health as macronutrients. Plant-required micronutrients are: Fe, manganese (Mn), B, Cu, Zn, chlorine (Cl), and molybdenum (Mo). Micronutrients are rarely deficient in terms of soil quantities in heavier textured (i.e., silt or clay-based soils), but deficiencies do occur periodically in sandy soils (naturally occurring or modified) with low cation exchange capacities. As with macronutrients, maintaining an appropriate soil pH is the most important factor in ensuring the availability of sufficient micronutrients.

Iron is the most frequently applied micronutrient in golf turf management. The most common fertilizer sources of Fe are detailed in Table 6-6.

Whereas N deficiencies are often visibly uniform across the turf, Fe deficiencies are often scattered randomly throughout the turf, and appear more severe on closely mowed surfaces such as greens and tees. The most severe deficiencies occur with warm days and cool nights, which favors shoot growth over root growth.

**BMP #5**

Use iron as a supplement to standard nitrogen programs to promote turfgrass greening without flushes of shoot growth.

Total Fe levels in typical Virginia soils range from 0.5 to 5%. However, because of its complexing in the soil with other nutrients, iron is the micronutrient most likely to be deficient. Iron occurs primarily as oxides and hydroxides that are sparingly soluble in well-aerated soils above pH 4.0. Root exudates of organic acids from deeply rooted plants are generally able to solubilize sufficient iron to optimize plant growth, but high N rates and close mowing decrease root growth relative to shoot growth, and limit uptake capability. The inherently low levels of Fe in high-sand putting green soils, and some of the native sandy sands, along with the relatively high supply of N and P in these management systems can further complicate Fe uptake.

### Table 6-6. Standard iron fertilizer sources used in golf turf management

| Source | %Fe |
|---|---|
| Iron sulfates | 19 – 23 |
| Iron oxides | 69 – 73 |
| Iron ammonium sulfate | 14 |
| Iron chelates | 5 – 14 |

The most popular forms of Fe applied in turf and landscape applications are organic chelates applied as sprays over the top of the turf canopy. Granular Fe sources are beneficial in increasing soil Fe levels where needed, but they do not provide rapid color response. These liquid organic chelates are easy to handle, mix, and apply, and they are compatible in the spray tank with many other pesticides and fertilizers. Chelation reduces the rate of complexing of Fe into insoluble compounds in the soil, thereby improving plant uptake.

Foliar applications of Fe result in a rapid, deep green color response that occurs without a surge in shoot growth. The immediacy (within minutes to a few hours) of the Fe effect on color is mostly due to 'staining' (i.e., Fe oxidation or 'rusting') of/on the foliage. However, longer term color enhancement is likely since Fe is a precursor to leaf chlorophyll production. Once inside the plant, Fe is an immobile nutrient and color enhancements are lost due to regular mowing of the turf. Typical color responses on frequently mowed putting greens might be 10-14 days; less frequently mowed fairway turf might sustain a color response for up to three weeks. Granular Fe applications generally do not provide as rapid color responses as foliar applications due to the rapid complexing of the Fe in the soil. Typical iron application levels are 5–10 pounds per acre (0.12–0.25 lbs per 1,000 $ft^2$).

Deficiencies of other micronutrients are rare except on mostly sand soils. Again, maintaining appropriate soil pH ensures satisfactory availability and prevents potential phytotoxicity issues. Some notable Zn and Mn toxicity issues on golf greens have occurred over the years where a popular fungicide (mancozeb) has been repeatedly applied for disease and algae suppression. Zn and Mn solubility can become so high at low soil pHs relative to other nutrients (Figure 6-1) that turf phytotoxicity occurs. Maintaining the pH at an appropriate level by application of a soil test-recommended lime application is the easiest way to manage this problem. Where supplemental micronutrient applications are needed (most

often indicated by tissue testing), chelated micronutrient formulations are very effective.

## 6.10 Managing Soil pH

Most of the native soils of Virginia essentially act as weak acids, with only a small portion of their potential acidity present in the active, or soil solution form. Exchangeable aluminum (Al), Mn, and Fe metals, along with pH-dependent charges on organic matter and clay edge sites constitute the major sources of potential acidity (also called the reserve or total acidity). The potential acidity, in conjunction with exchangeable bases, help buffer the soil to resist rapid changes in soil solution pH. Plants growing in acid soils must be able to contend with high levels of Al and Mn and low availability of P, Ca, and Mg. Therefore, acidic soil must be limed based on a soil test recommendation to make the rooting environment hospitable for root exploration and development. Selection of liming materials is typically based on the ability to neutralize soil acidity, chemical composition, fineness of grind, ease of handling, and cost (Little and Watson, 2002). Whenever possible, soil pH should be adjusted prior to establishment as pre-plant incorporation greatly accelerates the neutralization of the acidity throughout the root zone.

**BMP #6**
Maintain appropriate soil pH in order to optimize nutrient availability.

Golf turf soils are rarely too alkaline in this region. If pHs are too high, nutrient deficiencies and toxicities are just as prevalent as for low pH soils. High alkalinity is typically due to excessive lime applications made without soil test recommendations. This situation should be avoided due to the difficulty of managing high pH soils as compared to low pH soils.

### 6.10.1 Liming Materials

Limestone occurs naturally in sedimentary rock rich in the minerals calcite ($CaCO_3$) or dolomite ($Ca,Mg(CO_3)_2$). Most limestone is formed in thick, compacted deposits of calcareous skeletons and shells of sea animals on the ocean bed. Relatively pure deposits of calcite are called calcitic limestone, while materials containing more Mg are called dolomitic limestone. Dolomitic limestone is widely used as a lime (and Mg) source throughout the mid-Atlantic. When limestone is heated, carbonate is driven off and calcium oxide (calcitic limestone) or magnesium oxide (dolomitic limestone) formed. When treated with water (slaked), calcium oxide forms $Ca(OH)_2$ (also called slaked or hydrated lime). Because liming materials are very reactive and caustic, they are rarely used on mature turf stands, but can be safely incorporated into soil prior to turf establishment.

As with most sedimentary materials, limestone varies in purity and chemical composition. To compare the acid neutralizing value of various liming materials of differing purity levels, the Calcium Carbonate Equivalence (CCE) test uses pure $CaCO_3$ as a standard. Pure $CaCO_3$ has been arbitrarily assigned a value of 100%. Liming materials with CCE values greater than 100, such as magnesium carbonate, dolomitic limestone, calcium hydroxide, and calcium oxide have a higher neutralizing capacity than pure $CaCO_3$ (Table 6-7).

### Table 6-7. Neutralizing value (Calcium Carbonate Equivalence) of the pure forms of commonly used liming materials

| Lime Material | Neutralizing value (%) |
|---|---|
| CaO (calcium oxide) | 179 |
| $Ca(OH)_2$ (calcium hydroxide) | 136 |
| $MgCO_3$ (magnesium carbonate) | 119 |
| $CaMg(CO_3)_2$ (dolomitic limestone) | 109 |
| $CaCO_3$ (calcium carbonate) | 100 |

*Source:* Tisdale 1985.

Several commercially available materials that are not certified liming materials (do not have a CCE) claim they neutralize acidity at half (or even less) standard lime source rates. Most of these products have high water solubility and can effect rapid changes in soil pH in the top few inches of the soil. If the product has a very high CCE, then it truly is possible to do 'less with more' (as demonstrated in the earlier calculations), but if not, be wary of sources claiming amazing pH changes with very little product. Ultimately, the chemical reactions that occur in the soil are the same regardless of the source.

### 6.10.2 Liming Rates

CCE values (Table 6-7) are used to calculate an appropriate rate of liming material as recommended by soil test recommendations, which are based on the use of pure $CaCO_3$.

For liming of established turf, in general no more than 50 pounds of lime per 1,000 ft² in a single application are recommended and 25 pounds per application to golf putting greens. If the soil test suggests more, the amount should be split into incremental amounts and applied on monthly intervals. The beneficial effects of liming occur only where lime and soil are in contact. Traditional liming materials applied to mature turf stands are sparingly soluble and react strongly with the soils that they contact. As a result, most lime materials are relatively immobile in the soil and surface applications generally affect no more than the surface 2-3" during a growing season. To move more lime into the soil profile, lime should be applied in conjunction with hollow-tine core aerification events. Lime is typically applied during the active growing season when the turf can quickly rebound from the damage/surface disruption of the coring. Applying lime in the fall and winter months is also possible because the foliar burn (leaf desiccation) potential from the liming material is very low and the freezing and thawing of the soil over winter can aid in mixing lime throughout out the root zone.

### Liming Rate Example

A soil test recommends 50 lbs of lime per 1,000 ft². The lime source has a CCE of 90%. Therefore, 55.5 lbs of the source (50 lbs/0.9 = 55.5 lbs) per 1,000 ft² is necessary to achieve the recommended liming rate.

### 6.10.3 Soil Acidification

Turfgrass areas with excessively high pH can be amended gradually over time through the application of acid-forming N fertilizers such as ammonium sulfate. Where pH is so high it requires immediate attention, the chemical amendments of choice are elemental sulfur or aluminum sulfate. Depending on the source used, maximum application levels are quite restricted due to the caustic nature of these materials (no more than 5 lbs per 1,000 ft² in a single application). Similar to liming recommendations, adjustments to lower soil pH should only be based on a soil test.

## 6.11 Nutrient Application Programs and Strategies

Defining an ideal nutrient application strategy given all of the variables (grass, grass use, soil, climate, budget, equipment available, etc.) is impossible for golf turf management fertility programs. A site-specific NMP (Section 6.1) provides the basis for developing a nutrient management strategy that optimizes plant health in an environmentally responsible manner.

### 6.11.1 Fertilizer Application Timing

The timing of fertilizer applications (N in particular) is one of the most critical aspects for protecting water quality. The vast array of slowly available N sources, many of which are extremely immobile in soils, provides some flexibility in N application timing. N should be applied during periods of optimal turfgrass growth. For cool-season grasses, typical management programs result in ⅔ to ¾ of a seasonal N application applied in the fall, with the remaining ¼ to ⅓ applied in early to mid-spring. For warm-season grasses, the N application period typically extends from mid-spring through late summer. The DCR Nutrient Management Standards and Criteria (4 VAC 5-15) recommends the application for N fertilizers to cool-season turfgrasses beginning 6 weeks prior to the last spring average killing frost date and ending 6 weeks after the first fall average killing frost date. For non-overseeded warm-season turfgrasses, N applications should begin no earlier than the last spring average killing frost date and end no later than one month prior to the first fall average killing frost date. Utilizing lower N application levels during the early and late periods of the application window further promotes nutrient use efficiency and less potential for water quality impacts. Combining these timing recommendations with sound agronomic decision making minimizes the likelihood of potentially mobile (both surface and subsurface) nutrients entering water sources during non-active growing periods.

**BMP #7**
Apply nitrogen during periods of optimal turfgrass growth.

### 6.11.2 Fertilizer for Turfgrass Environment

Successful turfgrass establishments are best achieved through careful consideration of two factors: suitable soil preparation and optimum establishment timing. Soil tests should be used to determine lime and nutrient needs (particularly P and K) and all amendments incorporated into the top 4–6" of the soil profile prior to planting. Appropriate tillage is critical for the success of any type of establishment (seeding, sodding, plugging or sprigging).

Appropriate establishment timing promotes more rapid establishment and better long-term turfgrass performance. Sod installations provide significant inherent advantages in

water quality protection as well as almost immediate turf use. Sod establishment is typically successful at any time of the year for any turfgrass as long as it is not planted on frozen soils and its water needs can be met by rainfall or supplemental irrigation. However, even sod establishments benefit from favorable establishment timings that provide the most opportunity for plant maturity prior to seasons of environmental or intensity-of-use stresses. For cool-season turfgrasses, the ideal establishment period is late summer to mid-fall, with a secondary planting window of early to mid-spring being possible. Fall establishments are vastly superior for long-term turf success since they allow for the development of a mature root system prior to the typical heat and moisture stresses of a Virginia summer. Warm-season grasses are ideally established from mid-spring to mid-summer depending on the location in Virginia. Mature plants are critical for first-winter survival of warm-season grasses.

The amount of nitrogen used as a supplement in grow-in programs is highly dependent on the grass, the soil, and the N source. For example, cool- or warm-season grasses on heavier textured, predominantly silt/clay soils typical of golf fairways and roughs that are unlikely to have significant physical modifications prior to planting likely have limited leaching potential. Therefore, up to 1 lb N/1000ft$^2$ can be applied in a single application at planting with a ≥ 50% SAN source, which feeds the turf for up to 4 weeks. N sources containing predominantly WSN, should be applied at no more than 1 lb N/1,000 ft$^2$ over the first 4 weeks by splitting the applications into regular intervals. At 4 weeks after planting, 0.25 to 0.5 lb WSN/1,000 ft$^2$ per week should be applied for the next 4 weeks.

Appropriate water management is critical for successful turf establishment and reduces soil erosion and nutrient leaching/movement potential. From a practical standpoint, granular or sprayable fertilizers can only be made to a soil that is dry enough to minimize rutting potential from either equipment or foot traffic. Large scale grow-ins on golf courses are sometimes achieved through fertigation systems that provide light and frequent nutritional supplements through the irrigation system. While not a requirement for grow-in success, properly installed and functioning fertigation systems provide an extremely efficient method of nutrient delivery for turfgrass establishment.

Nitrogen-based establishment fertility programs for cool- or warm-season grasses on naturally occurring or modified sand based soils require more attention in order to meet plant needs and protect water quality. In these highly leachable soils, it is important to use ≥ 50% SAN source at up to 1 lb N/1,000 ft$^2$ for the first 4 weeks of establishment for either type of grass. For warm-season grasses, apply 0.25 to 0.5 lb WSN/1,000 ft$^2$ per week for the next 4 weeks. On cool-season grasses, up to 0.25 lb N/1,000 ft$^2$ per week (or 0.5 lb of a ≥ 50% SAN source every 2 weeks) should be applied after germination is complete for the next 8 weeks.

### 6.11.3 Maintenance Fertilization

Given the diversity in grasses and their intended uses on Virginia golf courses, maintenance fertility programs are also highly diverse in terms of fertility source, application rate, and frequency. Highly leachable sand-based soils and regular clipping removal, two characteristics associated with the putting green and tee management, further increase the intensity of nutrient management under these conditions.

Table 6-8 presents general seasonal N applications for all aspects of golf turf management developed from VA regulations (4 VAC 5-15). Maximum N levels are not intended to be interpreted as 'optimal' N levels for single applications. Every putting green, tee, etc. has its own site-specific nutritional requirements and it is highly likely (and probably desirable from a plant health and environmental perspective) that the applications are split into frequent, light applications of nutrients, especially for putting green management. As with establishment fertilization, fertilization applications should be timed during periods of active turfgrass growth and the percentages of readily- and slowly-available N in products should be used to determine application rates, with typically no more than 1 lb of N per 1,000 ft$^2$ applied per growing month.

## Table 6-8. General seasonal N strategies for golf turf management

| Turf Use | Grass Type | Maximum N Rate Per Application[1] | Total Annual N Rate[2] |
|---|---|---|---|
| Greens | | 0.75 | 3 to 6 |
| Tees | | 0.75 | 2 to 5 |
| Fairways (standard management)[3] | Cool-season<br>Warm-season | 1<br>1 | 2-3<br>2-4 |
| Fairways (intensive management)[4] | Cool-season<br>Warm-season | 0.5 to 1<br>0.5 to 1 | 3-4<br>3.5 to 4.5 |
| Overseeding Fairways[5] | Warm-season | 0.5 | 1.5 |
| Roughs | | 1 | 1 to 3 |

[1]For naturally occurring sand or modified sand-based soils on greens and/or tees, apply no more than 0.5 lbs WSN per 1000 sq ft$^2$ every 15 days or 1 lb N from sources containing 50% or greater SAN every 30 days.

[2]Use the higher levels for intensively managed turf during active growing periods where accelerated growth and/or rapid recovery are required; use lower rates for lower intensity managed turf and/or suboptimal growing conditions.

[3]Standard management fairways may or may not have irrigation and likely are mowed at heights of 0.75-1.25″ one to two times per week.

[4]Intensively managed fairways are irrigated and are likely mowed at heights ≤ 0.75″ three or more times per week.

[5]Initiate N applications of no more than 0.5 lb N per 1,000 ft$^2$ after ryegrass is well established and bermudagrass has entered dormancy. In spring, up to two applications of N at 0.5 lb N per 1,000 ft$^2$ can be used in February or March if growth and color enhancement are required.

### 6.11.4 Site-Specific Considerations

Additional considerations for fertilization management depend on weather forecasts and site-specific characteristics within each area of a golf course. For example, the following are recommendations for topographic, geologic, soils, climate, and cultural considerations that should be accounted prior to fertilization applications. Following these recommendations minimizes the amount of nutrients in runoff and/or groundwater:

- Minimize fertilizer application rates on slopes.
- Use N levels of 0.25-0.5 lb per 1,000 ft$^2$ per application on deep sandy soils or near shallow water tables.
- Avoid applying fertilizers prior to anticipated intensive, heavy rainfall events (Chapter 7).
- Ensure all fertilizers are applied or are moved into turfed areas so that they do not remain on hardscapes where they can move in stormwater.
- Establish minimal maintenance buffer zones around stream and lake boundaries (Chapter 4).

**BMP #8**
Consider site-specific conditions before making a fertilizer application.

# 7 Cultural Practices



"These practices help to avoid sediment and nutrient runoff by maintaining the health of the turf and decreasing soil compaction."



# 7 Cultural Practices

Golf cultural practices include mowing, cultivation practices, and overseeding, which maintain a turfgrass system (i.e., putting greens, tees, fairways, or roughs) to the desired use or function. For example, mowing creeping bentgrass and ultra-dwarf bermudagrass putting greens to a low height of cut (HOC) with well-adjusted and sharp blades in addition to proper implementation of cultivation practices such as core aerification, verticutting, and topdressing maintains a uniform surface over time for smooth ball roll. This chapter discusses BMPs related to the practices of mowing, cultivation, topdressing, and rolling, and discusses appropriate practices for overseeding. In addition to the playability benefits of implementing turfgrass management BMPs, these practices help to avoid sediment and nutrient runoff by maintaining the health of the turf and decreasing soil compaction.

## 7.1 Regulatory Considerations

No specific regulatory considerations apply with respect to turfgrass management. Adherence to these BMPs, however, can maintain and improve turf health and therefore decrease the potential for water quality impacts through over reliance on fertilizers or pesticides.

## 7.2 Mowing

By definition, a turfgrass is any plant that persists under regular mowing and traffic. Turfgrasses tolerate mowing because mowing does not remove the shoot meristems (growing points) necessary for regeneration. While frequent mowing places a stress on turf through removal of leaf tissue and therefore loss of photosynthetic area for carbohydrate production, proper mowing creates an aesthetically pleasing and functional surface. For example, mowing a species on the lower end of its adapted range improves its appearance and growth habit by promoting tillering (development of lateral shoots from axillary buds on the crown) and fineness of leaf texture. Frequent mowing at a slightly lower mowing height signals the plant to use its energy (i.e., carbohydrates) to increase shoot density rather than for leaf elongation. However, the tradeoff for increased density is decreased carbohydrate availability for root and stem (stolon and rhizome) growth. Improper mowing frequency and radical height reduction can magnify the negative consequences associated with this tradeoff.

**BMP #1**
Match the species or cultivar within a species to the mowing height needed for use.

### Cultural Practices BMPs

**BMP #1**
Choose the appropriate species or cultivar within a species to match the mowing height needed for use.

**BMP #2**
Raise HOC and lower inputs on shaded turf BMP.

**BMP #3**
Consider rolling to maintain green speeds in the summer.

**BMP #4**
Raise height of cut and lower inputs on shaded turf.

**BMP #5**
Vary the direction of mowing to improve aesthetics and quality of cut.

**BMP #6**
Return clippings to recycle nutrients.

**BMP #7**
Cultivate and topdress to dilute organic matter on putting greens.

### 7.2.1 Mowing Height

A number of variables influence the selection of appropriate mowing heights for the different functional areas of golf turf:

- species and cultivar differences
- depth of root growth
- rolling
- shade
- season

#### 7.2.1.1 Turfgrass species and cultivar mowing height differences

The intended use and the growth habit, leaf texture, and potential tiller density of different species and cultivars dictates the range of heights at which a turf can be mowed. For example, species characterized as spreading horizontally

via stolons or rhizomes, having very fine leaf texture, and exhibiting high tiller density such as hybrid bermudagrass or creeping bentgrass can withstand very low HOCs. Growth habit characteristics of species such as common bermudagrass, zoysiagrass, perennial ryegrass, or Kentucky bluegrass allow for mowing at a low-to-medium height range, making them useful in certain situations such as tees, fairways, or intermediate-cut rough grasses. Upright-growing, bunch-type species with wide leaf blades such as tall fescue are best maintained at higher mowing heights and are appropriate only for roughs.

Table 7-1 provides mowing height recommendations for greens, tees, and fairways. Mowing heights in the lower range are recommended only for short-term durations such as tournament play or other special events. Otherwise, turf thinning and damage due to environmental stress and pests may increase. Table 7-2 provides mowing height recommendations for roughs.

Tolerance of certain mowing heights also varies within turfgrass types due to the morphological differences between species or cultivars. For example, the following differences have been observed in Virginia golf courses:

- The finer-textured *Zoysia matrella* (e.g.,, 'Cavalier') tolerates lower fairway or tee mowing then *Zoysia japonica* (e.g.,, 'Meyer').
- Ultra-dwarf hybrid bermudagrasses such as 'Tifeagle' or 'Champion' tolerate lower putting green heights than older dwarf hybrid cultivars like 'Tifdwarf'.
- Improved creeping bentgrasses (e.g.,, cvs. Penn A4, Memorial, 007, Tyee) are often twice as dense as the old-standard 'Penncross' and therefore provide a higher quality putting surface at lower mowing heights.
- Certain genetic groupings of Kentucky bluegrass cultivars (e.g.,, Compact and Compact-Midnight types) offer improved tolerance to lower HOC for fairway or intermediate rough uses.
- Semi-dwarf types of tall fescue (e.g.,, cvs. Millenium, Rembrandt) offer improved density and finer leaf texture for primary roughs relative to forage-types like 'Kentucky-31', whose sole use on a golf course should be relegated to the secondary rough.

## Table 7-1. Recommended golf course mowing heights, by area

| Turf Species | Greens Healthy Maintenance | Greens Tournament Play | Tees, Collars Approaches | Fairways |
|---|---|---|---|---|
| | Inches | | | |
| Creeping bentgrass | 0.125–0.180 | 0.090–0.135 | 0.250–0.500 | 0.350–0.625 |
| Hybrid bermudagrass | 0.125–0.180 | 0.100–0.140 | 0.375–0.500 | 0.375–0.625 |
| Common bermudagrass | NA | NA | 0.500–0.625 | 0.500–0.750 |
| Zoysiagrass | NA | NA | 0.400–0.625 | 0.500–0.750 |
| Perennial ryegrass | NA | NA | 0.375–0.500 | 0.375–0.625 |
| Kentucky bluegrass | NA | NA | 0.500–0.750 | 0.625–1.000 |

## Table 7-2. Recommended mowing heights for roughs*

| K. bluegrass | P. ryegrass | Tall fescue | Fine fescues | Bermudagrass |
|---|---|---|---|---|
| Inches | | | | |
| 1.0–6.0 | 1.0–6.0 | 2.0–6.0 | 2.5–6.0 | 0.75–2.5 |

* For intermediate, primary and secondary roughs. Intermediate rough cuts are defined as a narrow (<10') step-up cut immediately adjacent to the fairway. HOC for intermediate roughs are usually in the lower part of the specified ranges, typically 1.0–1.75".

### 7.2.1.2 Root Growth

Carbohydrate reserves are stored in the roots (plus lateral stems). Deeper root growth increases the ability to obtain nutrients and moisture from the soil. When compared within the same soil type, a turfgrass species maintained at a higher HOC has a deeper root system than one maintained at a lower HOC (Figure 7-1). Conversely, golf greens and fairways with a shorter HOC have a shallower root system and need to be watered and fertilized more frequently than roughs. Therefore, shallow roots on a putting green imply that shoots have minimal carbohydrate reserves to draw from during summer stress.

**BMP #2**
Raise HOC slightly during summer to improve stress tolerance.



Figure 7-1. Higher HOC generally results in deeper roots.

### 7.2.1.3 Rolling

The rolling of putting greens offers turf health and playability benefits. Two types of rollers are currently used: (1) a set of three rollers that replaces the reels on a triplex mower; and (2) a stand-alone unit with operator facing perpendicular to the direction of machine movement (Figure 7-2). Research indicates that rolling increases green speed by at least 6" for 24–36 hours and achieves tournament-type green speed without lowering the mowing height or double cutting. Rolling without mowing also maintains adequate green speed and smoothness under stressful summer conditions. Rolling can also be used to smooth the surface and remove dew in late or early season periods when little shoot growth is occurring.

**BMP #3**
Consider rolling to maintain green speeds in the summer.



Figure 7-2. Stand-alone rolling unit. *Source:* Erik Ervin.

Rolling should be safe on push-up greens that have been topdressed to achieve a 3–4" sand layer over the original soil root zone. However, rolling should be used with caution as follows:

- Excess compaction and reductions in water infiltration can occur if rolling on other than sand-based greens.
- Green speed increases may not be realized if a thatch layer of greater than 0.5" is present.
- Because moisture acts as a lubricant and allows the closer association of soil particles, rolling should never be done when the soil is saturated since it can cause compaction and increase the need for core aerification.

### 7.2.1.4 Shade

Reduced light and changes in light quality in the shade cause shoots to elongate in attempts to capture as much of the filtered sunlight for photosynthesis as possible. This etiolation response results in a shallow-rooted turf with spindly, thin leaf blades that is more susceptible to disease and damage from traffic. To improve turf persistence in the shade, the following practices should be followed:

- Raise the mowing height by at least 30% to increase photosynthetic area and improve carbohydrate availability.

**BMP #4**
Raise HOC and lower inputs on shaded turf.

- Completely remove underbrush and selectively thin trees to improve air exchange and light availability.
- Adjust mowing patterns so as to minimize turning on shaded turf areas.
- Where possible, direct golf cart traffic away from shaded areas.

- Improve drainage in low-lying shaded areas and adjust irrigation run times to 50% or less of nearby full sun areas so as to minimize periods of soil saturation.
- Consider sequentially applying the plant growth regulator, trinexapac-ethyl, to reduce etiolation and conserve carbohydrates.

#### 7.2.1.5 Season

Mowing height can be varied seasonally to improve responses such as spring greenup, summer stress tolerance, and cold hardening. In spring through mid-summer, longer days result in a more prostrate growth habit for warm-season grasses. During this time, bermudagrasses and zoysiagrasses can be mowed closer to enhance density without negatively affecting overall plant health. Close mowing in early spring can remove dead tissue, open the canopy to greater solar radiation, and promote faster spring greenup. For example, if the intended maintenance HOC for a bermudagrass fairway is 0.5", begin spring mowing at 0.35", returning to 0.5" as 80–100% spring greenup occurs. The shorter days of late summer to autumn promote a slightly more upright growth habit for warm-season grasses. Raising HOC by 30% during this time reduces scalping potential while allowing more light interception by lower leaves. Overall, the result should be plants with greater carbohydrate storage for improved winter hardiness and canopies with greater biomass to protect crowns against winter traffic.

A similar approach could be taken with a tall fescue rough, but the first cleanup mowing should occur before active shoot growth resumes to avoid deleterious effects on spring root growth. For example, if the intended maintenance HOC for a tall fescue rough in spring is 2.75", the first mowing should be at 1.75", or about 40% below the intended maintenance height. This removes the upper brown leaf tissue and exposes the newer green growth to incoming radiation, enhancing soil warming and speeding greenup. As the spring shoot growth flush begins, HOC should be returned to 2.75". As the spring flush of shoot growth subsides and the heat of summer is looming, consider raising the height to 3" to better insulate the crown from high temperature stress, reduce weed competition, and increase late spring rooting potential for improved summer drought avoidance. With cooler temperatures of October, HOC can be lowered to 2.5" to encourage lateral growth and more efficiently mulch tree leaves into the rough. A similar seasonal approach to mowing heights for creeping bentgrass and *Poa annua* putting greens is recommended.

### 7.2.2 Mowing Frequency

Leaf growth in response to N availability and environmental conditions dictates mowing frequency. Maximum mowing frequency is required in the spring for cool-season grasses and in the summer for warm-season grasses. Turfgrass research at Virginia Tech in the 1950's was partly responsible for development of the 1/3 rule: Do not remove more than 30–40% of the leaf blade with any mowing. For most turfgrasses, shoots have priority over roots for carbohydrate allocation for maintaining enough leaf area for photosynthetic energy production. Repeated removal of > 40% leaf area initially stops energy from being stored in the roots and eventually stops root growth, reducing overall root viability. Coupled with summer stress, excessive mowing often results in shoot thinning, weed invasion, and sometimes, death. If rainfall results in turf of excessive height between clips, the height of cut should be lowered in small (25–40%) increments until the desired HOC is reached. Also, the lower a turf is mowed, the more frequent the need to be cut so as to protect healthy growth while not breaking the 1/3 rule (Table 7-3).

#### Example Application of 1/3 Mowing Rule

Based on the 1/3 rule, if the desired HOC is 2", the grass should be allowed to get no higher than 3" and then mowed back down to the 2" HOC: 3" x 2/3 = 2"

### 7.2.3 Equipment Care

Routine maintenance such as lubrication, oil changes, blade sharpening, tune-ups, belt adjustments, and daily cleaning are important in extending equipment life and lowering operating costs. Leaf blades should be checked regularly (daily for greens mowers) for tearing and mower blades sharpened and adjusted if needed (Figure 7-3). Mowing with a dull blade not only leaves an unsightly brown cast to leaf tips, but also depletes energy reserves that are better used to avoid drought and fight disease. Dull blades may also increase susceptibility to disease, increase turfgrass water use rates, and lower efficiency of gas use. Accurate records must be maintained to help pinpoint the costs of equipment operation and to justify the purchase of new mowers. Additionally, proper storage should be available to minimize exposure of equipment to weather, to prevent accidents, and to maintain security.

### Table 7-3. Mowing frequency required during active growth to conform to the 1/3 rule based on various mowing heights

| Mowing Height (inches) | 1/3 rule Height (inches) | Frequency |
|---|---|---|
| 0.12 | 0.18 | Every 1-1.5 days |
| 0.25 | 0.37 | Every 2 days |
| 0.50 | 0.75 | Every 2-3 days |
| 1.00 | 1.50 | Every 3-4 days |
| 1.50 | 2.25 | Every 4-5 days |
| 2.00 | 3.00 | Every 5-6 days |
| 3.00 | 4.50 | Every 6-7 days |
| 4.00 | 6.00 | Every 7-8 days |



Figure 7-3. Torn leaf blades from mowing with dull blades. *Source:* Erik Ervin.

When a job is finished, the unit should be cleaned and stored in a dry, secure area. See Chapter 10 for more details on equipment washing stations and BMP procedures.

## 7.2.4 Mowing Direction

Mowing in alternating lines to create various aesthetically-pleasing striping effects is most easily accomplished with cool-season rather than warm-season grasses because the blades of cool-season grasses lay over easier and reflect light more strongly due to their waxier cuticles. Dark-colored stripes result when the rollers on the back of the mower blades have laid the turf towards the viewer's eye; light colored stripes result when the turf is laid down away from the viewer's eye.

Warm-season grasses such as bermudagrasses and zoysiagrasses must be repeatedly reel-mowed in the same direction to "burn-in" or train the stiffer blades to lay in a certain direction for a pronounced striping effect. This mowing approach must be used cautiously because compaction, rutting, excessive wear from turning at the same location, and formation of grain that disrupts proper ball roll can occur. Varying the striping pattern on putting greens prevents grain, encourages more upright growth, and varies wear patterns. A rotating clock pattern is recommended so that mowing direction is changed daily. Cleanup laps should be routinely reversed or skipped two to three times per week to lessen wear damage.

**BMP #5**
Vary the direction of mowing to improve aesthetics and quality of cut.

## 7.2.5 Clipping Return

If proper mowing frequency is maintained following the 1/3 mowing rule, clipping return does not contribute to thatch accumulation and the clippings readily decompose during the growing season due to their high water content (75–80%). Clipping return has several benefits, including the recycling of plant nutrients such as N, P, and K. Nitrogen return is especially important as clippings containing approximately 4% N and return up to 1 lb of N per 1,000 ft² per year for turf reuse. Clipping return can play a major role in allowing maintenance of quality fairway and rough surfaces while only fertilizing with 2–3 lbs of supplemental N per 1,000 ft² per year. In addition, removing clippings can pose environmental concerns (e.g., municipal landfills typically no longer accept clippings) and budgetary concerns (time and labor for emptying buckets, raking, blowing, and sweeping clippings).

**BMP #6**
Return clippings to recycle nutrients.

The exceptions to this BMP are for specialized areas, such as golf greens, where clippings disrupt aesthetics or playability or next to watercourses where they may contribute to nutrient enrichment and sedimentation (Chapter 4). One option is to compost the clippings and reuse in flower beds or as fertile topdressings during establishment of new tee, fairway, or rough areas. Regular label-based applications of plant growth regulators such as trinexapac-ethyl, paclobutrazol, or flurprimidol can reduce clipping production while increasing tiller density.

## 7.3 Cultivation Practices

Cultivation involves disturbing the soil or thatch through the use of various implements to achieve important agronomic goals:

- compaction relief
- thatch/organic matter reduction
- improved water and air exchange

Development of distinct thatch layers greater than 0.5" on putting greens usually results from poor implementation of an Organic Matter Dilution (OMD) program along with excessive N fertilization and overwatering.

Except for situations that require complete renovation with tillage, the cultivation techniques used result in 1–60 days disturbance to the playing surface. These cultivation techniques include core aerification, deep drilling, verticutting, grooming, solid tining, spiking/slicing, and high pressure water injection. Table 7-4 lists each of these cultivation approaches and presents a relative ranking of the agronomic benefits of each. A discussion of each follows to describe their role in maintaining organic matter depth on putting greens, a recommended BMP.

### 7.3.1 Cultivation Approaches

The cultivation approach taken on putting greens depends somewhat on the root zone profile. Core aerification is an annual essential for putting greens and should be timed prior to nutrient and lime applications when possible to increase the efficiency of these applications. Other cultivation methods are used as infrequent renovation tools or as frequent practices that promote greater health and/or improvements in surface playability.

Most modern root zones consist of 10–12" of primarily sand, built to either USGA or University of California specifications. Sand resists compaction and retains good air and water exchange via higher aeration porosity. On sand-based greens almost all cultivation practices are aimed at management of the top 2–3". However, on many older greens (known as "push-ups"), native topsoil was used as the growing medium and often has a high clay fraction. Push-up greens usually exhibit poor internal drainage due to low aeration porosities and are contoured so that excess moisture runs off the surface. Most push-up greens are sand topdressed regularly and a >4" sand layer develops over time. One of the main

**BMP #7**
Cultivate and topdress to dilute organic matter on putting greens.

**Table 7-4. Turfgrass cultivation methods and rankings of agronomic benefits**

| Method | Compaction Relief Inches | Thatch Control | Water/air Movement | Disruption of Play |
|---|---|---|---|---|
| Core aerification | High | Good[1] | High | Medium to high[1] |
| Deep drilling | Medium | Low | High | High |
| Verticutting | Low | Best[1] | Medium | Low to high[2] |
| Grooming | None | Very low | Very low | None |
| Solid tining | Low[3] | None | High | Medium-low |
| Spiking/slicing | None | Very low | Low | None |
| High pressure water injection | Very low | None | Medium-High | Very low |

[1] Verticutting removes a greater amount of thatch, but does so only to a maximum of about 0.7"; core aerification is a better approach if excess thatch and organic matter accumulation from 0- 3" must be removed
[2] Use of bigger tines when core aerifying disrupts play for longer; similarly, use of verticutters with wider blades, closer blade spacing, and deeper settings increases length of play disruption.
[3] Compaction relief with solid tining is low except when equipped with a "kicking action" that results in some soil loosening.

differences between sand-based and sand-modified push-up greens is consideration of the different cultivation needs on the push-ups that have distinct sand over soil layer. For both root zone types, the primary zone of cultivation intervention is in the top 2–3". Using cultivation equipment and sand topdressing can keep 0–3" depth organic matter between 2–4%.

### 7.3.1.1 Core aerification

The USDA recommends OMD programs as follows: core aerating to achieve annual surface removal of 15–20% with enough topdressing to fill all holes plus extra sand (50–200 lbs/1,000 $ft^2$ every 2–4 weeks) for putting green conditioning between major cultivation events (Table 7-5 and 7-6, O'Brien and Hartwiger 2003). Virginia Tech researchers implemented various iterations of the OMD program for three years (2008–2010) on mature sand-based Penn-A4 greens at a course near Richmond and confirmed a minimum of 15% removal was required to meet this BMP (Figure 7-4, Ervin and Nichols 2011). Achieving this BMP should also result in the maintenance of 10–20% aeration porosity needed for the healthy root growth and surface water infiltration required to prevent summer bentgrass decline.



Figure 7-4. Core aerification. *Source:* Erik Ervin.

### 7.3.1.2 Deep drill

The deep drill and fill process is an example of a renovation tool that can be an effective way to improve putting green performance without a complete rebuild. Large diameter (usually 1") bits are drilled 8–10" deep into a push-up green to replace heavier soil with sand, creating channels for enhanced water infiltration and rooting (Figure 7-5). The process is slow and the equipment expensive, requiring most golf courses to hire a contractor. Moreover, going over the green once (with a 6" spacing between holes) renovates only approximately 5% of the root zone. Therefore, the process must be repeated multiple times for best effect.


Figure 7-5. Deep verticutting. *Source:* Erik Ervin.


Figure 7-6. Shallow verticutting. *Source:* Mike Goatley.

### 7.3.1.3 Verticutting

Deep verticutting (0.5–1" depth) can be considered for aggressive thatch removal as it can remove up to 15% of the thatch at one time. Deep verticutting is aggressive and potentially injurious; it should only be done during cooler periods of active growth on a well-rooted turf. For fastest re-establishment of a smooth, firm surface, slits must be filled completely with sand. For best results, verticut + sand/slit filling machines should be used (Figure 7-5).

Unlike deep verticutting, shallow verticutting (0.5"or less) does not remove thatch. Instead, it severs stolons to promote new growth while also standing up blades for removal of old growth and minor canopy thinning (Figure 7-6). The frequency and depth of shallow verticutting, needed to produce a highly playable putting surface varies, but can promote a longer, truer roll of the ball. It is a gentler practice than deep verticutting and can be practiced most of the growing season except for the hottest periods of summer.

### 7.3.1.4 Grooming

Like shallow verticutting, grooming does not help with compaction or thatch relief. Grooming, light verticutting and/or brushing units are mounted in front of the mower reel to improve the condition of the putting green surface for improved playability.

## Table 7-5. Tine size diameter and hole spacing effects on surface area removal

| Tine Inside Diameter (in.) | Tine Hold Spacing (in.) | Holes/sq. ft. | Surface Area Removal (%) | No. Corings Needed for 15% Removal |
|---|---|---|---|---|
| 0.25 | 1.25 x 1.25 | 92 | 3.1 | 4.8 |
| | 1 x 2 | 72 | 2.5 | 6.0 |
| | 1.5 x 1.5 | 64 | 2.2 | 6.8 |
| | 2 x 2 | 36 | 1.2 | 12.5 |
| 0.375 | 1.25 x 1.25 | 92 | 7.0 | 2.1 |
| | 1 x 2 | 72 | 5.5 | 2.7 |
| | 1.5 x 1.5 | 64 | 4.9 | 3.1 |
| | 2 x 2 | 36 | 2.8 | 5.4 |
| 0.50 | 1.25 x 1.25 | 92 | 12.5 | 1.2 |
| | 1 x 2 | 72 | 9.8 | 1.5 |
| | 1.5 x 1.5 | 64 | 8.7 | 1.7 |
| | 2 x 2 | 36 | 4.9 | 3.1 |
| 0.625 | 1 x 2 | 72 | 15.3 | 1.0 |
| | 1.5 x 1.5 | 64 | 13.6 | 1.1 |
| | 2 x 2 | 36 | 7.7 | 1.9 |
| | 4 x 4 | 9 | 1.9 | 7.9 |
| 0.75 | 2 x 2 | 36 | 11.0 | 1.4 |
| | 4 x 4 | 9 | 2.8 | 5.4 |



Figure 7-7. Tining. *Source:* Erik Ervin.

### 7.3.1.5 Solid tining

Solid tining is the process of creating an open channel by pushing solid tines of various diameters and depths into the soil (Figure 7-7). The open channels promote excellent air exchange and water infiltration without much surface disruption. Rolling following solid tining is recommended, however, to push down small tufts of turf that can bump up and lead to minor scalping. Solid tining can also help with the incorporation of light sand topdressing during warmer times of the year. Another excellent application is to use longer tines (>4") to break through thin subsurface compaction layers that have developed via repeated core aerification to a certain depth, such as 3". Further, the use of long solid tines can function to break the barrier to water and air movement between the sand over soil layer of pushup greens, promoting deeper rooting and more

## Table 7-6. Approximate sand topdressing volumes and weights for putting greens, tees, and fairways

| Sand Depth, inches | $Ft^3$ Sand/1,000 $ft^2$ | Lbs Sand/1,000 $ft^2$ | Tons Sand/acre |
|---|---|---|---|
| 0.006 | 0.50 | 50 | 1.1 |
| 0.012 | 0.75 | 75 | 1.7 |
| 0.024 | 1.00 | 100 | 2.2 |
| 0.036 | 2.00 | 200 | 4.4 |
| 0.048 | 4.00 | 400 | 8.8 |
| 0.100 | 8.00 | 800 | 17.6 |
| 0.120 | 12.00 | 1,200 | 26.4 |
| 0.170 | 16.00 | 1,600 | 35.2 |
| 0.250 | 20.00 | 2,000 | 44.0 |
| 0.500 | 50.00 | 5,000 | 110.0 |

### Example: Creeping Bentgrass OMD Program

**Site Description:** Sand-based creeping bentgrass putting green in a very shallow-rooted condition in early September.

**Program Goals:** The primary remediation goals are to: relieve surface compaction; remove thatch; dilute organic matter; and create channels for improved air and gas exchange. Achieving these goals results in a medium more conducive to active fall root growth.

**Considerations:** Late summer to fall user demand remains high so an approach is needed where surface healing occurs quickly, while still achieving remediation goals. Small coring holes, no matter how closely spaced, heal quicker than large holes and tend to be safer in terms of surface heaving on a shallow rooted green. The compaction and thatch layer are not deeper than 2", with well-aerated sand below, so there is no need to pull cores too deep.

**OMD Program:** For this situation, the use of an aerifier that pulls shallow (2–3.5"), small-diameter (0.375") cores on a tight spacing (1" x 2") for a 5.5% surface removal (Table 6-5) is recommended in general. Spring conditions offer the opportunity to be more aggressive with creeping bentgrass putting green OMD programs because the turf is better rooted with vigorous growth, allowing for faster surface healing. In this case, larger diameter cores (~0.5"), still tightly spaced (1" x 2") for a 9.8% surface removal offer remediating effects that are longer lasting and set the stage for a healthier putting green heading into the stresses of summer.

**Results:** This OMD program removed 15.3% surface area, replaced it with approximately 2,400 lbs sand/1,000 $ft^2$ and only required two core aeration events.

**OMD Implementation:** This case is just one example of how the recommendation for at least 15% surface area removal can be achieved. Implementing an OMD Program should be based on the experience and observations of a skilled golf course superintendent.

efficient water infiltration. Results are temporary, but since this is a fairly quick and gentle process, it can be repeated almost any time of year.

### 7.3.1.6 Slicing / Spiking

Slicing/spiking temporarily improves water infiltration and air exchange and is gentle enough to be practiced in summer. Spikers and slicers generally are pull-type non-powered units consisting of a series of blades mounted on a horizontal shaft (Figure 7-8). A slicer has thin, V-shaped knives bolted at intervals to the perimeter of metal wheels that cut into the soil. Narrow slits about ¼-inch wide and 2–4" deep are cut into the turf. A spiker has solid tines mounted on a horizontal shaft, with effects similar to a slicer but soil penetration is usually limited to about an inch and the spike pattern has a closer spacing. Stolon severing to promote new growth occurs with both units, but effects on water penetration and air exchange are minimal and temporary.

### 7.3.1.7 High pressure water injection

A more effective and slightly longer lasting summer approach for promoting water penetration and air exchange is high pressure water injection (Figure 7-9). Fine streams of high-velocity water are injected, creating channels that are 1/8–1/4" diameter to a depth of 4–8". These small diameter holes do not disrupt play and have been shown to improve water infiltration for three to four weeks. Thus, high pressure water injection, conducted every three to four weeks in the summer, serves as an excellent supplement to core aerification to prevent summer putting green decline.




Figure 7-8. Slicing/spiking. *Source:* Erik Ervin.



Figure 7-9. Results of high pressure water injection. *Source:* Nelson Caron.

## 7.3.2 Tees, Fairways, and Approaches

As opposed to putting greens, greater HOC and less concentrated traffic pressure on tees and fairways result in deeper-rooted grasses with more stress tolerance. Consequently, acceptable fairway, tee, and approach playing surfaces can be achieved with less intense cultivation and topdressing programs. Standard programs include one or two core aerification events to impact at least 10% of the surface area, along with at least one deep verticutting, especially on spreading species such as creeping bentgrass, hybrid bermudagrass, and zoysiagrass. These coring and verticutting practices are a stress on the turf and should only be done during periods of active growth. Deep solid tining is fairly gentle and can be done during the off-season. Use of other pieces of cultivation equipment as listed in Table 7-4 on fairway and tee areas is usually not required.

### Example: Cultivation Program for Fairways

A standard cultivation program for healthy cool- or warm-season fairways might include the following:

- core aerification to a 4" depth with large tines on a 2" x 2" spacing so as to remove 7–15% surface area
- verticutting (0.5–1" depth) to aggressively remove thatch on creeping bentgrass, bermudagrass, and zoysiagrass fairways

Exceptions to this program include high wear areas where play is concentrated (e.g.,, regular men's tees) or where cart and player traffic tend to get funneled (e.g.,, fairway on and off points).

On such areas, compaction, not thatch, is the primary problem requiring extra, site-specific core aerification events. If tees are sand-based, such compaction issues are minimized and the most important program to implement is regular filling of divots with a sand-seed mix and sand topdressing to dilute thatch and keep the tee ground level. Sand topdressing of native-soil fairways can also be quite successful for improving compaction resistance and diluting thatch. However, the program will only be successful if a multiple year commitment (2-4 years) is made and a minimum of approximately 40 tons sand/acre/year are applied to achieve a distinct sand layer of at least 2". Research has shown that locally-available masonry sand in the medium-coarse particle size range is sufficient. Only solid tining and verticutting should be practiced as the sand layer is being built up. Coring would pull native soil to the surface, contaminating the sand layer and negating some of its benefits by plugging macropores.

### 7.3.3 Rough

In Virginia, the primary rough grasses are tall fescue, Kentucky bluegrass, and hybrid bermudagrass. While tall fescue does not tend to accumulate thatch, the other two do. An integrated approach to limiting thatch development should be taken that involves moderate nitrogen and irrigation inputs along with periodic vertical mowing (Figure 7-10) and core aerification. Vertical mowing frequency should be based on observations of thatch depth, with depths of >0.75" being a trigger.



Figure 7-10. Rough de-thatching. *Source:* Erik Ervin.

### 7.3.4 Cool-season Roughs

Early spring can be an excellent time to vertical mow cool-season rough as thatch can more easily be pulled out of the semi-dormant canopy and removed. This type of slicing action can also sever stems and promote faster spring fill-in. Pre-emergent herbicides can be applied after de-thatching so as not to disturb the chemical layer required for adequate control of summer annual grasses. Core aerification in late summer to early fall, followed by seeding and fertilizing, promotes recovery of a full turfgrass canopy following the stresses of summer. However, the standard circular-motion spoon-tine aerifiers used on roughs as the 4–6" spacing between tines removes less than 3% surface area per pass and therefore does not improve compaction. High traffic areas of the rough that are thinned by concentrated cart traffic should be aerified 2–3 extra times per year with vertical coring units that remove 7–11% area. Without such site-specific cultivation, thinning in these areas may contribute pollution via sediment-bound nutrient movement.

### 7.3.5 Bermudagrass Roughs

Coring or vertical mowing during spring greenup of bermudagrass is not recommended as damage to carbohydrate-depleted stems at this time could significantly slow fill-in and predispose the bermudagrass to greater damage if a late frost occurs. Cultivation events can be scheduled anytime during active periods of growth, (i.e.,, May through September). As with cool-season roughs, determine the need for vertical mowing to de-thatch by observation. A standard summer core aerification of the primary rough is an acceptable practice except for areas where traffic is concentrated. For example, the arrangement of bunkers in relationship to the location of the cart paths often require the use of signs, ropes, cart poles, and alternating policies of keeping carts on the path (saturated conditions) and keeping carts on the fairway (dry conditions) to avoid concentrating traffic in these areas. If these attempts fail and these areas become highly worn and compacted, more frequent and aggressive aerification must be used.

## 7.4 Overseeding

Overseeding is the process of seeding a cool-season grass, primarily perennial ryegrass, into a dormant bermudagrass canopy to provide a green late fall to spring playing surface. Overseeding is not considered a BMP as it may negatively affect the underlying bermudagrass. Additional late fall to early spring fertilizer applications are often required to

ensure proper growth and development of the overseeded perennial ryegrass, which increases the chance of N and P runoff during the winter. The main reasons for overseeding bermudagrass are almost always aesthetics and the potential for increased winter golf revenue. This common Virginia scenario may have a number of disadvantages, including:

- poor aesthetics
- poor playability (i.e.,, ground-under-repair)
- added costs for re-establishment (fertilizer, aerification, seeding, sprigging, or sodding, irrigation, labor)
- greater weed pressure
- open soil susceptible to loss of sediment-bound N and P
- resource-depleted bermudagrass stand more susceptible to winter-kill

Thinning of the bermudagrass stand occurs due to competition. In the spring, perennial ryegrass competes very aggressively with the greening-up bermudagrass until air temperatures consistently reach the high 80°Fs, which may not occur until late June in many parts of Virginia. Such competition delays total bermudagrass fill-in and, if a heat wave causes the overseeding to quickly die, results in a thin, soil-exposed stand of bermudagrass (Figure 7-11). For courses that still choose to overseed, gradual transitions from bermudagrass to perennial ryegrass in the fall and back to bermudagrass in late spring are necessary to maintain consistent turf playability.



Figure 7-11. Thin bermudagrass fairway base after overseed removal. *Source:* Shawn Askew.

## 7.4.1 Timing

Seeding too early can result in excessive bermudagrass competition and disease pressure (gray leaf spot and pythium damping-off) that thins the perennial ryegrass seedlings to the point where re-seeding is necessary. Seeding too late may result in reduced seedling vigor and thin perennial ryegrass cover through the winter. Consistent night temperatures of around 50°F are one of the most dependable indicators for overseeding timing. In addition, overseeding should be completed two to three weeks prior to the first killing frost. These timings minimize bermudagrass competition and still provide sufficient soil and air temperatures for perennial ryegrass germination and development.

### 7.4.1.1 Fall procedures

Opening up and removing much of the slow-growing bermudagrass canopy by lowering the HOC for a slight scalping improves seed to soil contact and improves establishment success. Light verticutting or power raking/brushing prior to overseeding can also be advantageous. For large areas, perennial ryegrass seed can be effectively distributed with a rotary spreader. For best uniformity and to avoid skips, seed should be spread in at least two directions. To maintain definition between overseeded and non-overseeded areas, a drop spreader around these boundaries should be used. To prevent establishment of volunteer ryegrass outside of these boundaries, consider application of a preemergent herbicide strip in the primary rough, for example. Successful ryegrass stands have been achieved by seeding fairways and tees at 250–800 pounds of pure live seed per 1,000 $ft^2$. The specific rate chosen depends on the experience and expectations of the golf course superintendent. Greater establishment success is often achieved by sand topdressing (5–10 tons/acre) and dragging following seeding. Application of a starter fertilizer at seeding to supply 0.5 lb N per 1,000 $ft^2$ provides adequate N and P for seedling development.

In dry conditions, irrigating lightly 3-4 times daily keeps the surface moist but not puddled. Once seedlings are established, water is needed only to prevent wilt, discourage disease, and to maintain a firm surface for cart traffic. When seedlings reach about 1", approximately 14–28 days after seeding, mowing at a 0.75" HOC allows seedlings to root. Mowing with sharp blades during dry conditions avoids pulling seedlings from the canopy. As the stand matures, the HOC can be lowered to the desired range (~0.5–0.625"). Fertilizing after the first or second mowing and continuing until cold weather at a rate of

0.25–0.5 lbs N per 1,000 ft² every three to four weeks with a soluble N source is adequate for promoting density and color without encouraging disease. P and K applications should be based solely on soil test results (see Chapter 6).

### 7.4.1.2 Spring transition

To avoid serious decline of bermudagrass, overseeded grasses should be controlled as summer approaches. In the hottest areas of Virginia, perennial ryegrass may be encouraged to die out by scalping, increased rates of soluble N, aggressive vertical mowing, and reduced irrigation. Caution should be exercised when using this type of culturally-assisted natural transition as persistence of ryegrass throughout much of July could severely weaken the bermudagrass, predisposing it to subsequent winterkill. Experience, backed by recent Virginia Tech research, indicates a need for at least 100 days of perennial ryegrass-free bermudagrass growth to ensure a stand that persists under the repeated stresses of overseeding and Virginia winters. In most areas, this corresponds to a perennial ryegrass-free growth period of approximately June 20–September 30 and in most years requires the use of a transition-assisting herbicide, such as those in the sulfonylurea chemical class, which require warm soil temperatures (>60°F) for best activity and complete control in 2-4 weeks. Some of their useful characteristics are listed in Table 7-7.

Waiting until at least 75% bermudagrass green-up and fill-in (May into June) before application of a transition-assisting herbicide has a number of benefits. First, March–May offers a perennial ryegrass playing surface that is often unparalleled in terms of aesthetics and conditioning. Second, greater herbicide efficacy is assured as these materials control perennial ryegrass much more effectively in warmer temperatures. Third, transition from an overseeded surface to a 100% bermudagrass surface is smoother. Spraying too early can result in 3 to 4 weeks of thin, bare areas.

## Table 7-7. Commonly used transition herbicide characteristics

| Chemical Name | P. ryegrass | *Poa annua* | Sedges | Broadleaf Weeds | Turfgrass Injury |
|---|---|---|---|---|---|
| 1 = poor control or maximum turfgrass injury \| 10 = excellent control or minimal injury | | | | | |
| Foramsulfuron | 10 | 10 | 1 | 1 | 10 |
| Trifloxysulfuron | 10 | 9 | 9 | 8 | 8 |
| Rimsulfuron | 10 | 9 | 1 | 1 | 8 |
| Metsulfuron | 7 | 6 | 1 | 10 | 9 |

# 8

# Integrated Pest Management



“Pesticides alone will not control pests; a more effective approach is to develop an integrated pest management (IPM) program.”



# 8 Integrated Pest Management

When turfgrasses face stresses such as the heat and drought found in Virginia's transition zone climate, pests can become a problem. Pesticides alone will not control pests; a more effective approach is to develop an IPM program to reduce pest damage and reliance on pesticides. EPA defines IPM as "an effective and environmentally sensitive approach to pest management that relies on a combination of common-sense practices." The primary objective of an IPM program is to reduce the total pesticide load on the golf course by using a combination of tactics to control or manage pests. This approach considers all strategies to reduce pest damage to acceptable levels in the most economical means, while simultaneously accounting for impacts on humans, property, and the environment.

A formal IPM plan documents a golf course's specific management strategies and policies. An IPM process should first incorporate the use of regular monitoring and recordkeeping to identify pest problems, analyze the conditions that can lead to pest problems, and determine appropriate threshold or tolerance levels for pests. Strategies to prevent or discourage pest issues (such as the use of hardy turf species or modifying irrigation practices) should be part of the process. If damage thresholds are met or exceeded, a number of control and management strategies should be considered: biological, physical, mechanical, and chemical. In many cases, the use of chemical pesticides may be delayed until after other IPM strategies have been considered or used. Incorporating IPM strategies into an IPM plan provides the golf course superintendent and staff with a working reference document that can also be used to inform stakeholders (such as owners, regulators, golfers, and the public) regarding the IPM strategies and practices at the golf course.

A number of topics and BMPs already addressed in this document play a role in golf course IPM. These include irrigation (Chapter 3), fertilization (Chapter 6), and turfgrass management practices (Chapter 7). For example, over-irrigated turf may have higher densities of weeds, such as green kyllinga or yellow nutsedge, and diseases such as brown patch or gray leaf spot. Similarly, some diseases are caused by nitrogen deficiencies in the soil. This chapter focuses on the elements of an IPM program and BMPs implemented to address three types of turf pests: diseases, insects, and weeds. Aquatic weed management is discussed in Chapter 4. Pesticide management and safety are discussed in Chapter 9.

### Integrated Pest Management BMPs

**BMP #1**
Use biological controls when possible.

**BMP #2**
When needed, select the appropriate conventional pesticides and use judiciously.

**BMP #3**
Manage turfgrasses for reduced disease pressure.

**BMP #4**
Identify problems that limit turfgrass competitiveness for weed control

## 8.1 Regulatory Considerations

Pesticides must be registered with VDACS to be used in Virginia. Also, applicators must be certified by VDACS to apply pesticides in Virginia. Finally, a VPDES permit is required for the direct application of pesticides to surface waters and is available from DEQ (Section 4.1). Chapter 9 provides information related to pesticide regulations and BMPs for pesticide management.

## 8.2 Turfgrass Selection

Selecting appropriate turfgrass cultivars or species for site-specific conditions and management needs is an important first step for controlling turfgrass pests. Turfgrass selection is addressed in detail in (see Section 2.3.3) and in the design BMP #3 "Select appropriate turfgrass species and/or cultivars". For example, different varieties of turfgrass are susceptible to different kinds of diseases. NTEP data includes selected disease resistance ratings for tested species and cultivars[1]. Current varieties recommended in Virginia are published and updated annually by Virginia Tech[2] (Figures 8-1 and 8-2). In addition, breeding efforts use genetics to reduce pest damage and result in the introduction of new cultivated varieties that are either genetically resistant to pests or more tolerant of damage.

[1] see NTEP data from Virginia test locations at www.ntep.org
[2] accessible from http://www.pubs.ext.vt.edu/category/turf.html



Figure 8-1. NTEP trial plots of buffalograss cultivars showing fall color retention variation. *Source* Erik Ervin.



Figure 8-2. NTEP trial plots of bermudagrass cultivars showing winter kill differences. *Source* Erik Ervin.

## 8.3 Biological Controls

Biological control makes use of nonpathogenic microorganisms (bacteria, fungi, and nematodes) to reduce damage from pests. Biological control products are commercially available and, when introduced to the soil or plants, may have direct or indirect effects on pests. In some cases, a biological control agent may reduce pest populations or their ability to infect and colonize plants. In other situations, biological control agents may induce natural defense mechanisms within a plant. In general, the use of microorganisms for biological control has both advantages and disadvantages (Table 8-1).

**BMP #1**
Use biological controls when possible.

## 8.4 Use of Conventional Pesticides

Although the use of IPM strategies reduces the need for chemical pest controls, chemical controls remain vital for managing optimal turfgrass in Virginia. A wide range of chemical control options exist, from broad-spectrum chemicals that target many different pests to very specialized and highly selective products that target single pests. Many pesticides frequently used on golf courses are derived from naturally occurring compounds, such as plant or fungal hormones. IPM does not exclude the use of synthesized chemistries, but rather promotes the use of the least toxic and most selective pest management alternatives available. Pesticide recommendations for professional turfgrass managers in Virginia can be found in Section 6 of the *2011 Pest Management Guides: Horticultural and Forest Crops* (VCE).

Judicious use of conventional pesticides can be achieved for most pests by using management tactics such as the following:

- timing applications based on available scouting methods and thresholds
- exploiting the 'weak link' in the insect life cycle
- using degree-day programs
- considering plant phenology (the interaction of plants with climate)
- planting tolerant turfgrass varieties
- implementing cultural controls

### Table 8-1. Advantages and disadvantages of using microorganisms for biological control of turf pests

| Advantages | Disadvantages |
|---|---|
| • can be applied using standard equipment<br>• low vertebrate toxicity<br>• can suppress target pests in sensitive areas | • timing of application is important (generally evening applications are best)<br>• sensitive to desiccation<br>• short shelf life (3 to 6 months)<br>• repeat applications are sometimes necessary |

For example, the annual bluegrass weevil, a recent introduction (2007) to Virginia, is a pest of annual bluegrass and creeping bentgrass fairways and greens. It overwinters as an adult in pine duff and other plant material and has multiple generations. One of the timing indicators used to control re-infesting adults occurs in early spring when forsythia is at the 'half' green, 'half' gold post-bloom stage. One or two applications of pesticides at this time targets the adult stage for season-long control, as opposed to making seven or eight applications to control different life stages from overlapping generations throughout the season.

**BMP #2**
When needed, select the appropriate onventional pesticides and use judiciously

## 8.5 Turf Diseases

Both warm- and cool-season turfgrasses are susceptible to a number of different 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.

In order to effectively treat turf diseases and implement an IPM program, it is important to know which disease is most likely to be active. Managers who do not understand disease pathology risk treating the symptom, rather than the underlying disease. Turf diseases are typically most common in the summertime for cool-season grasses (such as tall fescue or Kentucky bluegrass) and in the spring and fall for warm-season grasses (such as bermudagrass or zoysiagrass). These diseases occur largely due to the shift in growth habits of the grasses from active growth to survival, giving a competitive advantage to disease pathogens. For example, spring dead spot is the most common disease for bermudagrass. Symptoms include dead patches in the turf that appear in the spring as the turf emerges from winter dormancy. Dead patches in the turf can be caused by a number of diseases or nutrient conditions; however, the pathogen responsible for this disease is most active in the root zone during the fall and winter. This disease is often unpredictable, but is usually found in high traffic or compacted areas and after severe winters.

Understanding the potential diseases for a given species or cultivar and the environmental conditions associated with them is essential. In situations where diseases develop, proper diagnosis assists with decisions on how best to proceed. Diagnostic services are available from Virginia Tech and private laboratories and can help prevent choosing the wrong products or management tactics. Some of the more common golf turf disease problems are described in Table 8-2 and shown in Figures 8-3 and 8-4.

### Table 8-2. Common golf turf diseases

| Conditions Favoring Disease Development | Disease (Common Names) |
|---|---|
| **Cool-season grasses** | |
| Low N | • dollar spot<br>• anthracnose<br>• brown ring patch |
| High N | • brown patch<br>• *Pythium* diseases<br>• snow molds (*Microdochium* patch and *Typhula* blight) |
| General | • Fairy ring caused by various basidomycete fungi (both cool- and warm-season grasses)<br>• leaf spots and melting out |
| **Warm-season grasses** | |
| Low N | • dollar spot |
| High N | • large patch<br>• leaf spots |
| General | • spring dead spot |



Figure 8-3. Dollar spot mycelium in the morning on Kentucky bluegrass. *Source:* Erik Ervin.



Figure 8-4. Rhizoctonia brown patch and dollar spot during July on a creeping bentgrass research green. *Source:* Erik Ervin.

A good resource for additional information is *Compendium of Turfgrass Diseases* (Smiley et al. 2005).

### 8.5.1 Reducing Disease Pressure

Managing turfgrasses for reduced disease pressure is a dynamic process that requires constant monitoring and readjusting. Stress can be brought on by a number of environmental factors, such as soil pH, soil moisture, and temperature and nutritional extremes. Turfgrass management practices such as core aerification and sand topdressing, while beneficial, can also stress turfgrasses.

Most university research has focused on pest management related to N. Some of the most common disease-related issues arise from N deficiency, such as dollar spot and anthracnose. However, excess application of N may lead to increased incidence of common diseases such as brown patch or *Pythium* blight. Deficiencies in other macro- or micronutrients may also contribute to increased susceptibility to pests. Many turf pests, especially diseases, can be suppressed with proper fertilization. Chapter 6 describes nutrient management planning.

Irrigating at the proper time, frequency, and duration can minimize pest damage. For example, sites that are over-irrigated may have greater incidence of diseases, such as brown patch or gray leaf spot. Irrigating just before sunrise while dew and guttation water (water exuded from the plant) are present reduces the duration of leaf wetness. Turfgrass management practices, such as mowing height, frequency, and maintenance can impact pest pressures (Chapter 7).

**BMP #3**

Manage turfgrasses to reduce disease pressure.

For example, dull blades or reels cause leaf blades to shred, increasing wounded surface area and creating opportunities for pathogen infection.

### 8.5.2 Biological Control of Turf Diseases

Many cultivars of fescue and perennial ryegrass contain a naturally occurring beneficial fungus, called an endophyte, which reduces the likelihood of attack by many insect and disease pests. In addition, a number of commercially available biological fungicides may reduce the severity of turfgrass diseases. While these fungicides may not offer complete control, some have been shown to suppress diseases such as brown patch and dollar spot and aid in turfgrass recovery.

### 8.5.3 Fungicides

Faced with high expectations for flawless grass, golf course superintendents often rely heavily on the use of fungicides to help manage diseases. Fungicides play an important role in disease management and should be incorporated as a regular part of IPM planning. Tables 6.1 and 6.2 in section 6 of *Pest Management Guide: Horticultural and Forest Crops* (VCE 2011) lists fungicides labeled for use on professionally managed turf in Virginia. Generally, diseases are much more difficult to control once symptoms are present, thus most fungicides are more effective when used preventatively. Many excellent fungicides are available for use on golf courses, though none have the ability to prevent or control all diseases. Furthermore, because of the diversity of pathogens and the selective nature of most active ingredients, most fungicides target only a specific site (or sites) of fungal metabolic pathways.

For optimal control, most fungicides should be applied preventatively when conditions become favorable for disease development. As noted above, most common diseases of cool-season grasses occur during the summer months; most common diseases of warm-season areas occur during the spring and fall. However, not all pathogens are active at the time symptoms are observed. For example, symptoms of spring dead spot on warm-season grasses appear at spring green-up, although the pathogen is most active in the fall and winter. Therefore, fungicide to treat spring dead spot should be applied in the early fall prior to pathogen infection and colonization. When to reapply chemicals depends on active ingredients, product formulation, target pests, environmental conditions, and the product label, which may restrict the number of applications per year or limit the frequency and timing (for example, once every

2 weeks). Systemic fungicides that move acropetally (upward) within the plant typically provide control for longer than contact fungicides.

## 8.6 Turf Insects/Arthropods

Annually recurring insect pest groups on Virginia golf courses include numerous species:

- several annual white grub species
- black turfgrass *ataenius* white grub (2-3 generations)
- billbugs
- annual bluegrass weevil (Coleoptera)
- armyworms, cutworms, and sod webworms (Lepidoptera)
- nuisance ants and red imported fire ant (Hymenoptera)

Occasional pests include the northern mole cricket (Orthoptera) in sandy soils and common chinch bug (Hemiptera). Common turf pests are listed in Table 8-3.

### Table 8-3. Common turf pests and impacts to golf course turfgrasses

| Pest | Golf Course Impacts |
|---|---|
| Annual white grubs | Feed on roots of cool-season grasses. |
| Armyworms and cutworms | Larvae feed at night on many varieties of cool and warm-season grasses on the surface and rest during the day. They are easier to detect using visual inspection and other methods based on irritating detergent-based disclosing solutions to assess larval numbers. |
| Nuisance ants | Mound-building ants disrupt surface uniformity, and in extreme cases, can render the turfgrass almost unplayable for golf and sports turf activities. |
| Red imported fire ants | From early spring to the end of summer, fire ants excavate the soil beneath the turfgrass and push it to the surface to make room for the young in the colony. The excavated soil initially forms a small cone-type mound. Increased mounding smothers the grass, while the underground expansion of the ant colony leads to uprooting and accelerated drying out of the grass. If not corrected, the turf becomes unthrifty, takes on a grayish appearance, and is easily uprooted. |

### Table 8-4. Biological control – wasps, fungi, bacteria, and nematodes

| Category | Description |
|---|---|
| Wasps (digger) | Tiphiidae and Scoliidae are two families that occur in Virginia. *Tiphia vernalis* and *T. popilliavora*, are external parasites of white grubs. *Scolia manilae* was introduced into Hawaii and successfully reduced Oriental beetle grub levels to non-serious status. |
| Fungi | *Beauvaria bassiana*, a white muscardine fungus, and *Metarhizium anisopliae*, a green muscardine fungus, infect white grubs and other turfgrass insects. The endophytic fungus and its toxin occur inside all plant parts except the roots of fine and tall fescue and perennial ryegrass. |
| Bacteria | *Bacillus popilliae* causes milky spore disease only in the grub stage of Japanese beetle. *B. thuringiensis* bui bui (not labeled) is more broad spectrum with respect to white grub pest species in turfgrass. |
| Nematodes | Many species attack white grubs in turfgrass. *Heterorhabditis bacteriophora* and *H. megidis* are two of the more promising. |

The turf insects discussion in Section 6 of P*est Management Guide: Horticultural and Forest Crops* (VCE revised annually) provides complete listings of insects, insecticides, and management information on timing, insect thresholds, suggested detection and monitoring methods, and cultural and biological control recommendations. Another excellent resource is *Turfgrass Insects of the United States and Canada* (Vittum et al. 1999).

## 8.6.1 Biological Control of Insect Pests

Biological control agents (Table 8-4) should be used whenever practical for insect pests on Virginia golf course turf. In addition, bio-pesticides, such as insect growth regulators (IGR) can be used to control insect populations.

## 8.6.2 Chemical Control of Insect Pests

### 8.6.2.1 Annual white grubs

The two windows for timing an insecticide application to control the larval stage of annual white grubs are spring (April) and summer (mid-July). Unless grub populations are causing noticeable damage, a spring application targeting the overwintering white grub stage is generally not recommended since the third instar (i.e., larval stage) grubs feed only long enough to build fat reserves and other nutrients to pupate. One of the benefits from a spring application, however, is control of the grub stage of black turfgrass ataenius and billbugs. The summer application positions insecticides and insect growth regulators to target the early instar grubs of the new generation. One indirect benefit of preventing these early instars from reaching the third instar stage in late summer is the avoidance of costly sod stripping that otherwise would occur from skunks, raccoons, and crows in turf containing fully mature white grubs preparing to overwinter.

Most insecticides for control of white grubs need ≥ 0.5" of water after application to move the chemical into the thatch layer and to activate the active ingredient. Reducing the thatch layer to ≤ 0.5" (Section 7.3) increases penetration of most turf insecticides.

Some of the newer insecticides claim April – August control of white grubs in addition to other soft bodied insects, such as armyworms and cutworms. Two products are based on dual mode of action insecticides. Another represents a new class of insecticides, with an entirely novel mode of action. Research in Virginia supports this claim for annual white grubs (Youngman, personal statement).

### 8.6.2.2 Armyworms and cutworms

The black cutworm and fall armyworm are two of the more common species infesting golf course greens and fairways. The black cutworm makes a small burrow just beneath the surface of the turfgrass where it rests and feeds within the burrow during the day. On most golf courses, the black cutworm needs to be managed from April to August using either conventional insecticides or a molting hormone mimic. Recent research conducted on North Carolina golf courses has shown promising results for a novel insecticide that provides season-long control of black cutworms. Apparently, the black cutworm moth prefers to lay eggs near the greens in the longer grass; the young larvae then move to the green. Treating the green and one boom-width around the green with a single application provides up to four months control of black cutworms.

Unlike the black cutworm, which is a season-long pest on golf course turf, the fall armyworm is a serious late-season pest that in high numbers chews turfgrass to the ground. Management options and pesticides for the fall armyworm are similar to those described for black cutworm.

### 8.6.2.3 Nuisance and red imported fire ants

Nuisance ants are more typically encountered in the central and western parts of the state, while the red imported fire ant is the primary ant of concern in the southeastern part of Virginia. Fire ant colonies are established throughout the Tidewater area. Individual colonies have been documented in other locations, but are considered to be isolated infestations. The United States Department of Agriculture (USDA) and VDACS implemented the federal and state Fire Ant Quarantines in 2009 in the Tidewater area of Virginia to control the artificial spread of fire ants. For more information on fire ants, VCE publishes a fact sheet[1] (VCE 2010).

As with all insecticides, nuisance ant and fire ant baits provide effective control if applied according to label guidelines. One of the bait products showing promise for controlling ants is a juvenile hormone mimic (IGR). In most cases, it is best to treat at the first sign of mound building in spring, especially when using the dual insecticide products. A follow-up treatment 3-4 weeks later may be needed. In North Carolina, golfers are encouraged to mark any emerging red imported fire ant mound they come across with a flag. This helps the superintendent take care of new mounds in a timely manner.

[1] pubs.ext.vt.edu/444/444-284/444-284.html

## 8.7 Turf Weeds

Weeds are unwanted plants that are unsightly, disrupt playability, harbor pests, and competitively displace desirable turfgrass. Bermudagrass may be a desirable turf on a golf fairway but a serious weed in the neighboring golf rough, tees, or putting greens. Weeds exploit openings in the turfgrass canopy, where seedlings germinate and survive to become a persistent colony of perennials or seed producing annuals.

### 8.7.1 Problem Identification

The first step in any turf weed management program is to identify the problem that limits growth, density, and competitiveness of the desirable turfgrass. A 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. Simply killing weeds is not enough. If the underlying problem that has allowed weeds an opportunity for invasion is not fixed, new weeds will simply invade the area after the current weeds are controlled.

Many of the problems associated with the potential for invasive weeds can be addressed through implementation of the BMPs identified in this document related to turfgrass selection, nutrient management programs, irrigation, and cultural practices. For example, sites that are over-irrigated may have higher densities of weeds, such as green kyllinga or yellow nutsedge (Fig. 8-5), cultural practices, such as mowing height, frequency, and maintenance can also impact turf weed populations. For example, not following the 1/3 mowing rule and mowing too short can open the canopy and provide a competitive advantage to germinating weeds. Because of the importance of soil quality in growing healthy turf, emphasis should be placed on soil testing for the maintenance of turf that can withstand pressure from weeds.

**BMP #4**
Identify problems that limit turfgrass competitiveness for weed control.



Figure 8-5. Yellow nutsedge being controlled by an herbicide application. *Source:* Erik Ervin.

### 8.7.2 Turf Weed Identification

Several weed identification guides are available in printed form and on the internet. The Virginia Tech's Turfweeds.net offers identification images and text on over 200 weeds of Virginia and surrounding areas. Major weeds are listed in Table 8-5. VCE also offers free weed identification and control recommendations though its county agents. Fresh plant samples can be placed in a re-sealable storage bag and mailed to the Virginia Tech Weed Clinic from the County Extension Office.

### 8.7.3 Chemical Weed Control

Section 6 of *Pest Management Guide: Horticultural and Forest Crops* (VCE) lists herbicides labeled for use on professionally managed turf in Virginia and provides tables and guidance for the use of herbicides specifically on putting greens, fairways, and sand bunkers. The tables in the Pest Management Guide include information on relative effectiveness, timing recommendations, and application rates. In addition, BMPs for pesticide management strategies should be followed (Chapter 9).

Weeds in sand bunkers present considerable problems in golf course management. EPTC (Eptam 5G) is used in bunkers. All weed growth must be removed before application. Eptam must be raked into the sand to a 2- 3" depth immediately after application. It does not injure greens when blasted or tracked on the turf by players.

#### 8.7.3.1 Annual grass weeds

Several pre-emergence herbicides control most annual grasses, although goosegrass is more difficult to control than most of the other annual grasses. Pre-emergence herbicides kill seedlings as they germinate and therefore are applied in advance of germination. Midseason to late post-emergent applications for annual grasses are considered to be less desirable than pre-emergent or early post-emergent control. Late post-emergent treatments usually result in turfgrass discoloration and browning of crabgrass foliage. However, early post-emergent treatments can provide excellent control and allow turfgrass to begin to cover during the summer and fall. Some annual grass weeds are notoriously difficult to control. For instance, a manager may succeed in controlling crabgrass, but in

## Table 8-5. Major weeds of Virginia turfgrass

| Category | Species |
|---|---|
| Annual grass weeds | • Smooth crabgrass (*Digitaria ischaemum*)<br>• Goosegrass (*Eleusine indica*)<br>• Foxtail (*Setaria spp.*)<br>• Annual bluegrass (*Poa annua*) |
| Perennial grass weeds | • Bermudagrass "wiregrass" (*Cynodon dactylon*)<br>• Dallisgrass (*Paspalum dilitatum*)<br>• Thin paspalum (*Paspalum setaceum*)<br>• Nimblewill (*Mulenbergia schreberi*)<br>• Roughstalk bluegrass (*Poa trivialis*) |
| Common broadleaves | • Dandelion (*Taraxacum officinale*)<br>• White clover (*Trifolium repens*)<br>• Plantain (*Plantago* spp.)<br>• Chickweed (*Stellaria media*)<br>• Henbit (*Lamium amplexicaule*) |
| Hard-to-kill broadleaves | • Yellow woodsorrel (*Oxalis stricta*)<br>• Ground ivy (*Glechoma hederacea*)<br>• Wild violet (*Viola purpurea*)<br>• Common lespedeza (*Lespedeza striata*)<br>• Dollarweed (*Hydrocotyle* spp.)<br>• Virginia buttonweed (*Diodia virginicus*) |
| Sedges and "grass-like" plants | • Yellow nutsedge (*Cyperus esculentus*)<br>• Annual sedge (*Cyperus compressus*)<br>• False green kyllinga (*Kyllinga gracilima*)<br>• Purple nutsedge (*Cyperus rotundus*)<br>• Star-of-Bethlehem (*Ornithogolum umbelliferum*)<br>• Wild garlic (*Allium vineale*) |

the process allow a difficult weed, such as goosegrass, to grow without competition in the space left by the dying crabgrass weeds. Fenoxaprop, mesotrione, quinclorac, and metribuzin are some common active ingredients used to control annual grasses in certain turfgrasses during late spring and summer.

### 8.7.3.2 Perennial grass weeds

Most perennial grasses are controlled by physical removal or by nonselective chemicals. Undesirable patches or clumps of perennial grasses (such as bermudagrass, fescue, nimblewill, orchardgrass, and quackgrass) can be achieved through nonselective control using glyphosate (Roundup, Kleenup) in the spring or summer during active growth. Glyphosate has no soil residual and reseeding can occur as soon as the foliage has turned brown (7–10 days).

### 8.7.3.3 Common broadleaves

Common broadleaves have a range of susceptibility to chemical controls (*Pest Management Guide: Horticultural and Forest Crops*, VCE). Weeds which are intermediate in response should be given repeat treatment rather than increasing the rate of a single application. Furthermore, broadleaf weeds respond best to herbicides when they are most actively growing and in the seedling stage, usually in the spring and fall. It may sometimes be desirable to treat at times other than the recommended timing. When this treatment is necessary, time applications to coincide with good growing conditions and avoid contact with desirable plants. For example, application of high rates of herbicides during hot dry conditions may brown desirable grasses and therefore should be avoided.

The effectiveness of post-emergence broadleaf herbicides is better when rainfall or irrigation does not occur for 24 hours after application. In addition, combination products may be more effective than individual chemicals on a particular weed.

### 8.7.3.4 Sedges and grass-like plants

For sedges, post-emergent applications of halosulfuron (Sedgehammer) or sulfentrazone (Dismiss) are effective. Apply when sedges are actively growing and turfgrasses are not under stress. Halosufuron is not labeled for golf greens. Repeat applications are usually required for complete control. Bentazon (Basagran) is effective only on yellow nutsedge and will require a minimum of 2 applications, spaced 10 days apart, for control. Imazaquin (Image) , trifloxysulfuron (Monument), sulfosulfuron (Certainty), and flazasulfuron (Katana) are effective for purple

nutsedge, wild onion, and wild garlic control in established bermudagrass; it is not safe on cool-season grasses. A mix of 2,4-D and dicamba applied in spring and fall provides some control of wild garlic and wild onion in cool-season grasses, but should be combined with improvements in fertility to increase turf competitiveness.

### 8.7.4 Plant Growth Regulators (PGRs)

PGRs are used to reduce the amount of mowing needed for maintaining turfgrass. On the golf course, they also improve turf density and color. Further, PGRs are used to selectively suppress *Poa annua* in cool-season greens, tees, and fairways and to reduce seedhead emergence (Figure 8-6 ). Currently available PGRs and some tips for their best use are described in Table 6.24 in Section 6 of *Pest Management Guide: Horticultural and Forest Crops* (VCE).



Figure 8-6. *Poa annua* yellowed by a PGR treatment on a creeping bentgrass green. *Source:* Erik Ervin.

# 9

# Pesticide Management



“Pesticides may be an appropriate control method as part of an IPM strategy.”



# 9 Pesticide Management

The first step in pesticide management is to consider all alternatives to address the pest issue and determine whether using pesticides is the appropriate control method as part of an IPM strategy (Chapter 8). When pesticide use is warranted, confirm that the product is labeled for use on the intended site and that the product controls the target pest. Other features to evaluate include toxicity, chemical and physical product characteristics, site-specific characteristics that influence the potential for fate and transport in the environment, and proper storage and handling methods. If and when pesticides are used, make sure that staff has the knowledge and skills needed to handle and apply pesticides properly. For more information on pesticide management see the most current version of the following VCE publications:

- *Virginia Core Manual: Applying Pesticides Correctly*
- *Turf Pest Control*
- *Pest Management Guide for Horticultural and Forest Crops*

The information presented in the IPM chapter (Chapter 8) provides guidance for selecting appropriate pesticides and timing pesticide applications for specific turf weeds, diseases, and insects. Chapter 4 provides information specific to aquatic weed management. Following maintenance operations BMPs, such as those related to pesticide equipment washing and waste disposal (Chapter 10), is also important to protecting water supplies.

## 9.1 Regulatory Considerations

In any pesticide product, the component that kills or otherwise controls the target pest is called an active ingredient. The product may also contain inert (inactive) ingredients such as solvents, surfactants, and carriers. However, not all inert ingredients are harmless, and these ingredients may be controlled or regulated because of environmental or health concerns.

### Pesticide Management BMPs

**BMP #1**

Select the least toxic pesticide with the lowest exposure potential.

**BMP #2**

Select pesticides that have a low runoff and leaching potential.

**BMP #3**

Consider the impact of site-specific and pesticide-specific characteristics before applying a pesticide and time applications to avoid heavy rain or prolonged irrigation.

**BMP #4**

Minimize off-target drift potential by using properly-configured application equipment and appropriate methods and timing.

**BMP #5**

Store, mix, and load pesticides at least 100 feet away from sites that directly link to surface water or groundwater.

**BMP #6**

Apply pesticides according to label directions, paying careful attention to application site conditions, methods, equipment calibration, and rates specified on the label.

**BMP #7**

Prepare only the amount of pesticide mix needed for the immediate application.

**BMP #8**

Keep records of all pesticide use to meet legal requirements, evaluate pest control efforts, and plan future management tactics.

### 9.1.1 Federal Regulations

EPA regulates pesticide distribution, sale, and use under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and its amendments. Among other requirements, FIFRA prohibits the use of any pesticide inconsistent with its labeling and requires all pesticides used in the U.S. to be registered by EPA. Registration assures that pesticides are properly labeled and that when used in accordance with the label, the pesticides do not cause unreasonable harm to the environment. The use of registered pesticides is dictated by the label, which includes legal application sites and situations. Pesticides classified as restricted use pesticides (RUPs) can only be applied by certified applicators.

A number of other federal regulations impact pesticide users, including the Superfund Amendments and Reauthorization Act (SARA) Title III (42 CFR 103), also known as the Emergency Planning and Community Right-to-Know Act, and the Resource Conservation and Recovery Act (RCRA). In some cases, SARA Title III requires the Local Emergency Planning Committee (LEPC)[1] to be notified of spills.

Any spill that could enter groundwater or surface water must be reported to EPA under the authority of the Clean Water Act. Call VDACS OPS at (804) 371-6561 or the EPA Region 3 office for reporting assistance. If the spill constitutes a reportable quantity, the applicator must notify the National Response Center at (800) 424-8802. State regulations for spill reporting are described in the section below.

### 9.1.2 State Regulations

In Virginia, VDACS OPS enforces the Virginia Pesticide Control Act regulations. VDACS certifies applicators, registers pesticide products, and issues pesticide business licenses in order to permit the safe and effective control of pests. Additionally, applicators must adhere to requirements of a VPDES permit issued by DEQ that covers pesticide discharges to surface waters (See Section 4.1.3).

In Virginia, most occupational pesticide users, including turf managers and their employees, must be certified as either a Registered Technician or a Commercial Applicator. Legal obligations of certified Commercial Applicators in Virginia and a short discussion of each requirement are described below. For more information, consult the latest version of the *Virginia Core Manual: Applying Pesticides Correctly* or the "Regulations and Basic Information: Safe and Effective Use" section of the *Pest Management Guide for Horticultural and Forest Crops*.

1. *Follow the Pesticide Label.* State and federal laws prohibit the use of any pesticide inconsistent with its label. Applicators must read, understand, and follow label directions carefully. Pesticides may not be applied to any site not listed on the product label. Materials may not be applied more often or at rates higher than the label directs. Pesticide applicators are bound to follow all label directions for transport, mixing, loading, application, storage, and disposal of pesticide products and containers.
2. *Adhere to Certification Requirements.* In Virginia, two certification options exist: Registered Technician and Commercial Applicator. Registered Technicians pass an exam which demonstrates that they are able to handle and apply pesticides correctly. Commercial Applicators demonstrate competency in both basic safety (by passing the Commercial Core exam) and category-specific knowledge in one or more areas, including pest identification, pesticide properties, product selection, and category-specific hazards. Decision-makers for pesticide use require this category-specific knowledge and should be certified as Commercial Applicators.
3. *Keep Certificate in Force.* Registered Technician and Commercial Applicator certificates must be renewed every two years. The renewal fee is $30.00 for a Registered Technician and $70.00 for a Commercial Applicator. The renewal fee is waived for federal, state, and local governmental employees and their certificates are renewed automatically, provided they have met recertification requirements.

   All Virginia-certified applicators must participate in an ongoing pesticide education program. At a minimum, Registered Technicians and Commercial Applicators must attend at least one fully approved recertification session per category every two years. Registered Technicians and Commercial Applicators who choose to recertify by re-examination—or who must be examined to reactivate a lapsed certificate—must apply for examination and pay an application fee.
4. *Supervise Employees.* Certified Commercial Applicators must provide on-the-job training, instruction, and supervision of Registered Technicians employed by them or assigned to them by their

[1] DEQ maintains a list of LEPCs at www.deq.state.va.us/sara3/lepc.html.

employer. Registered Technicians may use Restricted-Use Pesticides (RUPs) only under the direct supervision[1] of a Commercial Applicator. Commercial Applicators are responsible for the work of Registered Technicians under their supervision, and must provide these Registered Technicians with clear, specific instructions on all aspects of pesticide use. A Registered Technician may apply general-use pesticides unsupervised. Uncertified persons may apply pesticides commercially while in training to become Registered Technicians only when under the direct, onsite supervision (with constant visual contact) of a certified Commercial Applicator.

5. *Handle Pesticides Safely*. Unsafe use, handling, storage, and disposal practices can be cited under the Virginia Pesticide Control Act enforcement regulations (2 VAC 20-20-10 through 20-220). VDACS OPS conducts site inspections; Appendix G provides a description site inspections. The enforcement regulation also requires that containers other than the original registrant's or manufacturer's containers used for the temporary storage or transportation of pesticide concentrates or end-use dilutions must have abbreviated labeling for identification. The most recent edition of the Virginia Core Manual or the PMG provides additional details.
6. *Keep Accurate Records.* Virginia regulations require Registered Technicians and Commercial Applicators to record all pesticide applications and maintain application records for two years. No specific form or format is required, but records must contain the information listed below and presented in a sample recordkeeping form in Appendix H:
   - name, address, and telephone number of the property owner, and address or location of the application site, if different
   - name and certification number of the person making or supervising the application
   - date of application (day, month, and year)
   - type of plants, crop, animals, or sites treated
   - principal pests to be controlled
   - acreage, area, or number of plants or animals treated
   - identification of pesticide used: brand name or common name of pesticide and its EPA product registration number
   - amount of pesticide concentrate and amount of diluent (such as water) applied by weight or volume, to the area or sites treated
   - type of application equipment used

   This list describes the minimum recordkeeping required by law. Recording additional data about pesticide application can also inform IPM strategies (Section 9.8).
7. *Report Pesticide Accident*. Any pesticide accident or incident that constitutes a threat to any person, to public health or safety, or to the environment must be reported to VDACS OPS. Initial notification must be made by telephone within 48 hours of the occurrence. If required, a written report describing the accident or incident must be filed within 10 days of the initial notification. Accidents or incidents involving spills may also have reporting requirements under SARA Title III. In some cases, LEPCs must be notified of pesticides spills. In the event of an emergency release that could harm other people or property, the Virginia Emergency Response Council (VERC) at the Virginia Department of Emergency Management (VDEM) Operations Center, (800) 468-8892, must be notified. Emergency response procedures are provided in Section 9.6. Guidance for spill kits is provided in Appendix I.

### 9.1.3 Local Regulations

Depending upon the type and quantity of products stored, local ordinances may influence storage location or require fire department inspection. If not required, local emergency responders should be notified of the pesticide storage area location (See Chapter 10 for more information). Additionally, local governments regulate and dictate the required code and methods for backflow prevention. Backflow prevention requirements are discussed in more detail in Section 3.1.5.

[1] The supervising Commercial Applicator must either be physically present or be where the Registered Technician may contact the supervising Commercial Applicator by telephone or radio.

## 9.2 Human Health Risks

Human health risks associated with pesticides are related to pesticide toxicity and exposure levels. To manage toxicity, pesticide usage should be minimized as part of an IPM strategy (Chapter 8) and the least toxic, but effective pesticide selected. Exposure can be limited through good work habits, engineering controls (when possible), and protective clothing.

**BMP #1**
Select the least toxic pesticide with the lowest exposure potential.

### 9.2.1 Pesticide Toxicity

Pesticides vary greatly in toxicity, and toxic effects may be acute or chronic. The acute toxicity of a chemical is expressed in terms of lethal dose to 50% of a population of test animals ($LD_{50}$), based on the amount of pesticide ingested or absorbed per unit of body weight. Therefore, the higher the $LD_{50}$ value, the less acutely toxic the chemical. $LD_{50}$ values are usually expressed as milligrams/kilogram of body weight. For example, a chemical with an $LD_{50}$ of 5,000 mg/kg requires about 0.2 ounce of the chemical per pound of body weight to reach the $LD_{50}$ value. In this example, the value for a 150-pound person is about 12 ounces.

Pesticide labels do not provide $LD_{50}$ information; consult the Pesticide Material Safety Data Sheets (MSDS) $LD_{50}$ information for end-use formulated products. Labels provide other useful information related to toxicity (such as signal words), restricted versus general use classification, personal protective equipment (PPE) requirements, restricted-entry intervals, active ingredient concentrations, and any precautions or instructions. Typical precautions and instructions include first aid, toxicity to nontarget organisms including humans and domestic animals, physical or chemical hazards (for example, "eye irritant"), and engineering control requirements.

### 9.2.2 Acute and chronic toxicity

Acute toxicity refers to a single exposure by mouth, skin, or inhalation, or repeated exposures over a short time. Signal words (such as DANGER) are provided on pesticide labels to indicate acute toxicity of both active and inert ingredients (Table 9-1). Signal words may also denote whether the pesticide is caustic (burns) or causes eye irritation or damage. In addition to signal words, the word POISON and the skull and crossbones symbol must be displayed on labels of products that are acutely toxic by oral, dermal, or inhalation exposure (Table 9-1).

Chronic toxicity effects are associated with long-term exposure to lower levels of a toxic substance, such as ingestion in drinking water. Signal words do not indicate the risk of chronic effects.

### 9.2.3 Managing Human Exposure to Pesticides

Exposure can be managed by practicing good work habits, using engineering controls whenever possible (such as closed-loading, water-soluble packaging), and wearing PPE. Pesticide labels provide minimum PPE requirements, which must be followed according to federal and state requirements (Section 9.1) and put on before opening pesticide containers. Different handling activities require different PPE. The use of additional PPE may be warranted based on labeled human hazard warnings, application situation and site, and common sense. For example, overhead applications or treating an area with handheld application equipment may warrant using additional PPE.

## 9.3 Environmental Fate and Transport

When applying pesticides, the goal is to select and apply a product that reaches the target and remains long enough to control the pests before degrading into harmless compounds in the soil, air, or water. Understanding the environmental fate of a pesticide allows the applicator to select an effective product with minimal risk of causing environmental problems. The characteristics of a pesticide, how it is applied, its application rate, and site-specific conditions determine the fate of a pesticide in the environment. Transport is affected by organisms and environmental media: air, soil, and water.

**BMP #2**
Select pesticides which have a low runoff and leaching potential.

When applied properly, a pesticide is directed to and absorbed or taken up by the target. For example, foliar-applied sprays are absorbed by plant leaves. Soil-applied pesticides may be taken up by plant roots. Once in plant tissue, pesticides may be broken down. Alternatively, they may remain intact in the plant, in which case they may impact the environment, depending on how long they persist and what is done with the treated plant material. In turf, thatch can prevent pesticides from reaching their intended target (such as white grubs), thus reducing pesticide efficacy.

## Table 9-1. Label signal words and toxicity information

| Signal Word & Symbol | Toxicity Level & Class | Oral $LD_{50}$ (mg/kg) | Dermal $LD_{50}$ (mg/kg) | Inhalation $LD_{50}$ (mg/l) | Contact Injury Concern | Toxicity Concern |
|---|---|---|---|---|---|---|
| DANGER-POISON | Highly toxic, Hazard Class I | Trace - 50 | Trace - 200 | Trace - 0.2 | Signal word based on oral, dermal, and/ or inhalation toxicity | A very small dose could kill a person (a few drops to 1 teaspoon) |
| DANGER | Highly toxic or hazardous in some manner, Hazard Class I | Trace - 50 | Trace - 200 | Trace - 0.2 | Corrosive: permanent or severe skin, eye, or respiratory damage | Based on the corrosive or irritant properties of the product |
| WARNING | Moderately toxic, Hazard Class II | 50 - 500 | 200 - 2,000 | 0.2 - 2 | Moderate skin, eye, or respiratory damage | Small to medium dose could cause death, illness, or skin, eye, or respiratory damage (1 teaspoon to 1 ounce) |
| CAUTION | Slightly toxic, Hazard Class III | 50 - 5,000 | 2,000 - 20,000 | 2 - 20 | Mild skin, eye, or respiratory irritation | Medium to large dose could cause death, illness, or skin, eye, or respiratory damage (1 ounce to 1 pint or 1 pound) |
| CAUTION (or no signal word) | Hazard Class IV | > 5,000 | > 20,000 | > 20 | Slight concern for skin, eye, or respiratory injury | Slight to none (over 1 pint or 1 pound) |

Pesticides that miss the target (or persist in plant tissue) break down due to the action of sunlight, microorganisms, and a variety of chemical and physical reactions. The rate of degradation is affected by the physical, chemical, and biological characteristics of the pesticide as well as environmental conditions. Pesticides that persist in the environment may transfer due to leaching, runoff, or drift.

Whether pesticides hit or miss the target, nontarget organisms such as earthworms, honeybees, and other beneficial arthropods and microorganisms may take up pesticides by ingestion or absorption. Pesticide labeling requirements identify hazards to nontarget organisms and appropriate precautions for avoiding such exposures. Unintended, large-volume releases can cause significant

environmental impacts (such as fish kills) or human health impacts. Most pesticides that bioaccumulate in animal tissues are no longer used in the United States, although some remain present in the environment.

## 9.3.1 Pesticide Characteristics

The pesticide properties that affect environmental fate are volatility, solubility, adsorption, and persistence.

### 9.3.1.1 Volatility

Some pesticides volatilize readily, which means that they transform from a solid or liquid form into a gas, allowing them to move into the atmosphere. Volatility is influenced by environmental conditions, such as temperature, relative humidity, and air movement. High temperatures and low humidity increase evaporation rate. The level of a pesticide's volatility may be indicated on the label.

### 9.3.1.2 Solubility and Adsorption

Solubility is the measure of an active ingredient's ability to dissolve in water at room temperature, expressed in mg/L (ppm). Solubility is a fundamental physical property of a chemical; the higher the solubility value, the more soluble the pesticide. Once in the soil, pesticides vary in how tightly they are adsorbed to soil particles. The partition coefficient ($K_{oc}$) takes into account the pesticide's solubility and adsorption characteristics and is the ratio of pesticide concentration in the bound to soil particles (adsorbed-state) and dissolved in the soil-water (solution-phase). The higher the $K_{oc}$ value, the stronger the compound's tendency to attach to soil and move with soil. Pesticides with $K_{oc}$ values > 1,000 indicate strong adsorption to soil. Pesticides with lower $K_{oc}$ values (<500) tend to move more with water rather than to be adsorbed to soil. The sorption properties of thatch can also influence pesticide mobility into the soil. However, little information on thatch sorption of pesticides is available.

### 9.3.1.3 Persistence

The rate of pesticide breakdown in the environment is affected by a number of processes, such as exposure to light (photodegradation), chemical reactions in the soil (chemical degradation), or the action of soil microbes or other organisms (biodegradation). Pesticides vary in their degradation rates depending upon their chemical structures. Degradation rates are expressed in terms of half-life, which is the number of days it takes for the concentration of a pesticide in soil to be reduced by one-half.

The half-life value for a pesticide is a lumped parameter that includes the net effect of volatilization; photo, chemical, and biological degradation; and hydrolysis (break down in water). Half-life values are an approximation and may vary because persistence is influenced by a number of site-specific variables such as soil type, temperature, and pH.

## 9.3.2 Pesticide Transport

Some pesticides are more likely than others to move offsite, due to their volatility, solubility, adsorption, or persistence. For example, volatile pesticides are prone to drift, and highly water-soluble pesticides are more likely to move into groundwater. These characteristics have implications for fate and transport in the environment and the potential for environmental impacts. Offsite transport may occur through leaching, lateral/laminar runoff in solution, movement with and attached to eroded soil particles, or drift.

**BMP #3**

Consider the impact of site-specific and pesticide-specific characteristics before applying a pesticide and time applications to avoid heavy rain or prolonged.

In general, pesticides that are less soluble, readily adsorb to soil particles, and are not persistent in the environment typically pose less of a concern for surface water and groundwater contamination. Pesticide labels include environmental hazard statements related to a pesticide's chemical characteristics under the heading "Precautionary Statements". Pesticide labeling does not usually provide solubility, adsorption, and persistence values. This information is available from a number of other sources, including the following: VCE, OSU Extension Pesticide Properties Database[1], Pesticide Information Profiles[2], trade associations, pesticide dealers, and pesticide registrants. Finally, the pesticide's MSDS includes water solubility information for the formulated pesticide product.

[1] http://npic.orst.edu/ingred/ppdmove.htm
[2] http://extoxnet.orst.edu/pips/ghindex.html

### 9.3.3 Estimating Pesticide Loss Due to Pesticide Characteristics

The chemical properties of volatility, water solubility, adsorption ($K_{oc}$) and persistence (half-life) must be considered together to estimate pesticide loss (Table 9-2). For example, depending on site conditions, a nonvolatile, persistent pesticide with high solubility is likely to leach or move offsite in solution as runoff. One with a high adsorption coefficient ($K_{oc}$) is more likely to move with eroded soil particles. For nonpersistent pesticides, movement offsite through surface runoff or leaching to groundwater depends primarily on whether heavy rain or irrigation occurs soon after application. Pesticides with high to intermediate adsorption values and short half-lives are typically not readily leached, degrade fairly rapidly, and therefore may have the least potential to impact water quality. Quantitative prediction of pesticide loss via runoff and leaching requires computer models analyzing a number of variables, such as soil type, application rates, and the frequency and duration of rain or irrigation following application.

#### Table 9-2. Effect of pesticide chemical characteristics in determining contamination potential

| $K_{oc}$ | Half-life | Transport Mechanism | Water Quality Impact |
|---|---|---|---|
| Small | Long | Leaching | Groundwater |
| Small | Short | Leaching | Groundwater* |
| Large | Long | Runoff | Surface water |
| Large | Short | Runoff | Surface water* |

** following heavy rain or irrigation events shortly after application*

*Source:* Adapted from Rao et al. 1983.

### 9.3.4 Site Characteristics

Properties of the application site also influence environmental fate and transport. Significant features are soil/substrate characteristics, proximity to surface water, and depth to groundwater.

#### 9.3.4.1 Soil Characteristics

The major soil characteristics that affect the fate and transport of pesticides are texture, permeability, and organic matter content (Table 9-3). Soil texture indicates the relative proportions of sand, silt, and clay in the soil. Soil permeability is a measure of the ability of air and water to move through soil and is influenced by the size, shape, and continuity of the pore spaces. Soil organic matter is any material produced originally by living plants or animals that is returned to the soil and goes through decomposition; the amount of organic matter in the soil influences the amount of water it can hold.

#### 9.3.4.2 Surface Water

#### Table 9-3. Relationship of soil characteristics to fate and transport

| Soil Characteristic | Relationship to Fate and Transport |
|---|---|
| Texture | Coarse, sandy soils generally allow water to pass through rapidly. Finer textured soils generally slow the downward movement of water and may also contain more clay (and sometimes organic matter) to which pesticides may adsorb. |
| Permeability | Sandy soils are more permeable than clay and silt soils. Compacted soils slow the downward movement of water. |
| Organic matter content | Soils with more organic matter can slow down or stop the movement of water. Water may move through bare soils more rapidly than soil with vegetative or mulch cover. |

Pesticides may reach surface waters via several transport mechanisms, such as:

- surface runoff following precipitation events or irrigation
- spray or vapor drift that settles on surface waters
- adsorbed on eroded soil that reaches surface waters

The probability of pesticides reaching surface waters is influenced by site-specific and pesticide-specific characteristics (Table 9-2), the potential for drift, and timing of application. The use of vegetated buffers is the single most important strategy for avoiding pesticide runoff into surface waters (see design BMPs, Section 2.3.2, and surface water management BMPs, Section 4.2.3).

In addition, the following practices should be followed to avoid the potential for surface water contamination:

- Identify and protect sensitive areas.
- Do not apply pesticides under conditions conducive to spray or vapor drift.
- Do not apply pesticides to turf where saturated soil conditions exist because saturated soils have reduced infiltration rates.
- Avoid application on steep slopes, which increase the rate of stormwater runoff.
- Do not allow irrigation water containing pesticides to flow into waterways.
- Do not compost or use clippings with pesticide residues as mulch near surface waters.

The timing of pesticide applications is influenced by weather and irrigation scheduling. Prolonged heavy rain or irrigation may cause excess water to remain on the soil surface, especially in saturated soils or soils with low infiltration rates, and can lead to surface runoff. If heavy rain is likely, outdoor handling operations should be delayed (such as mixing, loading, application, and disposal).

### 9.3.4.3 Groundwater

Pesticides can reach groundwater by leaching or can be transported directly through sinkholes and permeable rock. Pesticides can be transported to groundwater (the saturated zone) after moving with water through the vadose zone (the unsaturated zone). Leaching potential depends on:

- the pesticide's chemical characteristics (solubility, adsorption, and persistence)
- soil characteristics (texture, permeability, and organic matter content)
- groundwater recharge rates (rate at which precipitation or irrigation water reaches the saturated zone)

The depth to the water table (the top of the saturated zone) affects the length of time required for a pesticide to move through the vadose zone before reaching groundwater. Consequently, areas with shallow water tables (shorter travel distance through the vadose zone) are more vulnerable to groundwater contamination from pesticides. The depth to the water table can vary seasonally, and generally is closest to the surface in spring and fall. Drought, seasonally dry conditions, and groundwater withdrawal for irrigation can lower the water table in summer.

The permeability of geological layers between the soil and groundwater is also important. For example, gravel deposits are highly permeable and allow any soluble pesticides to move rapidly downward to groundwater. Porous sandstone substrates allow pesticides in solution to pass through rock layers and reach groundwater. Conversely, clay deposits are almost impermeable and may prevent most water and any dissolved pesticides from reaching the groundwater.

Site-specific and pesticide-specific characteristics (Table 9-2), and timing of application influence the potential for pesticides to reach groundwater. For example, finer textured soils, compacted soils, and soils with higher organic matter content generally slow the downward movement of water (Table 9-4). In sandy soils, the use of pesticides with high water-solubility is not recommended, due to the increased rate of percolation. For any pesticide, including those that are nonpersistent (i.e., those with a short half-life), irrigation or heavy rains soon after pesticide application increase the chances of groundwater impacts.

Pesticides may also be transported more directly to groundwater through sinkholes, with little time for degradation processes to breakdown the pesticide. Sinkholes may be present in areas with karst topography. Karst topography is characterized as regions of carbonate bedrock (limestone and dolomite) that come into contact with, and are dissolved by, water creating systems of underground caverns and fissures. Sinkholes form when the bedrock and soils collapse. In Virginia, karst topography occurs within the Valley and Ridge physiographic province of western Virginia and is also found in limited areas in Virginia's Blue Ridge, Piedmont, and Coastal Plain physiographic provinces.

Pesticides should not be applied in areas that drain into sinkholes, because even a moderate rain or irrigation can carry the pesticide directly to the groundwater. NRCS provides valuable information on the geology of an area, including sinkholes formations and potential.

### 9.3.5 Pesticide Loss Due to Drift

Pesticides may move away from application sites in air as dry particles, liquid spray droplets, or vapors in a process known as drift.

#### 9.3.5.1 Particle Drift

Particle drift is the offsite movement of spray droplets (or dry particles) during application. Particle drift is not product specific, although the type of formulation, surfactant (for liquid applications), or other characteristics of the pesticide may affect spray drift potential and distance. For example, dry, lightweight particles such as dusts are easily carried offsite by moving air, while granules and pellets are much heavier, settle quickly, and are much less likely to drift. For liquid sprays, drift distance is significantly affected by droplet size (Table 9-4).

**Table 9-4. Drift distance (water droplets)**

| Droplet Size Classification | Microns | Drift (feet)* |
|---|---|---|
| Extremely coarse | 600 | 0.20 |
| Very coarse | 500 | 0.30 |
| Coarse | 400 | 0.49 |
| Medium | 300 | 1.28 |
| Fine | 200 | 4.89 |
| Very fine | 100 | 24.84 |
| Ultra fine | 50 | 44.72 |

* Conditions: drop distance 3 ft, wind speed 5 mph, relative humidity 75%, air temperature 75°F; spray pressure 30 psi

*Source:* Ozkan 2005.

To avoid spray drift, carefully consider equipment selection (nozzle selection for liquid sprays), equipment operation (application rates, volumes, release height), and weather (winds, temperature, and humidity). Nozzle selection includes consideration of the target disease or organism, the application site, the amount of overlap desired, and desired droplet size (Shepard et al. 2006). For example, drift may be more an issue for fairways than for greens because the HOC of the turfgrass is higher and the area to be treated larger. A nozzle should be selected that delivers a droplet size that meets treatment goals (such as foliage coverage versus crown penetration), delivers a spray volume that provides adequate and uniform coverage, and reduces the potential for drift (VCE 2009c). In general, application rates and volumes that produce small (Fine-Very Fine) droplets should be avoided. When complete coverage is necessary and small droplets must be applied, precautions should be taken to manage drift.

Spray droplet sizes that are too large may not provide adequate coverage needed to control certain diseases (Shepard et al. 2006), requiring additional applications for pest control. Light and steady winds favor pesticide applications; days with strong winds or gusts should be avoided. Low relative humidity and/or high temperatures can increase drift by reducing the spray droplet size through water carrier evaporation. Temperature inversions can increase the risk of drift when air layers mix following an inversion. Labels may have product-specific instructions related to droplet size, nozzle selection, and regulating pressure—as well as restrictions on environmental conditions during and following application.

Tactics to reduce spray particle drift include the following:

- Select a nozzle that produces coarser droplets without sacrificing the efficacy of the pesticide.
- Increase application volume by using larger capacity nozzles.
- Operate at the lower end of the nozzle's effective pressure range.
- Reduce release height.
- Spray when winds are light (3–10 mph and steady).
- Spray when wind is moving away from sensitive crops or areas.

#### 9.3.5.2 Vapor Drift

Vapor drift is associated with a pesticide's volatility. It occurs when a pesticide's active ingredient evaporates. The potential for vapor drift is product specific. Ester formulations tend to have greater volatility potential, while amine formulations have virtually no volatility.

Turfgrass pesticides with known volatility should be avoided. In some cases, the pesticide label may indicate

**BMP #4**

Minimize off-target drift potential by using properly-configured application equipment and appropriate methods and timing.

low volatility. However, low volatility does not mean that a chemical will not volatilize under conducive conditions, such as high temperatures or low relative humidity.

Tactics to reduce vapor drift include the following:

- Choose nonvolatile formulations.
- Do not spray in hot, dry conditions.
- Do not spray when the air is very calm to avoid temperature inversions.

## 9.4 Pesticide Transport, Storage and Handling

Concentrated pesticides must be stored and handled appropriately to avoid unintended releases that may harm people and the environment. Pesticide handling and storage is enforced under the Virginia Pesticide Control Act (Section 9.1.3).

### 9.4.1 Pesticide Transport

The safest way to transport pesticides is secured in the back of a truck, preferably in a locked compartment or enclosed cargo box. Steel or plastic-lined beds are the easiest to clean if a spill occurs. Before loading, containers should be inspected to ensure that all caps, plugs, and other openings are tightly closed, and no pesticides are present on the outside of containers. Pesticide labels should be intact, undamaged, and readable. Packing or shipping containers provide extra cushioning. Paper and cardboard containers should be protected from moisture. Containers should be handled carefully to avoid rips or punctures. In case of spills, drivers must know emergency response procedures (Section 9.6).

A number of recommended practices apply to the transportation of pesticides, including the following:

- Avoid extreme temperatures (very high or very low air temperatures).
- Do not transport pesticides in the passenger section of a vehicle.
- Place pesticides where they will not come in contact with food, clothing, or other things that people or animals might eat or touch.
- Transport highly volatile pesticides separately from other chemicals.
- Never leave pesticides unattended in an unlocked trunk compartment.
- Follow labeling requirements for containers used for the temporary storage or transportation of pesticide concentrates of end-use dilutions (2 VAC 20-20-210).
- Keep application equipment in good working order: calibrated to dispense the proper amount of material, leak proof, fitted with cutoff valves, and properly labeled.

### 9.4.2 Pesticide Storage

In choosing a location for a pesticide storage facility, consider ease of access and security and follow any local requirements that apply (Section 9.1.3). Ideally, the storage area should be sited near the mixing and loading work site and equipment cleaning area or pad. The storage area should be located where only authorized people have access. Pesticide storage facilities should also be located at least 100 feet from wells, springs, sinkholes, and other sites that directly link to groundwater. This buffer distance prevents groundwater contamination from floods, runoff, or firefighting water.

At a minimum, a storage area should be secure, dry, well-lit, well-ventilated, protected from extreme heat and cold, well organized, and laid out so that pesticides may be stored properly (for instance, separate areas for herbicides, fungicides, insecticide; large containers on lower shelves; and bags placed where they will not tear or decompose). Recommended features include impervious shelving; a continuous, sealed floor; secondary containment; and a sump. Spill cleanup materials should be kept in or near the storage facility (See Appendix I for a list of spill kit materials). An eyewasht and access to clean water should be nearby. A sloped entrance/exit ramp allows the use of wheeled handcarts for moving material in and out of the storage area safely. Prefabricated storage cabinets and buildings are available that are well-designed and can be moved or sold.

A warning sign and emergency contact information should be displayed in a prominent place. PPE should be available but stored outside the pesticide storage area. An inventory of all pesticides and an MSDS for each product should be available and accessible in case of emergency.

Best practices for pesticide storage include the following:

- Mark containers with date of purchase.
- Use older chemicals first.
- Consult inventory when planning and before making purchases.

- Update inventory after pesticide purchase and use.
- Identify and keep a separate inventory of unwanted or unusable materials and store separately from usable pesticides and other materials.
- Conduct routine inspections of the storage area and building.
- Identify container damage or deterioration, which indicates that a product may no longer be effective or a leak may result.

### 9.4.3 Pesticide Mixing and Loading

Backflow prevention devices are required in Virginia when mixing or loading pesticides (see Section 3.1.5). Pesticides should be prevented from back-siphoning into water sources by keeping the water pipe or hose well above the level of the pesticide mixture. An air gap prevents contamination of the hose and keeps pesticides from back-siphoning into the water source. When pumping water directly from the source into a mix tank, a check valve, anti-siphoning device, or backflow preventer to prevent back-siphoning must be used in case of pump failure.

Whenever possible, mixing and loading sites should be located at least 100 feet from surface water, direct links to groundwater, and drains to prevent releases from spills, leaks, and overflows. If located near a water source, methods such as dikes, sump pits, and containment pads should be used to keep pesticides from reaching the water. Pesticide containment can be best achieved by the use of a properly designed and constructed chemical mixing center (CMC). CMCs feature an impermeable lined or sealed concrete pad and a liquid-tight sump for liquid recovery. Disposal of liquids and sediments from the pad and sump should follow proper disposal procedures (Section 9.5.5). More information on CMCs is available in *Designing Facilities for Pesticide and Fertilizer Containment* (MidWest Plan Service 1995).

**BMP #5**
Store, mix, and load pesticides at least 100 feet away from sites that directly link to surface water or groundwater.

### 9.4.4 Pesticide Application

As discussed previously, site-specific and pesticide-specific characteristics of the pesticide should be considered as part of the pesticide selection process, as well as the timing of the application to avoid potential for drift, runoff, or leaching. Pesticide application recommendations, including label requirements, should be followed to protect human health and the environment; pesticides should never be over applied, which is both illegal and increases the risk of pesticide reaching surface water or groundwater. To ensure proper application rates, application equipment should be calibrated at the start of every spray season and monthly during that period. The equipment should be checked daily when in use (including visual confirmation of nozzle delivery), and when any part (such as the nuzzle or pump) is replaced or repaired.

**BMP #6**
Apply pesticides according to label directions, paying careful attention to application site requirements, methods, equipment calibration, and rates specified on the label.

Checklists are helpful for review before handling pesticides. A sample checklist is provided in Appendix J.

### 9.4.5 Pesticide Waste Minimization and Disposal

The best strategy for dealing with unwanted pesticides is to minimize or eliminate them by buying only enough pesticide for one season, calibrating equipment correctly, mixing only the amount of pesticide needed per application, and selecting pesticides that are easy to measure or ready to use.

Disposal options for unwanted or unusable concentrate or product include:

- legal use
- valid label disposal directions
- return to point-of-sale or manufacturer/registrant
- indemnification
- professional waste disposal firm
- local, state, or federal waste disposal program
- indefinite proper storage

Excess mix may be applied to a selected site following all label directions (including rate, number, frequency, and timing of applications).

**BMP #7**
Prepare only the amount of pesticide mix needed for the immediate.

Rinsate can be used as a diluent for another batch of finished spray mix or applied to a labeled site following all label directions.

Pesticide container management can reduce leftover packaging. Minimizing container disposal efforts can be achieved by the following practices:

- choosing low-rate products (which reduces container volume)
- selecting products packaged in a manner that eliminates the need for container disposal (such as water-soluble packaging)
- using returnable/refillable containers
- recycling or reconditioning containers
- choosing products packaged in containers that can be disposed of legally and conveniently

Unused pesticides, pesticide containers, equipment wash water, and container rinsate should be disposed of properly. For details about proper container rinsing (triple-rinsing and jet rinsing), see the Virginia Core Manual: *Applying Pesticides Correctly*.

## 9.5 Emergency Preparedness and Spill Response

Golf course personnel should be trained to follow the golf course emergency response plan before an emergency occurs. Emergency preparedness includes having appropriate and readily accessible PPE, MSDSs on all pesticides used and stored onsite, and reporting notification information. In the case of an emergency, call CHEMTREC at (800) 424–9300. CHEMTREC is a service of the Chemical Manufacturers Association and can provide emergency response information. An example checklist of spill kit materials is provided in Appendix I.

Following an accidental release, spills should be controlled, contained, collected, and stored, as follows:

- **CONTROL** actively spilling or leaking materials (for example, by setting the container upright, plugging leaks, or shutting the valve) using the appropriate PPE as indicated on the label.
- **CONTAIN** the spilled material. Barriers and absorbent material should be used for liquids. For dusts, the material should be misted to avoid drift. Containment is usually not necessary for granules and pellets.
- **COLLECT** spilled material, absorbents, and leaking containers. These items should be placed in a secure and properly labeled container.
- **STORE** the containers before applying as a pesticide or disposing of properly (Section 9.5.5).

Small liquid spills may be cleaned up by using an absorbent such as cat litter or mulch, diluting with soil, and then applying the soil and absorbent as a pesticide in accordance with label instructions or disposing as a waste. Solid materials can be swept up and reused.

## 9.6 Additional Pesticide Recordkeeping Elements to Support an IPM Program

In addition to recordkeeping as required by Virginia regulation (Section 9.1.2), additional information increases the effectiveness of pesticides usage as part of an IPM program, such as:

- stage of development of the treated turfgrass or plant material
- life cycle stage of target pest
- severity of infestation
- beneficial species present
- site conditions, such as air temperature, relative humidity, wind speed and direction, rainfall (date, amount), and soil moisture level
- other pertinent environmental conditions, such as: recent previous attempts to control, basis of selection for treatment(s), and results
- pesticide manufacturer, formulation, percent active ingredient, and EPA Establishment Number

The EPA Registration number, a required recordkeeping data element, is product-specific and identifies a product's manufacturer, formulation, and concentration. The EPA Establishment number identifies where and when a product was manufactured and is important in case of a product recall and when reporting efficacy problems.

Customized records with added data elements as part of an IPM program provide the following advantages:

- allow assessment of a number of factors that can improve the efficacy of future management strategies
- predict the occurrence of future pest problems and results of applied controls
- develop more accurate pest management budgets
- minimize pesticide use and costs while maximizing pest control efficiency
- reduce pesticide inventory and storage requirements
- provide proof of label and compliance

**BMP #8**

Keep records of all pesticide use to meet legal requirements, evaluate pest control efforts, and plan future treatments.

# 10

# Maintenance Operations





"Simple steps can help streamline waste disposal and prevent pollution."

# 10 Maintenance Operations

Maintenance operations on golf courses include a variety of activities, such as equipment fueling and maintenance; equipment washing, storage, and repair; mixing and loading of fertilizers and pesticides; and handing wastes generated by maintenance activities. These activities may use numerous chemicals, such as petroleum products, pesticides, fertilizers, solvents, and degreasers. An unintended release of any of these products can harm human health or the environment, so follow recommended maintenance operation procedures at all times. Additionally, the discharge or disposal of water from these maintenance activities (such as wash water or rinse water) must follow best practices to avoid contaminating surface or groundwater.

Waste reduction and pollution prevention initiatives can help to streamline the storage, handling, and disposal requirements for maintenance operations. A waste stream analysis can identify opportunities for waste reduction and pollution prevention. Simple steps can also help streamline waste disposal and prevent pollution, such as using only water to wash equipment or using nonphosphate detergents when detergents are required. Reducing the use of chemicals whenever possible also reduces the handling associated with waste disposal. Finally, innovative technologies such as recycling systems for equipment washing areas can not only reduce discharges but also conserve water.

### Maintenance Operation BMPs

**BMP #1**

Store and handle all chemicals appropriately using secondary containment as required.

**BMP #2**

Store fertilizers and pesticides separately and away from other chemicals.

**BMP #3**

Store pesticide and fertilizer application equipment in covered areas to protect from rainfall.

**BMP #4**

Remove grass from grass-covered equipment before washing.

**BMP #5**

Dispose of or recycle wash water appropriately and never discharge to surface waters or septic systems.

**BMP #6**

Store wastes separately and dispose of according to legal requirements.

## 10.1 Regulatory Considerations

A number of federal, state, and local regulations apply to maintenance facilities and operation to protect human health and the environment. Additional regulations, such as the Clean Water Act may apply, depending upon site-specific operations.

### 10.1.1 Federal

#### 10.1.1.1 Hazardous waste

Hazardous wastes are regulated by EPA under RCRA. Hazardous waste has properties that make it dangerous or potentially harmful to human health or the environment. These wastes could include some chemicals used in golf course maintenance operations such as solvents and pesticides. In Virginia, DEQ has implemented a hazardous waste program and therefore has primary responsibility for enforcing hazardous waste regulations. Hazardous waste releases may be regulated under SARA Title III (42 CFR 103), also known as the Emergency Planning and Community Right-to-Know Act, depending upon the chemical hazard and the volume released.

#### 10.1.1.2 Worker safety

OSHA regulations that apply to the use of regulated chemicals must be followed to protect worker health and safety. OSHA also requires appropriate signage, such as hazardous waste signs and pesticide warning signs.

#### 10.1.1.3 Underground storage tanks

EPA regulates underground storage tanks (USTs) under the Technical Standards and Corrective Action Requirements for Owners and Operators of USTs (40 C.F.R. Part 280). EPA has delegated the UST Program to Virginia, which allows DEQ to enforce the federal regulations for EPA.

#### 10.1.1.4 Pesticide Regulations

EPA regulates pesticide distribution, sale, and use as discussed in Section 9.1.

### 10.1.2 State

#### 10.1.2.1 Fuel storage tanks

Virginia DEQ's Tank Compliance Program regulates USTs and aboveground storage tanks (ASTs). Guidance is available from DEQ to assist with regulatory compliance (DEQ 2001)[1].

USTs are regulated in Virginia under two regulations: the Technical Standards and Corrective Action Requirements Regulation (9 VAC 25-580-10 et seq.) and the Petroleum UST Financial Responsibility Requirements Regulation (9 VAC 25-590-10 et seq.) Some differences exist between the federal UST regulation and Virginia's UST regulations; state regulations are sometimes more stringent or implemented differently from the federal regulations (DEQ 2001). For example in Virginia, tank owners and operators are required to show that they have complied with the Uniform Statewide Building Code by obtaining a permit issued by the local code official and any required inspections for UST installation, upgrade, repair, or closure.

Aboveground storage tanks (ASTs) are regulated in Virginia under the Facility and Aboveground Storage Tank (AST) Regulation (9 VAC 25-91-10 et seq). Other state laws apply to ASTs and are included in the statewide building and fire codes, which local code officials administer.

#### 10.1.2.2 Hazardous waste

Virginia hazardous waste management regulations closely follow federal standards established under RCRA and require permits for transportation, storage, treatment, and disposal of hazardous wastes.

#### 10.1.2.3 Pesticide regulations

VDACS OPS enforces the Virginia Pesticide Control Act (2 VAC 20) and regulations as discussed in Section 9.1.2.

### 10.1.3 Local

Local building and fire codes should be reviewed with respect to the siting, construction, and operation of maintenance facilities, such as fueling areas and pesticide storage areas. In addition, USTs in Virginia must be permitted by the local code official and inspected as required. Finally, any discharges to sanitary sewer systems require a permit from the local wastewater treatment facility.

[1] http://www.deq.virginia.gov/waterguidance/pdf/012025.pdf

## 10.2 Storage and Handling of Commonly Used Chemicals

Storage and handling of all chemicals used in maintenance operations requires knowledge of regulatory requirements, complete inventories of chemical products used on the golf course, staff trained in proper procedures, and an up-to-date emergency response plan.

**BMP #1**
Store and handle all chemicals appropriately using secondary containment as required.

### 10.2.1 Petroleum Products

Petroleum products used in golf course equipment usage must be properly stored, dispensed, and disposed of. When accidentally released, petroleum products can evaporate into the air, or contaminate surface waters, soil, or groundwater. Releases can also be a fire hazard and present toxicity issues.

#### 10.2.1.1 Fuel storage

Bulk fuel may be stored in ASTs or USTs, using certified, double-walled, self-contained steel tanks. Following regulations and guidance with respect to siting, design, construction, maintenance, leak detection, and inspection is important to ensure that catastrophic failures or chronic leaks do not occur.

Fuel stored in gas cans should be labeled clearly and accurately. When not in use, gas cans should be stored in a separate metal cabinet and away from other flammable chemicals, pesticides, and fertilizers.

#### 10.2.1.2 Fueling areas

Fueling areas should be properly sited, designed, constructed, and maintained to prevent petroleum products from being released into the environment through spills or leaks. Fueling areas should be sited on impervious surfaces, equipped with spill containment and recovery facilities, and located away from surface waters and drinking water wells. Roofing covering the fueling area minimizes contact with stormwater (Figure 10-1). Catch basins in fueling areas should be directed towards an oil/water separator or sump to prevent petroleum moving offsite. Floor drains in fueling areas should be eliminated unless they drain to storage tanks.



Figure 10-1. Covered fuel island and equipment washing area. *Source:* Terry Buchen.

Runoff in containment systems in the fueling area must first be evaluated for contamination with petroleum either by observation (the presence of oily sheen, smell of fuel or oil, etc.) or commercially available test kits. Contaminated water must be treated before being discharged. Treatment methods include:

- commercially available treatment systems
- permitted discharge to an offsite wastewater treatment system
- transport to a treatment facility

#### 10.2.1.3 Petroleum releases

Equipment failure (such as in piping systems or from tank corrosion), human error such as overfills, and leaks during pumping from truck to storage tank are among the most common reasons for unintended petroleum releases in fuel storage and fueling areas. Preventing these releases requires diligence in inspection and maintenance of the storage tanks and care during filling of storage tanks and fueling of equipment. Should a release occur, minor fuel splatters or drips can be cleaned using absorbents. Larger releases should be treated appropriately, such as containment with absorbent booms, and authorities notified as required. In addition, a spill kit should be located in the fueling area (see Appendix I).

### 10.2.2 Fertilizers

The nutrients in fertilizers, particularly nitrogen and phosphorus, can present water quality issues if not handled properly. Fertilizers also must be stored properly because their oxidizing properties pose fire hazards.

**BMP #2**
Store fertilizers and pesticides separately and away from other chemicals.

#### 10.2.2.1 Fertilizer storage

Fertilizers should be stored in a dry area, ideally, a concrete building with a metal or other flame-resistant roof. At the least, fertilizers should be stored on a concrete pad and covered from the elements. Nitrate-based fertilizers, while stable themselves, act as an oxidizer and can react with combustible and reducing materials. The presence of a fire hazard depends on other general combustible materials in the vicinity of nitrate-based fertilizers, which can accelerate a fire. Therefore, nitrate-based fertilizers must be stored separately from pesticides, solvents, and fuels.

#### 10.2.2.2 Fertilizer loading and unloading

Fertilizers should be loaded into or unloaded from application equipment away from surface waters or drinking wells. To minimize accidental release and allow for easy cleanup of spilled fertilizer, a covered impervious surface (for example, a concrete pad) is ideal. The surface area should be cleaned after loading or unloading to further control dust and spills and prevent accidental offsite release.

### 10.2.3 Pesticides

Pesticides should be stored away from fertilizers in an appropriate storage area. Mixing, loading, unloading, and washing of pesticide application equipment and containers should be performed in an appropriate site (such as a CMC) to prevent offsite transport of pesticides from accidental releases, contaminated wash water, or stormwater runoff. Following an accidental release, spills should be controlled, contained, collected, and stored. Pesticides from accidental releases and wash water should be managed or disposed of properly. See Section 9.5 for more information on the storage and handling of pesticides.

### 10.2.4 Solvents / Degreasers

Unintended releases of solvents and degreasers present potential human health hazards (toxicity, fire hazard) and environmental hazards. Solvents can emit volatile organic compounds (VOCs), which present a human health concern in indoor air quality. Solvents or degreasers disposed of in storm drains can impact drinking water or can impact surface water and soils if present in stormwater runoff. Even small amounts of solvents should never be allowed to drain onto pavement or soil or discharged inappropriately. To prevent unintended releases, storage and usage recommendations should be followed at all times. Whenever practical, solvent baths should be replaced with recirculating aqueous washing units. Soap and water or other aqueous cleaners are often as effective as solvent-based ones.

#### 10.2.4.1 Storage

Lockable metal cabinets with adequate ventilation should be used to store solvents and degreasers. These products should also be stored away from ignition sources (such as welding/acetylene torch areas or grinders), fertilizers, and pesticides. To reduce the possibility of VOC emissions and fire hazards, solvents should be covered during storage.

#### 10.2.4.2 Solvent / degreaser use

PPE, especially eye protection, should be used according to label directions when using solvents. Solvents and degreasers should be used over a collection basin or impervious pad in order to collect all used material. Most solvents can be filtered, stored in marked containers, and reused or recycled. Disposal should follow regulations. In addition, any wash water generated from equipment washing contaminated with solvents or degreasers should be collected and disposed of properly.

An inventory of stored solvents, MSDSs for each solvent, PPE, and any other emergency response equipment recommended by the manufacturer should be readily accessible, but not stored with the solvents.

## 10.3 Equipment Storage and Maintenance

All equipment used in the maintenance and operation of golf courses should be stored, maintained, and cleaned in a way that eliminates or minimizes the potential for pollution. When not in use, equipment should be stored in a clean, safe and protected area, such as covered and sealed impervious areas. Fluid leaks from stored equipment should be identified and the equipment repaired. Assigned parking areas aid in the identification of equipment with fluid leaks (Figure 10-2).

Application equipment must be stored in covered areas protected from rainfall because of the potential for pesticide or fertilizer residue to wash off the exterior of this equipment. Pesticide and fertilizer equipment should be stored separately from other equipment. Pesticide application equipment can be stored in the CMC (Section 9.5.3).

### 10.3.1 Equipment Washing Areas

Equipment washing areas are primarily used to wash mowing equipment, which can transport organic matter such as grass clippings or soil into surface waters with runoff. Washing procedures should incorporate the minimal use of water and spring-operated shutoff nozzles to conserve water resources. In general, unless the wash water contains contaminants such as petroleum products, pesticides, solvents, or degreasers, it may not need to be collected before being discharged (see Section 9.5.5 for cleaning of pesticide application equipment). However, even uncontaminated wash water should never be allowed to discharge directly into, or in the vicinity of, surface waters and storm drains.

**BMP #3**
Store pesticide and fertilizer application equipment in covered areas to protect from rainfall.



Figure 10-2. Equipment wash rack with air hose pre-cleaning area. *Source:* Terry Buchen

**BMP #4**
Remove grass from grass-covered equipment before washing.

Washing areas can be simple or more complex. The simplest system is a "dog leash" system that uses a short, portable hose to wash off the grass over a turfed area. The wash water infiltrates into the soil. The washing location should be moved around, depending upon the amount of water used and the percolation rate of the soil, to avoid any potential problems with mud and surface runoff.

Well-designed equipment washing areas incorporate an impervious surface and a system to recycle, discharge, or divert wash water and minimize the potential for environmental impacts (Figure 10-3). Clippings should be brushed or blown off equipment with compressed air prior to washing since dry clippings are easier to handle, store, and dispose of than wet ones. In addition, this practice decreases the possibility of nutrients, such as nitrogen and phosphorus, leaching out of wet clippings and into the wash water. Any remaining grass clippings can be separated from the wash water using an above ground screening system or a tank containing separation baffles that trap the clippings to separate them from the water. Collected wet clippings can be composted or used as mulch if they are not contaminated with pesticides or petroleum.

## 10.3.2 Wash Water Disposal and Recycling



Figure 10-3. Equipment wash rack with air hose pre-cleaning area. *Source:* Terry Buchen.

Disposal of wash water depends on a number of variables, including the volume of wash water generated, the nature of the surrounding area, and the frequency of the operations. For limited wash-down of ordinary field equipment, it may be legal to allow the wash water to flow to an area for infiltration, such as a grassed retention area or swale. Discharge to a septic system is illegal. Other options for managing wash water include:

- discharge to a sanitary sewer system
- treatment onsite
- recycling

Discharges to a waste water treatment system require a permit and may require pretreatment, such as the use of an oil/water separator (see Section 10.3.4) and separation of grass clippings (see discussion below) or other solids.

**BMP #5**
Dispose of or recycle wash water appropriately and never discharge to surface waters or septic systems.

### 10.3.2.1 Onsite treatment

Onsite treatment uses separation systems to separate clippings from the water. Soaps or degreasers can be used in washing equipment that is treated onsite. Separation systems can use an above or below ground catch and release system to capture clippings and discharge wash water. Aboveground systems capture clippings through a screening mechanism and discharge wash water to the ground surface for infiltration. There must be no connection to surface water in this system. Clippings must be collected regularly and returned to a turfed area or composted. Belowground catch and release systems capture clippings by an aboveground screening mechanism or a belowground tank before discharging the wash water to an underground infiltration network. If a tank is used to capture clippings, the clippings must be disposed of by a licensed liquid industrial waste hauler.

### 10.3.2.2 Recycle wash systems

Two types of recycling systems are available to purify wastewater and pipe it back for reuse: 100% closed-loop recycle and partial recycle systems. Although expensive, recycle systems conserve water resources and lower water bills and sewer discharge fees.

Closed-loop recycle systems recycle both wash water and rinse water with no discharges of wastewater to ground or surface waters. These systems must be properly operated and maintained to prevent accidental discharges. Florida DEP has published BMPs for the use of closed-loop recycle systems in *Guide to Best Management Practices for 100% Closed-loop Recycle Systems at Vehicle and Other Equipment Wash Facilities* (FL DEP 2005a) and an accompanying BMP checklist (FL DEP 2005b)[1]. In some cases, the use of closed-loop systems may require an industrial wastewater permit.

Partial recycle systems separate wash water from rinse water and recycle the wash water. Excess rinse water may be disposed of onsite. More information on partial recycle systems is also available in FL DEP's guidance on closed-loop recycle systems (FL DEP 2005a).

[1] See http://www.dep.state.fl.us/water/wastewater/docs/GuideBMPClosed-LoopRecycleSystems.pdf and http://www.dep.state.fl.us/water/wastewater/docs/ChecklistGuideClosed-LoopRecycleSystems.pdf.

#### 10.3.2.3 Oil / Water Separators

Oil/water separators are generally not necessary, unless the water from the system is to be reclaimed for some particular end use (such as recycle systems), or as required by an industrial wastewater permit, local government, or receiving utility. Oil/water separators cannot be used for treating water-soluble chemicals (anti-freeze, solvents, etc.). In addition, emulsifying cleaning compounds disperse oil in wash water making oil/water separators ineffective; therefore, high pressure water only or non-emulsifying detergents or other cleaners should be used for cleaning equipment where oil/water separators are used. Further, the amount of solids that enter the oil/water separators (such as clippings and dirt) should be minimized. Finally, pesticide application equipment should not be washed on pads with oil/water separators to avoid contaminating salvaged oil.

Oil collected in these systems may be classified as a hazardous waste, making disposal expensive. Usually, filters from these systems may be disposed of at an approved landfill. Keep all disposal records to document proper disposal of this waste.

## 10.4 Waste Handling

Waste handling areas should be clearly marked, have spill containment in place, and be secure from vandalism. All waste should be properly labeled and stored. Wastes should be segregated, such as hazardous from non-hazardous, acids from bases, chlorinated from nonchlorinated solvents, and oils form solvents, in order to minimize disposal costs and facilitate recycling and reuse.

**BMP #6**
Store wastes separately and dispose of according to legal requirements.

### 10.4.1 Hazardous Materials

Any material deemed a hazardous material according to regulations must be sealed, secured, and properly labeled before being disposed of by an approved, licensed contractor.

### 10.4.2 Pesticides and Pesticide Containers

Pesticides that have been mixed and cannot be applied to a site in accordance with the label must be disposed of as a waste. Depending on the active ingredients, these substances may be classified as hazardous waste. Pesticide containers should be disposed of appropriately (Section 9.5.5).

### 10.4.3 Used Oil, Antifreeze, and Lead-Acid Batteries

Used oil, oil filters, and antifreeze should be collected and stored in separate marked containers. Recycling is the best option for handling used oil. Oil filters should be drained and disposed of legally, such as at a hazardous waste collection site. Antifreeze must be recycled or disposed of as a hazardous waste. Commercial services are available to collect this material.

Lead-acid storage batteries must be recycled or disposed of as a hazardous waste. All lead-acid battery retailers are required to accept returned batteries for recycling. Used batteries should be stored on an impervious surface and preferably under cover.

### 10.4.4 Solvents and Degreasers

Used solvents and degreasers should be collected, stored, and appropriately identified and dated. Spill containment should be in place below the stored solvents and degreasers. Approved, licensed contractors can recycle or dispose of the used solvents and degreasers.

### 10.4.5 Composting

Grass clippings that are not contaminated with pesticide residues or diseased can be composted. Compost areas should be located away from surface waters in order to protect water quality.

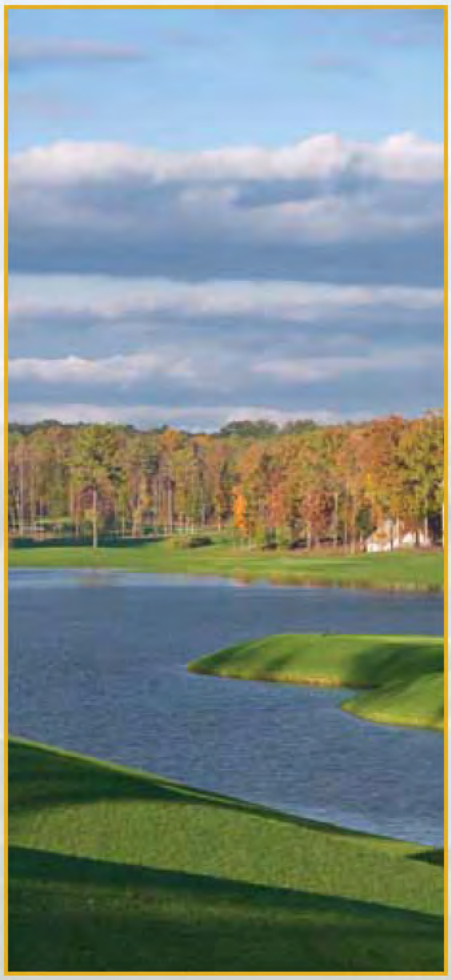
### 10.4.6 Paper, Plastic, Glass and Aluminum Recycling

Recycling of all commonly recycled materials, such as office paper, recyclable plastics, glass, and aluminum should be encouraged. Recycling containers can be placed at convenient locations on the golf course and in course buildings.

# 11

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# Appendices





WILLIAMSBURG ENVIRONMENTAL GROUP, INC.

*Environmental Consul*

January 11, 2011

Peter McDonough
Golf Course Superintendent
701 Club Drive
Keswick, VA 22947

**Re**: **Keswick Club Winter 2010 Water Quality Monitoring**
**WEG Project # 1435A**

Dear Mr. McDonough:

Sampling was conducted during December of 2010 to characterize the water quality and ecological health of two streams passing through the Keswick Club property. The property is located in Keswick, Virginia (Figure 1), bordered by State Route 731 on the west, 744 and Interstate 64 on the south and the CSX Railroad to the northwest (Figure 2). Basic water chemistry was measured at each of five monitoring stations (Figure 3), and streamflow discharge measurements were taken. Macroinvertebrate samples and water grab samples were also collected. While water chemistry measurements and grab sampling provide an explicit snapshot of current conditions, biological monitoring offers a more comprehensive reflection of longterm water quality. Together, they provide a complementary, two-pronged assessment strategy. Monitoring will be conducted twice annually.

## METHODS

*Water Chemistry*

Field measurements were taken at each of five sampling stations. Parameters included dissolved oxygen, temperature, conductivity, and pH. Water quality probes were calibrated prior to sampling in order to ensure accuracy. In addition to in-situ measurements, water samples were collected for laboratory analysis. Sample bottles for nitrate, phosphorus, and ammonia TKN were provided by EnviroCompliance Laboratories, Inc. located in Ashland, Virginia. Grab samples were collected at the channel thalweg at all sampling stations and were immediately retained in an iced cooler until release to the laboratory.

*Streamflow*

Flow velocities and water depths were measured at six-inch intervals across the channel using a Marsh McBirney FLO-MATE Model 2000. The manufacturer rates the accuracy of this meter at

±2% of reading. Based on the field measurements, discharge volume was calculated in cubic feet per second.

*Biological Monitoring*

Sample collection followed the *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers* (RBP) (Barbour et al. 1999). As prescribed by this document, a "Multihabitat Approach" was employed. Using a D-frame net, "jabs" and/or "kicks" were taken in areas of different habitat types (pools, riffles, undercut banks, submerged aquatic vegetation, woody debris, etc.), sampled in rough proportion to their frequency within the study reach. A single sample was retained from each monitoring station, consisting of the composite of the jabs and kicks. In addition, submerged woody debris (if present) was brushed into the D-frame and added to the sample. Samples were preserved at the time of collection with 70% ethyl alcohol.

Sample sorting was performed at WEG's invertebrate laboratory. Sorting involves separating organisms from detritus and other substrate material prior to taxonomic identification. Following Virginia DEQ biomonitoring protocols, a 100-count subsample (± 10%) was taken. After sorting, organisms were identified to genus level in order to generate a taxa list for each monitoring station.

The following water quality metrics were calculated based on the local benthic macroinvertebrate community. Collectively they provide valuable information about potential pollution sources, degree of impairment, ecological health, and benthic community structure.

**Total Taxa Richness:** Total taxa richness is the number of different taxanomic groups in a sample as defined by the lowest level of taxonomy performed. High taxa richness usually indicates a complex community with multiple trophic levels, in turn suggesting normal and stable water chemistry conditions. Alternately, low taxa richness is typical of impaired systems where only tolerant families can survive and reproduce.

**EPT Richness:** EPT richness is the total number of different mayfly (Ephemeroptera), stonefly (Plecoptera), and caddisfly (Trichoptera) taxa identified in a subsample. These three orders are generally intolerant of pollution and other stressors, so EPT richness is a measure of the diversity of sensitive taxa. Accordingly, EPT richness will decrease with increased environmental stressors.

**Percent EPT-H:** This metric is a composition metric for estimating the proportion of mayflies, stoneflies, and caddisflies (other than the family Hydropsychidae) represented in the benthic community. Similar to the EPT Richness metric, Percent EPT-H represents the relative abundance of sensitive organisms. As such, Percent EPT-H decreases with increased pollution and/or environmental stress. Hydropsychids are excluded from this metric because they are tolerant of organic pollution and in high abundance, they typically indicate nutrient impairment.

**Percent Dominant Taxon:** This metric calculates the proportion of the most abundant taxon in the subsample. In more stressed systems, taxa richness is typically lower. As conditions become less favorable, the benthic community becomes more constrained, hence, the dominant taxon will likely represent a greater percentage of the total subsample.

**Percent Chironomidae:** This metric is the ratio of midge larvae to the total number of organisms in the subsample. Because Chironomids are so tolerant to a wide range of pollutants, the metric is expected to increase with increased impairment.

**Hilsenhoff Biotic Index (HBI):** This metric is based on tolerance values assigned to the various taxa and is a measure of the community's tolerance to organic pollution. Tolerance values are state-specific, and were provided by the DEQ's Freshwater Biological Monitoring Program. In this metric, tolerance values are used to weight family abundance within the subsample to yield a score. The biotic index is calculated as follows:

$$\text{MFBI} = \sum_{i=1}^{S} \frac{x_i t_i}{n}$$

$x_i$ = number of individuals in taxon

$t_i$ = tolerance value of taxon

$n$ = total abundance of sample

$S$ = total number of taxa

The HBI score is interpreted using the following table from Hilsenhoff, 1987 as presented in DEQ's *The Quality of Virginia Non-Tidal Streams: First Year Report* (2003):

| Score | Water Quality | Degree of Organic Pollution |
|---|---|---|
| 0.00-3.50 | Excellent | No apparent organic pollution |
| 3.51-4.50 | Very Good | Slight organic pollution |
| 4.51-5.50 | Good | Some organic pollution |
| 5.51-6.50 | Fair | Fairly significant organic pollution |
| 6.51-7.50 | Fairly Poor | Significant organic pollution |
| 7.51-8.50 | Poor | Very Significant organic pollution |
| 8.51-10.00 | Very Poor | Severe organic pollution |

**Simpson's Index of Diversity:** Simpson's Index of Diversity is a measure of the taxonomic balance of the community by taking into account relative abundance. This metric does not consider pollution tolerance, as with the HBI. Instead, it represents the probability that two randomly selected individuals from the subsample will be from different taxa. The index is calculated as follows:

$$D = 1 - \sum_{i=1}^{S} (x_i/n)^2$$

$x_i$ = number of individuals in taxon

$n$ = total abundance in subsample

$S$ = number of taxa in subsample

Scores range from 0 to 1 where 0 represents communities devoid of life and 1 represents the most diverse communities.

**Feeding Group Composition:** Feeding groups are indicative of each taxon's ecological role within the community. Groups consist of collector-filterers, collector-gatherers, predators, scrapers, and shredders. Relative abundance of each of these groups is calculated to evaluate the trophic balance of the system. An imbalance among these groups may indicate an imbalance in overall stream health.

## RESULTS

*Water Chemistry and Streamflow*

Water chemistry testing is important for characterizing current conditions and for identifying specific sources of pollution at the time of sampling. Streamflow was below previously measured levels and largely groundwater driven at the time of sampling. These data provide a snapshot of water quality in Tributaries 1 and 2 on the Keswick Club property in December of 2010. A summary of findings is presented in Table 1.

Table 1. Water chemistry measurements and streamflow – Winter 2010

| | Tributary 1 | | | Tributary 2 | |
|---|---|---|---|---|---|
| Parameter | STA1 | STA2 | STA3 | STA4 | STA5 |
| Temperature (ºC) | 2.30 | 3.90 | 3.20 | 3.70 | 3.60 |
| Dissolved Oxygen (mg/L) | 9.40 | 10.30 | 10.70 | 9.80 | 8.10 |
| pH | 7.38 | 7.33 | 7.59 | 7.51 | 7.37 |
| Conductivity (µS/cm) | 110 | 140 | 140 | 130 | 170 |
| Nitrate (mg/L) | 2.00 | 1.90 | 1.50 | 1.20 | 0.30 |
| Ammonia TKN (mg/L) | 0.10 | 0.30 | 0.20 | 0.30 | 0.50 |
| Total Phosphorous (mg/L) | 0.01 | 0.02 | 0.03 | 0.02 | 0.03 |
| *Streamflow* | | | | | |
| Average Velocity (fps) | 0.06 | 0.12 | 0.23 | 0.11 | 0.11 |
| Discharge (cfs) | 0.14 | 0.19 | 0.2 | 0.17 | 0.29 |

All water quality parameters, both measured in the field and tested in the laboratory, fell within acceptable ranges for supporting aquatic life, as defined by DEQ standards and criteria. Water temperature was typical of seasonal norms and fluctuated slightly due to variations in canopy cover and riparian buffer zone width. Dissolved oxygen concentrations were more than double the DEQ recommended minimum of 4 mg/L, and pH was near the median of the allowable range of 6 to 9 at all monitoring stations. Conductivity values were similar to those measured in previous monitoring, and do not appear to be indicative of impairment. All of these values were closely comparable between upstream and downstream monitoring stations. Nitrates, Ammonia TKN, and Total Phosphorus also showed minimal differences between upstream and downstream. These findings suggest that the surrounding land use had little influence on water quality at the time of 2010 winter monitoring.

*Biological Monitoring*

Benthic macroinvertebrates are used as indicators of water quality because their community composition is defined by the cumulative impacts of multiple stressors over time. As such, the presence or absence of key taxa and overall community structure provide a long term representation of water quality conditions. This section describes the findings of winter 2010 biological monitoring, conducted concurrently with water chemistry and streamflow sampling. A complete taxa list and the results of the water quality metric calculations are included in the Appendices.

According to the Hilsenhoff Biotic Index (HBI), water quality entering the property was "Good" on Tributaries 1 and 2, with index scores of 5.37 and 5.25 respectively. Tributary 1 showed a gradual decline in water quality moving downstream, with HBI ratings of "Fair" at Station 2 and "Fairly Poor" exiting the property at Station 3. The percent EPT-H metric, representing the relative abundance of pollution-sensitive taxa, supports this finding, reduced from nearly 15 percent of the subsample at Station 1 to approximately 9 percent at Station 2 and only 2 percent at Station 3. The Total Taxa Richness metric also shows a consistent decline moving downstream; however, overall diversity, as reflected in Simpson's Index of Diversity (SID) was largely consistent among sites. Field observations noted a clear change in abundance and taxa

representation between Stations 2 and 3. The tributary south of Club Drive may contribute to the decline in water quality with its confluence approximately 400 feet upstream of Station 3.

Biological conditions in Tributary 2 were similar to those in Tributary 1, with an HBI rating of "Good" at the upstream sampling location (Station 4) and water quality in the "Fairly Poor" range exiting the study area at Station 5. Overall EPT Richness was only reduced slightly; however, the Percent EPT-H metric showed a notable decline in the relative abundance of sensitive organisms with over 18 percent representation at Station 4 and less than 5 percent at Station 5. While the SID showed a slight increase in diversity from upstream to downstream, this is partially due to an abundance of Chironomids within the capped 100 (± 10%) sample size at Station 4, representing nearly half of the subsample. While other taxa enter diapause or overwinter as eggs, Chironomids typically overwinter in their larval stage and are present and abundant during this time of the year. It is likely that a lower percentage of Chronomids will be represented in spring or summer sampling. As such, the SID may be expectedly higher at Station 4 during warm weather monitoring. It is also important to note that the SID metric does not account for pollution tolerance. While overall diversity has increased from upstream to downstream, sensitive taxa have been replaced by more pollution tolerant organisms.

Feeding group composition was disproportionately represented by gatherers and filterers at all monitoring stations on both tributaries. As generalist feeders, these groups have a broad range of food sources, and, as a result, are more tolerant to pollution that may affect food availability. These findings suggest some level of impairment at all stations; however, the inequities among community trophic levels are more pronounced at downstream sites. Seasonal productivity may also play a partial role, and a different distribution of feeding groups may be seen during warm weather monitoring.

Overall, land uses within the property appear to have marginalized water quality in both onsite tributaries. Water chemistry sampling shows that pollutant inputs are currently minimal or nonexistent; however, the biological data suggest acute impacts associated with seasonal management activities. Wet weather and summertime sampling in correspondence with these management activities will be important for evaluating specific impacts and in developing a mitigation strategy to improve and protect longterm water quality.

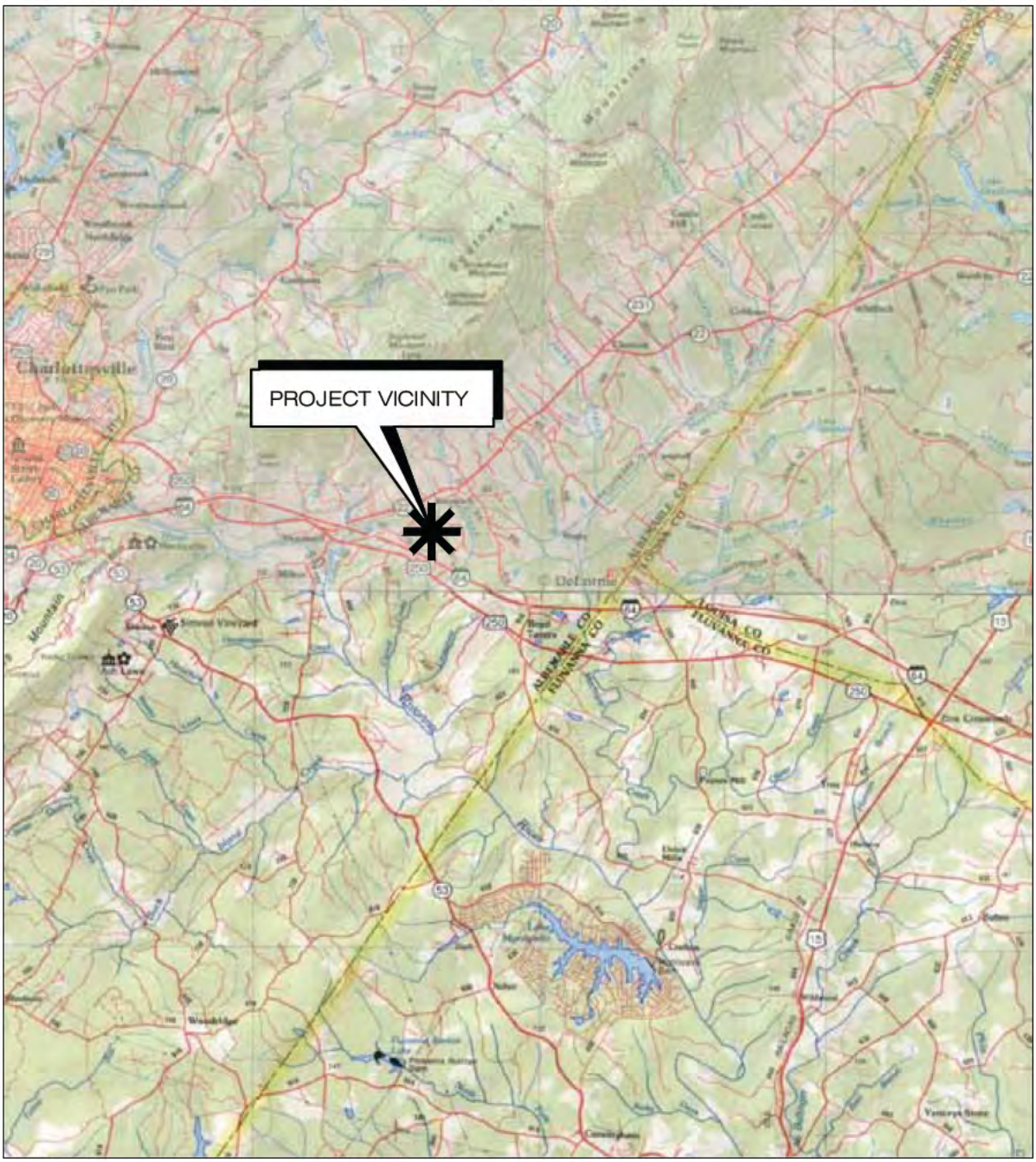
If you have any questions, please feel free to call (757) 220-6869, or email mlajoie@wegnet.com.

Sincerely,



Matthew P. Lajoie
Aquatic Biologist, Certified Taxonomist

Attachments
cc: WEG file




SCALE: 1 INCH = 2.4 MILES

SOURCE: VIRGINIA ATLAS AND GAZETTEER, DeLORME MAPPING CO., 1995.

WILLIAMSBURG ENVIRONMENTAL GROUP, INC.

FIGURE 1
PROJECT VICINITY MAP
KESWICK

ALBEMARLE COUNTY, VIRGINIA | JANUARY 2011




2000' 1000' 0' 2000'

SCALE: 1 INCH = 2000 FEET

LATITUDE: 38°00'48.57"N
LONGITUDE: 78°21'36.73"W

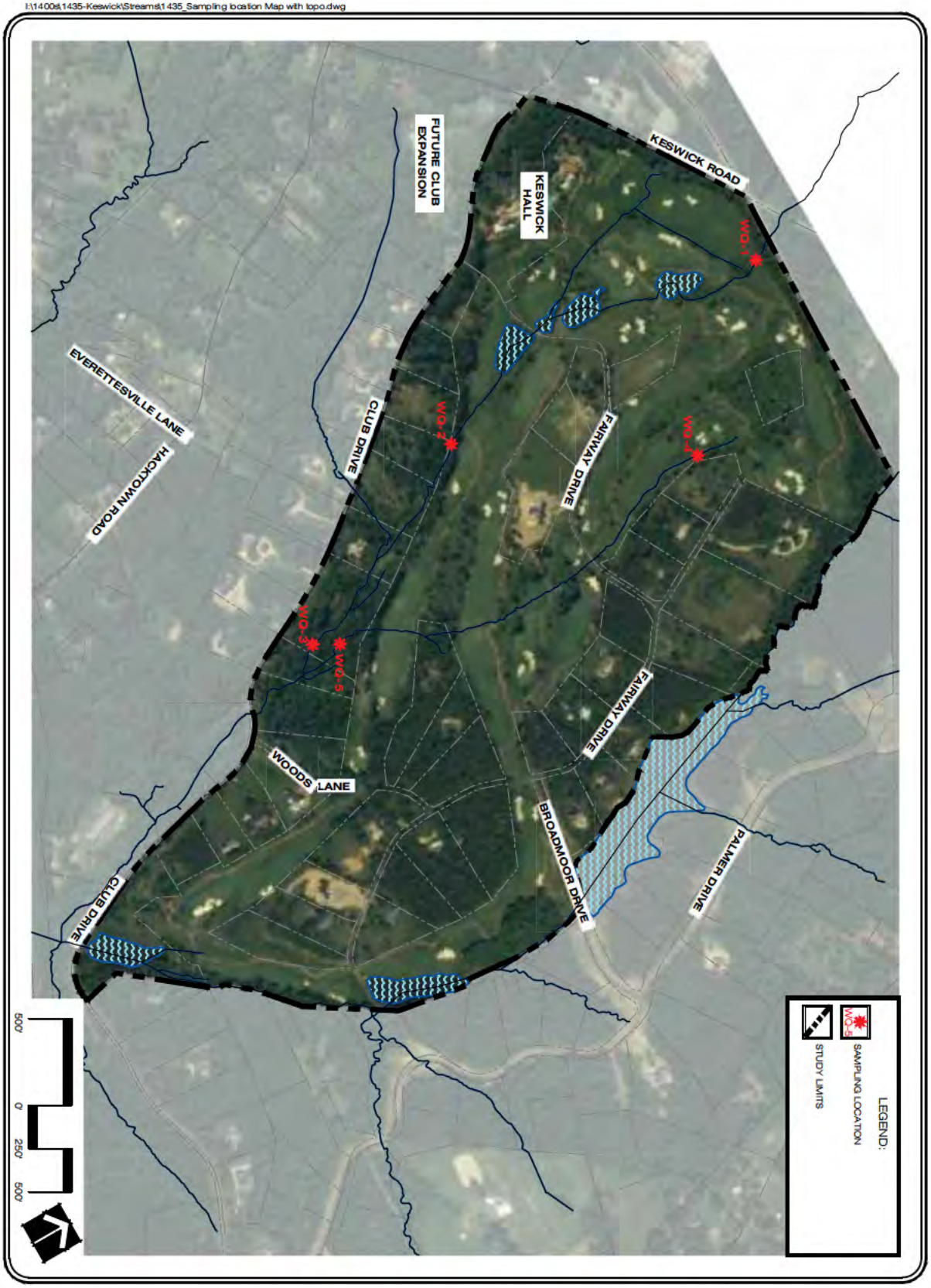
SOURCE: USGS 7.5 MINUTE SERIES TOPOGRAPHIC MAP, KESWICK, VA QUADRANGLE, 1964 (REV 1984)

WILLIAMSBURG ENVIRONMENTAL GROUP, INC.

FIGURE 2
PROJECT LOCATION MAP
KESWICK

ABLEMARLE COUNTY, VIRGINIA | JANUARY 2011

I:\1400s\1435-Keswick\Streams\1435_Sampling location Map with topo.dwg




DATE: JANUARY 2011

JOB NUMBER: 1435A

SCALE: 1 INCH = 500 FEET

SOURCE: BASE MAPPING PROVIDED BY ALBEMARLE COUNTY GIS

**FIGURE 3**
**SAMPLING LOCATION MAP**
**KESWICK CLUB**
**ALBEMARLE COUNTY, VIRGINIA**

WILLIAMSBURG ENVIRONMENTAL GROUP, INC.
Environmental Consultants

# A.1 Benthic Macroinvertebrate Monitoring Data

Table 2. Master taxa list from all five stations.

| Order/Major Group | Family | Genus | Common Name | FFG | TV |
|---|---|---|---|---|---|
| Oligochaeta | Lumbriculidae | - | aquatic earthworm | CG | 8 |
| Gastropoda | Lymnaeidae | - | Lymnaeid snail | SC | 7 |
| Gastropoda | Physidae | - | bladder snail | SC | 8 |
| Bivalvia | Corbiculidae | Corbicula | Asiatic clam | CF | 8 |
| Bivalvia | Sphaeriidae | Pisidium | fingernail clam (1) | CF | 8 |
| Bivalvia | Sphaeriidae | Musculium | fingernail clam (2) | CF | 8 |
| Amphipoda | Crangonyctidae | Crangonyx | scud | CG | 6 |
| Isopoda | Asellidae | Caecidotea | sowbug | CG | 8 |
| Decapoda | Cambaridae | Cambarus | crayfish | SH | 5 |
| Plecoptera | Perlodidae | Clioperla | patterned stonefly | PR | 2 |
| Plecoptera | Perlodidae | Isoperla | patterned stonefly | PR | 2 |
| Plecoptera | Capniidae | Allocapnia | small winter stonefly | SH | 1 |
| Plecoptera | Taeniopterygidae | Strophopteryx | winter stonefly | SH | 2 |
| Coleoptera | Gyrinidae | Dineutus | whorligig beetle | PR | 5 |
| Coleoptera | Psephenidae | Psephenus | water penny | SC | 4 |
| Coleoptera | Dytiscidae | Agabus | predacious diving beetle | PR | 6 |
| Diptera | Tipulidae | Pseudolimnophila | cranefly (1) | SH | 3 |
| Diptera | Tipulidae | Tipula | cranefly (2) | SH | 3 |
| Diptera | Simuliidae | Simulium | blackfly | CF | 6 |
| Diptera | Chironomidae | - | midge | CG | 6 |
| Megaloptera | Corydalidae | Nigronia | fishfly | PR | 5 |
| Trichoptera | Hydropsychidae | Cheumatopsyche | common netspinner caddis | CF | 6 |
| Trichoptera | Philopotamidae | Chimarra | fingernet caddis | CG | 3 |
| Trichoptera | Phryganeidae | Ptilostomis | giant caddis | SH | 4 |
| Trichoptera | Rhyacophilidae | Rhyacophila | freeliving caddis | PR | 0 |
| Odonata/Anisoptera | Gomphidae | Stylogomphus | clubtail dragonfly | PR | 1 |

Table 3.1. Station 1 Biological Monitoring Summary

| Order/Major Group | Family | Genus | Common Name | Total | FFG | TV |
|---|---|---|---|---|---|---|
| Gastropoda | Lymnaeidae | - | Lymnaeid snail | 7 | SC | 7 |
| Gastropoda | Physidae | - | bladder snail | 3 | SC | 8 |
| Amphipoda | Crangonyctidae | Crangonyx | scud | 15 | CG | 6 |
| Decapoda | Cambaridae | Cambarus | crayfish | 1 | SH | 5 |
| Plecoptera | Perlodidae | Clioperla | patterned stonefly | 7 | PR | 2 |
| Plecoptera | Perlodidae | Isoperla | patterned stonefly | 4 | PR | 2 |
| Plecoptera | Capniidae | Allocapnia | small winter stonefly | 5 | SH | 1 |
| Coleoptera | Gyrinidae | Dineutus | whorligig beetle | 1 | PR | 5 |
| Coleoptera | Psephenidae | Psephenus | water penny | 3 | SC | 4 |
| Coleoptera | Dytiscidae | Agabus | predacious diving beetle | 1 | PR | 6 |
| Diptera | Tipulidae | Pseudolimnophila | cranefly (1) | 1 | SH | 3 |
| Diptera | Simuliidae | Simulium | blackfly | 7 | CF | 6 |
| Diptera | Chironomidae | - | midge | 52 | CG | 6 |
| | | | | 107 | | |

| | |
|---|---|
| Total Taxa Richness | 13 |
| EPT Richness | 3 |
| Percent EPT-H | 14.95 |
| Percent Dominant Taxon | 48.60 |
| Percent Chironomidae | 48.60 |
| Hilsenhoff Biotic Index | 5.37 |
| Simpson's Index of Diversity | 0.73 |

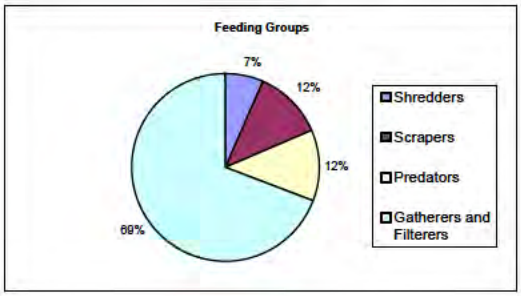



Table 3.2. Station 2 Biological Monitoring Summary

| Order/Major Group | Family | Genus | Common Name | Total | FFG | TV |
|---|---|---|---|---|---|---|
| Gastropoda | Lymnaeidae | - | Lymnaeid snail | 1 | SC | 7 |
| Bivalvia | Corbiculidae | Corbicula | Asiatic clam | 1 | CF | 8 |
| Amphipoda | Crangonyctidae | Crangonyx | scud | 17 | CG | 6 |
| Plecoptera | Capniidae | Allocapnia | small winter stonefly | 4 | SH | 1 |
| Plecoptera | Taeniopterygidae | Strophopteryx | winter stonefly | 3 | SH | 2 |
| Diptera | Simuliidae | Simulium | blackfly | 40 | CF | 6 |
| Diptera | Chironomidae | - | midge | 36 | CG | 6 |
| Megaloptera | Corydalidae | Nigronia | fishfly | 2 | PR | 5 |
| Trichoptera | Hydropsychidae | Cheumatopsyche | common netspinner caddis | 3 | CF | 6 |
| Trichoptera | Philopotamidae | Chimarra | fingernet caddis | 2 | CG | 3 |
| Trichoptera | Phryganeidae | Ptilostomis | giant caddis | 1 | SH | 4 |
| | | | | 110 | | |

| | |
|---|---|
| Total Taxa Richness | 11 |
| EPT Richness | 5 |
| Percent EPT-H | 9.09 |
| Percent Dominant Taxon | 36.36 |
| Percent Chironomidae | 32.73 |
| Hilsenhoff Biotic Index | 5.65 |
| Simpson's Index of Diversity | 0.73 |

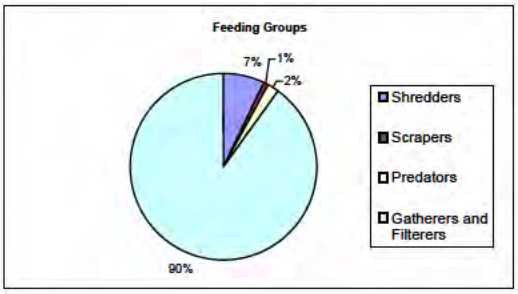



Table 3.3. Station 3 Biological Monitoring Summary

| Order/Major Group | Family | Genus | Common Name | Total | FFG | TV |
|---|---|---|---|---|---|---|
| Oligochaeta | Lumbriculidae | - | aquatic earthworm | 2 | CG | 8 |
| Gastropoda | Physidae | - | bladder snail | 4 | SC | 8 |
| Amphipoda | Crangonyctidae | Crangonyx | scud | 36 | CG | 6 |
| Isopoda | Asellidae | Caecidotea | sowbug | 26 | CG | 8 |
| Plecoptera | Capniidae | Allocapnia | small winter stonefly | 2 | SH | 1 |
| Diptera | Simuliidae | Simulium | blackfly | 9 | CF | 6 |
| Diptera | Chironomidae | - | midge | 18 | CG | 6 |
| | | | | 97 | | |

| | |
|---|---|
| Total Taxa Richness | 7 |
| EPT Richness | 1 |
| Percent EPT-H | 2.06 |
| Percent Dominant Taxon | 37.11 |
| Percent Chironomidae | 18.56 |
| Hilsenhoff Biotic Index | 6.56 |
| Simpson's Index of Diversity | 0.74 |

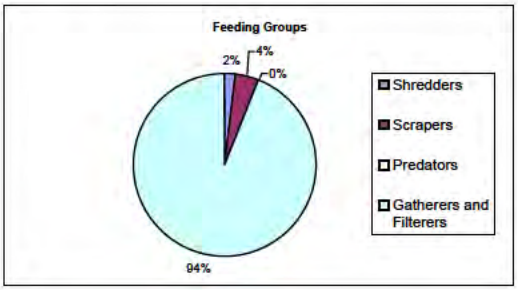


Table 3.4. Station 4 Biological Monitoring Summary

| Order/Major Group | Family | Genus | Common Name | Total | FFG | TV |
|---|---|---|---|---|---|---|
| Oligochaeta | Lumbriculidae | - | aquatic earthworm | 2 | CG | 8 |
| Bivalvia | Sphaeriidae | Pisidium | fingernail clam (1) | 3 | CF | 8 |
| Amphipoda | Crangonyctidae | Crangonyx | scud | 26 | CG | 6 |
| Isopoda | Asellidae | Caecidotea | sowbug | 1 | CG | 8 |
| Plecoptera | Perlodidae | Clioperla | patterned stonefly | 16 | PR | 2 |
| Plecoptera | Capniidae | Allocapnia | small winter stonefly | 4 | SH | 1 |
| Diptera | Tipulidae | Tipula | cranefly (2) | 1 | SH | 3 |
| Diptera | Chironomidae | - | midge | 53 | CG | 6 |
| Megaloptera | Corydalidae | Nigronia | fishfly | 1 | PR | 5 |
| Odonata/Anisoptera | Gomphidae | Stylogomphus | clubtail dragonfly | 1 | PR | 1 |
| | | | | 108 | | |

| | |
|---|---|
| Total Taxa Richness | 10 |
| EPT Richness | 2 |
| Percent EPT-H | 18.52 |
| Percent Dominant Taxon | 49.07 |
| Percent Chironomidae | 49.07 |
| Hilsenhoff Biotic Index | 5.25 |
| Simpson's Index of Diversity | 0.68 |

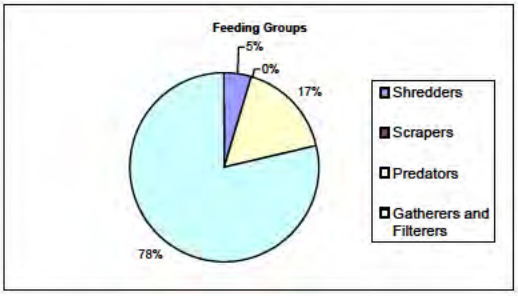
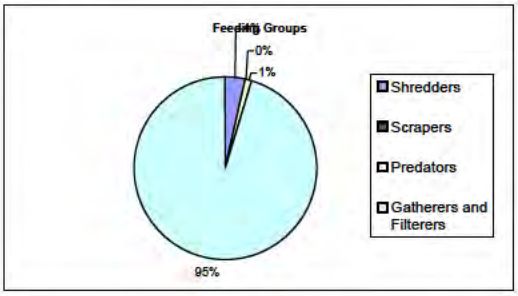



Table 3.5. Station 5 Biological Monitoring Summary

| Order/Major Group | Family | Genus | Common Name | STA5 | FFG | TV |
|---|---|---|---|---|---|---|
| Oligochaeta | Lumbriculidae | - | aquatic earthworm | 5 | CG | 8 |
| Bivalvia | Sphaeriidae | Pisidium | fingernail clam (1) | 2 | CF | 8 |
| Bivalvia | Sphaeriidae | Musculium | fingernail clam (2) | 6 | CF | 8 |
| Amphipoda | Crangonyctidae | Crangonyx | scud | 40 | CG | 6 |
| Isopoda | Asellidae | Caecidotea | sowbug | 35 | CG | 8 |
| Plecoptera | Capniidae | Allocapnia | small winter stonefly | 4 | SH | 1 |
| Diptera | Chironomidae | - | midge | 14 | CG | 6 |
| Trichoptera | Rhyacophilidae | Rhyacophila | freeliving caddis | 1 | PR | 0 |
| | | | | 107 | | |

| | |
|---|---|
| Total Taxa Richness | 8 |
| EPT Richness | 2 |
| Percent EPT-H | 4.67 |
| Percent Dominant Taxon | 37.38 |
| Percent Chironomidae | 13.08 |
| Hilsenhoff Biotic Index | 6.65 |
| Simpson's Index of Diversity | 0.73 |



## A.2 Representative Site Photographs

**Keswick Club Water Quality Monitoring**
**Winter 2010**



**Photograph 1. Station 1 looking upstream.**



**Photograph 2. Station 1 looking downstream.**

**Keswick Club Water Quality Monitoring**
**Winter 2010**



**Photograph 3. Station 2 looking upstream.**



**Photograph 4. Station 2 looking downstream.**



**Photograph 5. Station 3 looking upstream.**



**Photograph 6. Station 3 looking downstream.**

**Keswick Club Water Quality Monitoring**
**Winter 2010**



**Photograph 7. Station 4 looking upstream.**



**Photograph 8. Station 4 looking downstream.**



**Photograph 9. Station 5 looking upstream.**



**Photograph 10. Station 5 looking downstream.**

Enviro Compliance Laboratories, Inc.
10357 Old Keeton Road
Ashland, Virginia 23005-8110
(804)550-3971
Fax: (804)550-3826
www.envirocompliance.com
email: labdirector@envirocompliance.com

## Analytical Summary

Williamsburg Environmental GRP
Attn: Matthew Lajore
3000 Easter Circle
Williamsburg VA 23188

Project Name : Keswicki Country Club
Date Received: December 21, 2010
Date Sampled : December 21, 2010
Time Sampled : 10:40
Date Issued : January 03, 2011

Lab # 1(A-B)/Sample ID : Outfall 001

| Parameter | Result | Units | QL | Date/Time Prepared | Date/Time Analyzed | Method | Analyst |
|---|---|---|---|---|---|---|---|
| TKN | 0.1 | mg/l | .1 | 12-30/1300 | 12-31/1330 | 4500NH3F | AKS |
| Phosphorus (as P) | 0.01 | mg/l | .01 | 12-30/0900 | 12-30/1530 | 4500-P E | AKS |
| Nitrate (as N) | 2.0 | mg/l | .1 | 12-22/1444 | 12-22/1444 | 300.0 | GBH |

Lab # 2(A-B)/Sample ID : Outfall 002

| Parameter | Result | Units | QL | Date/Time Prepared | Date/Time Analyzed | Method | Analyst |
|---|---|---|---|---|---|---|---|
| TKN | 0.3 | mg/l | .1 | 12-30/1300 | 12-31/1330 | 4500NH3F | AKS |
| Phosphorus (as P) | 0.02 | mg/l | .01 | 12-30/0900 | 12-30/1530 | 4500-P E | AKS |
| Nitrate (as N) | 1.9 | mg/l | .1 | 12-22/1444 | 12-22/1444 | 300.0 | GBH |

BQL = Below Quantification Level
All methods are 40 CFR 136 March 12, 2007, Table IB approved.
Reference to Standard Methods is 18th ed.

Rachel A. Young

Greg L. Hudson
Laboratory Director

Report #: ROC89875 Page 1 of 1

NELAP ACCREDITED TNI LABORATORY

VELAP ID#: 460032

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# Analytical Summary

Williamsburg Environmental GRP
Attn: Matthew Lajore
3000 Easter Circle
Williamsburg VA 23188

Date Received: December 22, 2010
Date Issued : January 06, 2011

Lab # 1(A-B)/Sample ID : Outfall 03
Sampled: December 22, 2010 10:15

| Parameter | Result | Units | QL | Date/Time Prepared | Date/Time Analyzed | Method | Analyst |
|---|---|---|---|---|---|---|---|
| Nitrate (as N) | 1.5 | mg/l | .1 | 12-23/1725 | 12-23/1725 | 300.0 | GBH |
| TKN | 0.2 | mg/l | .1 | 01-06/0930 | 01-06/1522 | 4500NH3F | AKS |
| Phosphorus (as P) | 0.03 | mg/l | .01 | 01-06/1000 | 01-06/1330 | 4500-P E | AKS |

Lab # 2(A-B)/Sample ID : Outfall 04
Sampled: December 22, 2010 11:40

| Parameter | Result | Units | QL | Date/Time Prepared | Date/Time Analyzed | Method | Analyst |
|---|---|---|---|---|---|---|---|
| Nitrate (as N) | 1.2 | mg/l | .1 | 12-23/1750 | 12-23/1750 | 300.0 | GBH |
| TKN | 0.3 | mg/l | .1 | 01-06/0930 | 01-06/1522 | 4500NH3F | AKS |
| Phosphorus (as P) | 0.02 | mg/l | .01 | 01-06/1000 | 01-06/1330 | 4500-P E | AKS |

Lab # 3(A-B)/Sample ID : Outfall 05
Sampled: December 22, 2010 13:30

| Parameter | Result | Units | QL | Date/Time Prepared | Date/Time Analyzed | Method | Analyst |
|---|---|---|---|---|---|---|---|
| Nitrate (as N) | 0.3 | mg/l | .1 | 12-23/1802 | 12-23/1802 | 300.0 | GBH |
| TKN | 0.5 | mg/l | .1 | 01-06/0930 | 01-06/1522 | 4500NH3F | AKS |
| Phosphorus (as P) | 0.03 | mg/l | .01 | 01-06/1000 | 01-06/1330 | 4500-P E | AKS |

BQL = Below Quantification Level
All methods are 40 CFR 136 March 12, 2007, Table IB approved.
Reference to Standard Methods is 18th ed.

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Report #: ROC89889 Page 1 of 1

NELAP ACCREDITED TNI LABORATORY

VELAP ID#: 460032

# Appendix B Design Case Studies

## B.1 Design Case Study #1: Lessons in Integrated Drainage Design — Willow Oaks Country Club (George Golf Design)

How futile must it be to defy a river? Can you stop it, outsmart it? These questions faced Willow Oaks Country Club (WOCC) members in 2005. In 1957, golf architects William and David Gordon gave the Richmond club a course to call home. An elegantly simple golf course on the banks of the James River, WOCC grew as a place of leisure and stature. However, after years of flooding, drainage problems, and declining turf conditions, it was time to renovate the course. The answers to their questions lay in listening to the river. They embraced the demands, the nature, the fury, and the beauty of the river. The club embarked on a project that addressed these faults while also infusing a new sense of vigor to the aesthetics, strategy, and playability of the golf course (Figure B-1).

Many significant challenges surfaced throughout the project (Table B-1). One of the greatest obstacles facing the design team was the ill drained, topographically challenged, and oft-flooding nine holes residing in the floodplain of the river. This damage would keep the course closed for weeks, and even minor rain events onsite could cause closures for several days. But drainage was not the only factor in this area. Since working in the floodplain is governed by the City of Richmond for FEMA, no net increase in 100-year flood elevations are allowed. The 100 feet of Resource Protection Area (RPA), overseen by the Virginia DCR Chesapeake Bay Local Assistance Department (CBLAD), buffering along the James River and tributaries limited the work allowed in these areas. Add to these the necessity of respecting the site's natural features that fall under the jurisdiction of the USACE and Virginia DEQ, the likelihood of encountering the same bedrock responsible for the Hollywood Rapids, and the desire to preserve the heritage of the oaks which lend their name to the club—and the path to solutions becomes complex. And all solutions need to be done within a budget. "We wanted to preserve our resources and aggressively address our problems, but in a way that would spend our members' dollars efficiently and ensure our long-term financial viability", said Paul Sinclair, who served two terms as president of the club during the long renovation process.



Figure B-1. Willow Oaks Country Club golf course redesign plan.

And spend wisely they did. The goals of correcting these many deficiencies were sizeable, but with an understanding of the inherent nature and beauty possessed by the site it was possible to integrate the constraints and concerns into one collective solution. The project became a complex exercise in simplicity, where the problems were stripped down to their most basic components. At its core was the river. All solutions must flow from a foundation based on symbiosis with the James River. Fill to elevate some key golf features was part of the plan, but the real answer lay in cutting to take advantage of all available elevation change to the river elevation, providing for surface drainage under normal circumstances, and providing a connective low ground for flood conveyance that would offset the judicious fill. The skeleton of the daily drainage network, this path was conceived as a natural mimicking stream system linking all water onsite eventually back to the river after having refreshed the local water bodies and being

filtered through the low-energy native areas. Once the decision was made to yield a portion of the property back to the James River floodplain on compromising terms all other pieces began to fall into place, allowing Watershed Consulting of Richmond, Virginia to shepherd the project through floodplain permitting.



Figure B-2. Aerial view of Willow Oaks.
*Source:* George Golf Design.

This meandering low-ground gave the designers the advantage of negotiating cut areas away from any key features on the site, namely golf course in-play areas, shallow bedrock, and mature specimen trees. These processes were all implemented in the field by Landscapes Unlimited (GCBAA). Without unnecessary, over-shaped support around the new greens the usefulness and overall function of the drainage patterns were reinforced. Key golf features were constructed to be protected from the river's more frequent flood events while the surrounds and out of play areas were left as sacrificial to the ebb of the powerful river, hence the long, flowing tie-outs. An aesthetic was born of form and function, golf and nature hand in hand.

Selective thinning of trees provided benefits, such as air movement, increased sunlight, and improved turf quality even in the most difficult micro-climates on property. However, this process had a more direct visual impact, exposing the most magnificent and once hidden specimen trees, bolstering pride in the character and feel of the club and revealing historic views through shoots of mature hardwood and pine from the club house steps all the way to the river.

Floods still occur at Willow Oaks Country Club, but the property now responds without sacrificing the quality of the golf course. Waters that used to rip through the golf course during a 5-year flood event, now build from the channelized corridors in a controlled, gentle manner. Flood waters rise and fall in tandem with the James River, as the golf course now sheds water quickly once the river recedes. Most days throughout the year when flooding is not an issue, the drainage system provides relief from local storm events yielding ideal playing characteristics, pristine bunkers, and beautiful turf. Rather than utilizing costly large diameter pipe in an attempt to attain goals the more natural drainage system resulted in a significant cost savings for the project, allowing much of the property to be grassed with sod rather than seed which greatly reduced the risk of erosion. A point of pride for the project, the river was noticeably free of sediment during construction by 80,000 plus daily passersby on the Powhite Parkway Bridge. Habitat onsite is now improved over what was a course already abundant in wildlife. Even Clearance and Jimmy James, the club's resident great blue herons, are enjoying the new watercourses, having never left during construction. Perhaps the two wanted to watch as the partnership between the James River and Willow Oaks Country Club was renewed.



Figure B-3. Green at hole 3 at Willow Oaks Country Club.
*Source:* George Golf Design.

## Design Case Study #1: Willow Oaks Country Club

### Design Challenges

- Poor day-to-day golf course drainage, with small drainage fixes having failed or outlived their usefulness. All existing drainage patterns eliminated or silted in and pond water levels "perched" too high, effectively limiting the natural flow of water.
- No well-defined floodwater outlet combined with flat site left standing water after floods, causing hole closure for several weeks at a time. Unsightly barriers to keep water completely out ineffective and impermissible.
- Maintenance routines dominated by interruptions in care of key golf features and constant corrections for drainage-related issues.
- Although located on a shelf as much as 8 to 12 feet above the river, golf course not taking advantage of true elevation relief, and less than 1% grade over many of the lower holes, less than 0.5% in many areas.
- Extremely poor turf conditions, overall poor golf course playability, and failing *Poa annua* infested greens.
- Dense stands of trees encroached on golf course corridors, contributing to turf decline and playability problems, however, club members wanted to keep the mature feel of a heavily vegetated property.
- Members demanded the project remain cost effective.

### Design Solutions

- Well-defined drainage network connecting various components of surface drainage. Runoff forced to interior drainage networks and away from the RPA, allowing harvest of all available water for stream systems, ponds, and future potential irrigation transfer. Grades over-exaggerated in key areas to counter effects of future silt accumulation. Transformation of drainage patterns required only 150,000 cy of earth moving.
- Proposed streams planned around shallow bedrock from geotechnical boring information and routed into areas to highlight new rock outcroppings where feasible while avoiding key golf areas and specimen trees.
- RPA limits respected and replanted with a native grass treatment.
- Increased wet and dry storage volumes, greatly improving relief across site by removing 50,000 cy of earth from the floodplain.
- Lowered all existing water levels to optimum elevations for drainage and flood storage.
- Implemented innovative bunker mist and green approach irrigation.

### Design Results

- High quality, firm golf course conditions, excellent turf, and improved golf course strategy.
- Well-functioning daily drainage in primary and secondary golf course areas. Golf course closure greatly reduced days after floods, and eliminated for local rain events. Slow controlled velocities during flooding, causing much less turf and structural damage. Quickly exiting floodwaters now tied directly to the crest and fall behavior of the James River.
- Maintenance staff addresses the drainage network seasonally to ensure proper function rather than constantly fixing.
- Increased biodiversity onsite through habitat enhancement and creation.

## B.2 Design Case Study #2: Brownfield Re-Development — Lambert's Point Golf Club (George Golf Design)

While some golf courses boast of spectacular views and ideal locations, not many can also say that they are sitting atop a pile of trash. For Lambert's Point Golf Club in Norfolk, Virginia, the views are not of mountain ranges or long views into the wilderness, but of something completely different (Figure B-4).

On the banks of the historic Elizabeth River as high as 70 feet above the water's edge, golfers can observe tug boats docking tankers, cranes removing cargo from ships at the nearby shipyard, and the bustling of vessels from ports of call across the globe at the world's largest naval port (Figure B-5). That's quite a perch in the low country of the tidewater region. However, the scenery is less than half the story. It is from what these nine holes emerged that begs the greatest attention. Built on top of a 53 acre landfill, all of which was abandoned and unregulated, the 9 hole, par 34 (2800 yards) daily fee executive golf course serves as the new home course for Old Dominion University and its students, as well as many of Hampton Roads' local golf enthusiasts.

A win not only for the City of Norfolk, Lambert's Point has been a triumph from both environmental and design standpoints. Lambert's Point is essentially divided into two sites: one of which occupies 37 acres to the north and another portion of 16 acres to the south. Both areas are separated by a tidal canal that serves as the outlet for a submerged 96 inch effluent pipe from the neighboring Hampton Roads Sewer District (HRSD) treatment facility. From its onset, primary site analysis showed the presence of a highly eroded landfill cap, exposing garbage in several places on the surface. Steep slopes only compounded the problems. Growing concerns over the eroding banks along the water's edge called for immediate action to address environmental and safety related problems. In some instances, "gouging" of the banks was present due to repetitive tidal fluctuations and persistent high waters. The site's on-going devolution and instability prompted oversight by the USACE, intent on correcting the eroding shorelines to limit further erosion and pollution.

The site's condition initially created many hurdles during the design phases of the project as greens, tees, and other such golf features were proposed to be along the water's edge. Of principal concern was addressing shoreline erosion as structural improvements, including a stone and native vegetation treatment, were implemented at the toe of the slope for immediate bank stabilization, allowing time to address a more complete design solution that would ensure total site stability.



Figure B-4. 3rd hole at Lamberts Green.
*Source:* George Golf Design.



Figure B-5. Aerial view. *Source:* George Golf Design.

Above the shoreline, the settling of unstable trash due to high surface traffic, weathering, and erosion made for a constantly changing surface and rendering topographic maps to be highly unreliable (Figure B-6). The project became a "moving target" in both design and construction, requiring constant changes in the field as problems arose by the design team with help from Mid-America Golf & Landscape (GCBAA). The presence of an inconsistent, highly eroded cap forced the design and construction scheme to become very specialized. Cutting below the existing grade was not an option, thus everything had to be built up, and shaped with new relative low points to provide elevation change for fairways, greens, and bunkers. An estimated 140,000 cubic yards of fill were needed to complete the integrated landfill cap and golf features. Trees were not planted and extreme attention was paid to irrigation and drainage installation to eliminate further landfill cap disturbance. The irrigation system at Lambert's Point Golf Club contains a beneficial environmental twist. Additional pipes were marked and put in place in which reclaimed water from the neighboring sewer treatment facility could be used to irrigate the golf course, providing an alternate sustainable irrigation source.

Because of the surrounding market area for golf and because of the nearby university, it was obvious that a high end practice area be incorporated into the design scheme. To combat the challenge of limited acreage with which to work, the designers incorporated a driving range with two-tiered hitting bays into the plan. As a solution to space problems, customers can now enjoy the benefits of year round practice under a heated canopy. In addition, an expansive short game area provides people with ample resources to sharpen their game, often at lunch within a short walk from campus.

Lambert's Point Golf Club is not considered to be a preservation project, but rather a drastic transformation of a severely degraded landscape. With stabilizing turfgrass and natural fescue areas that mimic the links style of golf's origins, the health and vitality of the surrounding areas are on the rise, both environmentally and economically. Pollution to the Elizabeth River from excessive runoff and erosion has been contained, adding vitality to the neighboring waters. From trash to treasure, what used to be a 53 acre eyesore is now a positive, money-making amenity for the City of Norfolk.



Figure B-6. Before. *Source:* George Golf Design.



Figure B-7. 1st green - after. *Source:* George Golf Design.

# B.3 Design Case Study #3: New Course Development — Blue Ridge Shadows Golf Club (Ault Clark and Associates)

Blue Ridge Golf Course is part of an overall golf course home site development that has its own characteristics and circumstances, unlike a stand-alone facility. The course had to be routed in proximity to the home sites to enhance visibility while ever mindful of proper setbacks for safety and liability concerns. A team consisting of environmentalists, engineers, planners, marketing personnel, agronomists, an irrigation designer, and the golf course architect worked together to implement a design. Specific turf varieties were chosen that were best suited for both climate and playability and that could be maintained at a reasonable cost, making the facility sustainable. Concerns in the developable area included storm water runoff, utility easements, roads, buffers, setbacks, E&S measures, and grading operations, all of which directly or indirectly, affected the course design.

A challenge in designing the course was a construction budget of under $2.5 million. A preliminary Master Plan developed for the housing left the block for the golf course in the floodplain area which was unusable for housing, and on the upland areas some of the steepest topography on the site. The Plan identified a core golf course versus one that is integrated with houses on both sides. The floodplain area had been used for pasture and was basically dead flat, and even though it had a beautiful meandering stream flowing through (Crooked Run), would need a series of ponds not only for irrigation but to provide fill material for drainage. In addition, an abundance of topsoil in the floodplain had to be used on the higher holes that lacked sufficient topsoil.

## Design Challenges

Blue Ridge Shadows was the first project where the owners kept the golf course and commercial area and sold the development, as opposed to the other way around. It was also a golf course project to be built in the middle of four existing courses ranging from 36, 27, 18, and 19 holes, so it would have to be the best course in order to compete and succeed. Construction did not begin until over a year and half after the original design and bid was completed.

Without a doubt, one of the biggest challenges was building a player-friendly course on an extremely challenging and limited piece of acreage. The course plays over 7,200 yards from the tips, down to 5,000 from the forward tees (with three intermediate tees) in amongst



Figure B-8. 18th Green. *Source:* Ault Clark and Associates.

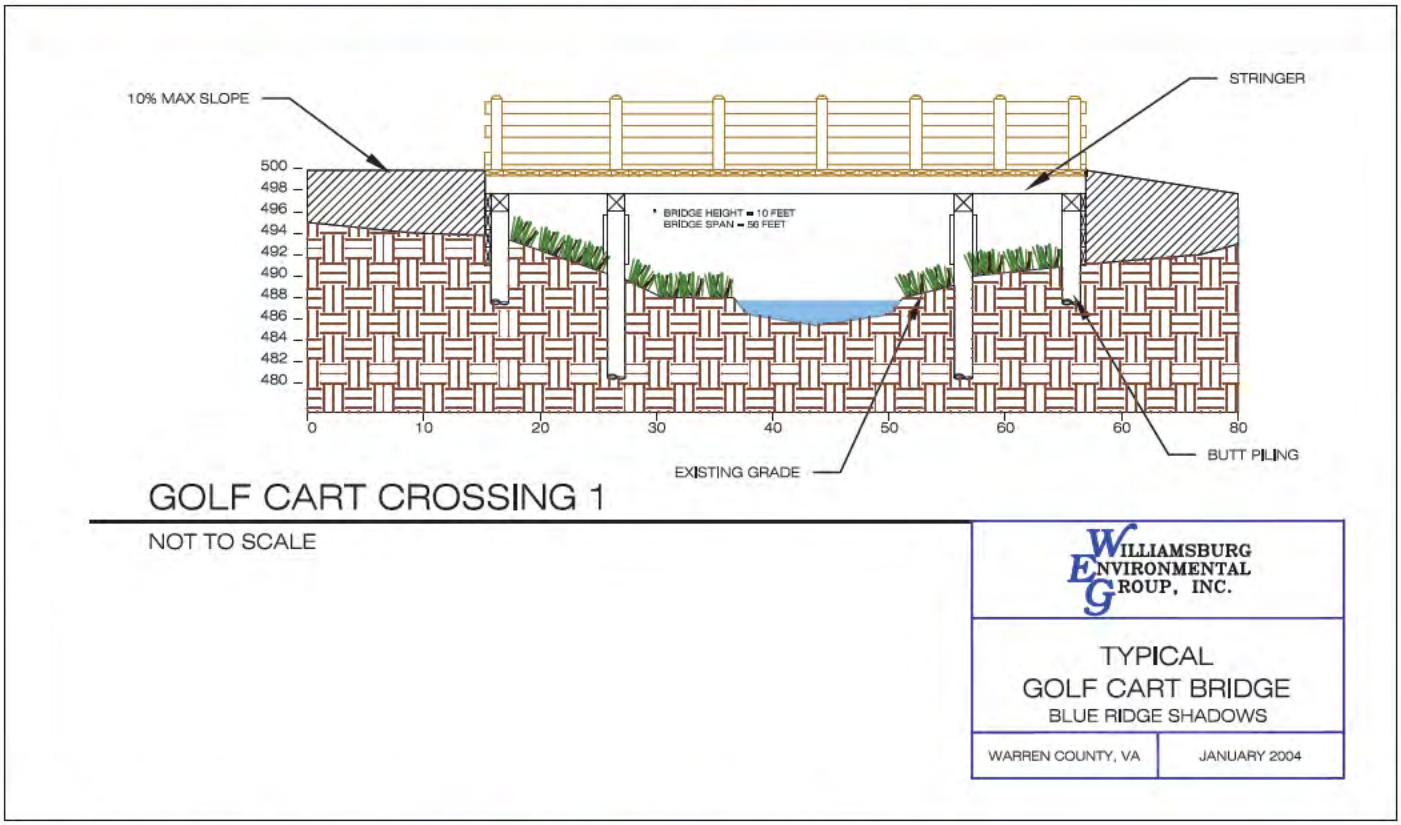
the hardwoods on the upper portion of the property and the creek on the lower. In addition, a waterfall with a recirculating pump behind was added at the 18th green.

A few of the design challenges faced were as follows:

- Keeping the clearing and grading costs on a site to a minimum while still creating a playable course. The upper portion of the site was completely wooded with severe topography and the lower portion needed to be drained and graded.
- Engineering challenges such as temporary access across the stream, location of sediment basins for the development, and wetland area mitigation. In addition, after design and construction plans were completed, it was determined by the engineers that an additional wetland area within the floodplain required some minor reparation, and a mitigation area was developed and monitored. Stream bank mitigation was also needed and buffer areas required due to encroachments into environmental areas within the development.
- Four permanent golf course bridges were needed to cross Crooked Run and each required a span profile with no support in the channel and specified elevation to accommodate flood waters.
- Restrictions on fill material in the practice area so it did not impact an adjoining road.







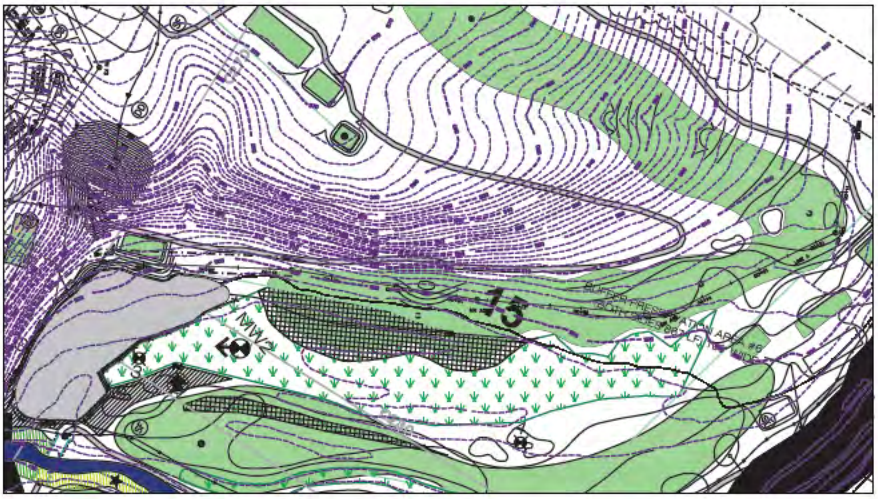

GOLF CART CROSSING 1

NOT TO SCALE

WILLIAMSBURG ENVIRONMENTAL GROUP, INC.

TYPICAL
GOLF CART BRIDGE
BLUE RIDGE SHADOWS

WARREN COUNTY, VA | JANUARY 2004



## Construction Obstacles

Obstacles encountered during construction included the following:

- The vehicular bridge that spanned Crooked Run and serviced not only the development, but the club area as well, was improperly designed and had to be redesigned and permitted, delaying the access and opening of the course for 6 months.

- Several major storm events put the floodplain holes under water during construction.
- Blue shale was encountered in the bottoms of the irrigation lake and had to be blasted. The rock that resulted from the blasting was used to build retaining walls around the greens next to the water features. Also, an imposing waterfall was built above the 13th green using this rock. The first pool is located just below the clubhouse. Three lower pools in which the water cascades down the face of the rocks add to the natural aesthetics of the course. Additionally, rock was used as rip rap along edge of the cart path for safety.
- The subdivision's engineering firm put the subdivision's storm water management ponds in the golf course, tripling the E&S costs. The environmental impacts were compounded as well, resulting in additional stream bank restoration, and wetlands mitigation and buffers.
- The subdivision's engineers had designed the subdivision with a 150,000 cubic yard excess of cut material, which ultimately had to be "wasted" on the golf course. This engineering error impacted the golf course construction in that it turned well-designed golf holes into design/build holes, impacting construction costs.
- The subdivision's sanitary sewer system ran across the golf course on holes # 1, 4 & 9. Due to this issue, redesign work was completed out of sequence after the golf holes were grassed. The sewer lines also required blasting.
- The subdivision's late, out of sequence installation of utilities (gas, telephone cable, electric) damaged golf holes and cart paths, which further burdened efforts to complete the golf course.
- To add further to the challenges of completing this course, Blue Ridge Shadows, LLC requested that United Golf begin mining operations on holes 16 & 17 for fill material for their commercial site, while completing holes for grassing.
- The tees and greens were built above the floodplain elevations.
- Finally - a snow tubing run? The owners wanted a snow tubing run down the side of the driving range. Although tricky to tie in, this may well prove to be a great way for the owners to realize a fair revenue stream in the middle of a cold, Virginia winter.

## Other Notable Challenges

In the owner's proffers it was stipulated that no wells were to be drilled for irrigation as it may affect the aquifer for adjoining homeowners (of which there were two and both houses were purchased by Blue Ridge Shadows LLC). This required excavating three interconnected ponds within the floodplain and obtaining a water withdrawal permit from Crooked Run to recharge the ponds. The transfer pump located in a vault was also used to charge the waterfall that returns back into the stream so as not to have an unattractive elevated building in the middle of the course. A submersible pump on a sled was designed for the irrigation system. The four bridges that were needed to cross Crooked Run all had to be single-span sections and elevated far above the floodplain

The floodplain itself was under federal and state permitting and required HEC2 profiles to ensure that the cut and fills balanced so as not to impede the floodway. There were then buffer areas established along the stream as part of the mitigation effort and several of our ponds received littoral shelves on the non-play side of the holes. There was also stream bank mitigation and within stream reconfiguration required to mitigate the development portion of the site.

## Summary

With all the design and environmental challenges, and obstacles, the team and owners worked together to overcome every hurdle and begin to get the course ready for seeding, sodding, and grow-in. Vince DeStephano, who had served as an assistant at Spy Glass Hill, CA and Shadow Creek, NV, was retained as the superintendent. Partially due to the grasses specified in the design, but most of all because of his maintenance program of low fertility and water use, the course is able to play "firm and fast" as it was intended and the maintenance budget kept in check as costly chemical applications are not necessary.

The one thing that stands out is that even with all the competition from other courses in the area, the course continues to draw players from near and far. Now that the hotel is open, golf packages will be offered in which golfers can stay and play any one of the 4 nearby courses, with the Blue Ridge Shadows being the flagship. Blue Ridge Shadows finished *6th Best New Course in America* in *Golf Digest's* ratings. It is currently ranked *4th Best Course in the State of Virginia* by *Golf Week.*

# Appendix C Calculating PET

## Table C-1. Formulas and conversion data for calculating PET

| | | |
|---|---|---|
| Plant water requirement | = | Weekly peak PET x crop coefficient |
| Effective precipitation | = | Historical precipitation (inches) x .70 |
| 27,154 | = | Gallons per acre inch |
| 325,848 | = | Gallons per acre foot |
| Preliminary net water requirement (in inches) | = | Plant water requirement x number of weeks in irrigation season – effective precipitation |
| Preliminary gross water requirement (in inches) | = | Preliminary net water requirement ÷ system efficiency |
| Seasonal bulk water requirement per acre (in inches) | = | Preliminary gross water requirement x acres of irrigated turf |
| Seasonal bulk water requirement (in gallons) | = | Preliminary gross water requirement x acres of irrigated turf |

# Appendix D Catch Can Tests for Irrigation Audits

## D.1 Catch can test procedures

### Step 1. Gather materials needed.

- Marking flags
- Catch cans / minimum 60 in quantity
- Catch can stands (if they are not integrated with the device)
- Two measuring tapes 100 ft. length
- 200 psi liquid filled pressure gauge
- Digital stop watch
- Two assistants to help with grid layout, timing and measurement readings
- Grid paper with clipboard



Figure D-1. Catch can with stand and measurement readings. *Source:* EC Design, LTD.

Complete irrigation audit kits may be purchased through various suppliers. These kits include all of the materials listed above in a complete kit with carrying case. Most professional catch cans include graduated milliliter measurements on the device for ease of measurement and recording as shown in Figure 5-3.

### Step 2. Locate existing sprinklers.

Using the marking flags, locate the existing sprinklers in the area chosen to test. Any disruption to the spray pattern will distort the test results. Be certain that the spray stream is not obstructed by the marking flag in any way.

### Step 3. Lay out the catch can grid.

Using two 100-foot measuring tapes, locate the center of the area to be tested by laying the tapes out perpendicular to each other. Identify the center and layout the first row of catch cans next to the tape at the determined interval. As a rule, the more catch cans within the grid, the more accurate the result. Triangular or square spacing the catch cans may be used. Ideally, all catch cans will be located within the sprinkler areas. The shape of the area usually determines the best grid layout. A typical grid layout uses the catch can spacing at 10-foot intervals. As an example, an area measuring 100 ft. x 100 ft. with cans spaced at 10-foot intervals may use up to 100 catch cans. Again, the size and shape of the area help determine the specific need. Green layouts should be arranged to include the entire surface including the approach. For fairway areas, a representative portion of the fairway should be chosen. It is recommended that tee areas be tested as a complete group rather than individually.

### Step 4. Obtain Pressure Measurements

Using the 200 psi liquid filled pressure gauge, obtain a measurement of the static water pressure. Static water pressure is the measurement of pressure when there is no movement of water. You can obtain this reading from either a quick coupling valve or through the proper sprinkler hose adapter. Record the static pressure reading.

### Step 5. Operate Sprinklers

As previously mentioned, it is best to conduct a catch can test under the exact same constraints that the system normally operates. Therefore, consider running the exact number of sprinklers simultaneously that best represents the actual planned irrigation schedule. If the sprinklers are usually scheduled to operate individually, then conduct the test with individual operation. If pairing exists, operate the sprinklers in the paired configuration.



Figure D-2. Sprinkler operation during catch can test. *Source:* EC Design, LTD.

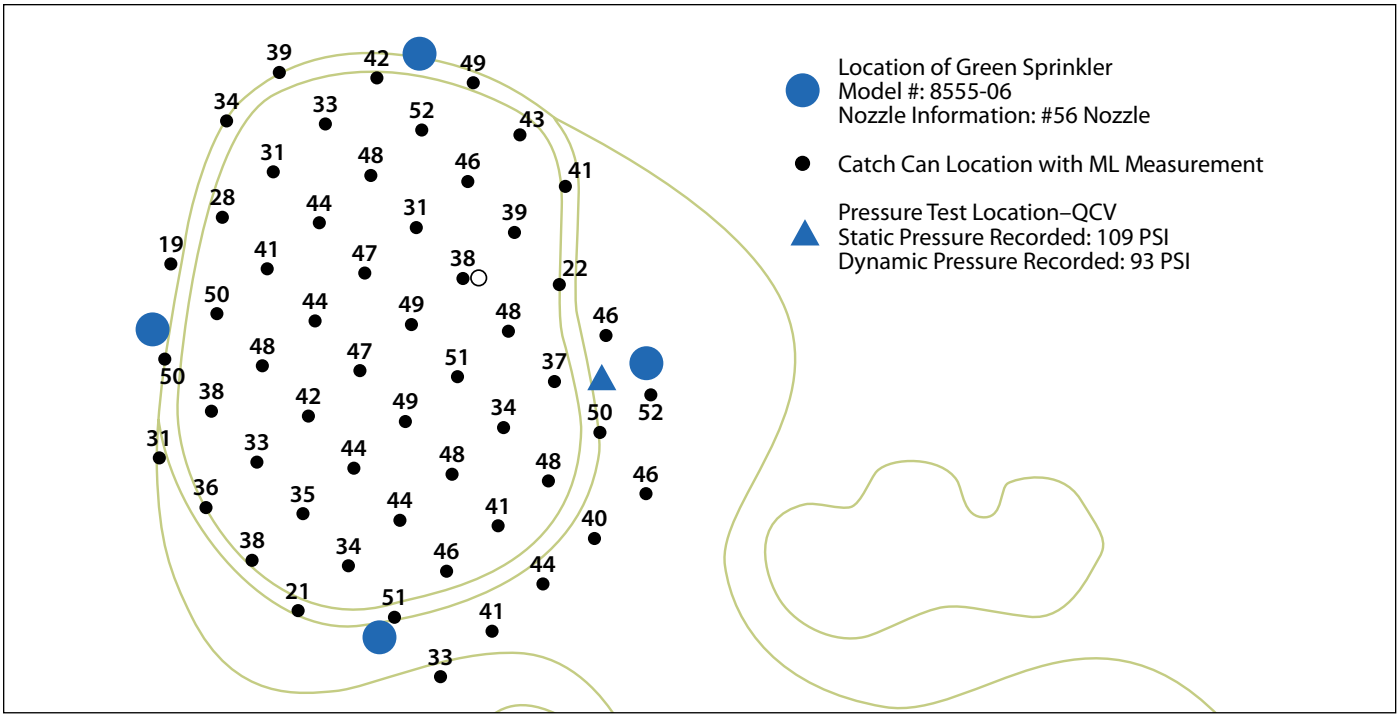



Figure D-3. Sample results of grid collection data, sprinkler information and pressures for green surface.

Be sure to record the start time of sprinkler operation with the digital stopwatch. On average, each rotation takes approximately 3 minutes. This varies by sprinkler manufacturer. Sprinklers that provide consistent rotation times provide the user the greatest ability to accurately schedule irrigation programs. Be sure to be consistent regarding the actual run time applied for the test within the same area. The amount of water captured by the catch can devices is important. The sprinklers need to run long enough to catch a measurable amount of water. In most cases, 3 to 5 rotations of the sprinklers in the area provide enough time to collect the needed amounts. Remember that you are testing for the ratio of dry areas to wet areas so ideally you will have some catch cans with small amounts of measurable water and some that are nearly full. During operation, record the dynamic pressure from a nearby quick coupling valve. At the end of sprinkler operation, record the end of the runtime.

## Step 6. Map Grid Collection Data

Graphically illustrate the data as it is being recorded. It may be helpful to use grid paper and a clipboard for developing field working drawings. If available, GPS equipment may be used to record the location of the catch cans, sprinklers, quick coupling valves and annotate the measurements and notations digitally. Figure D-3 provides an example of grid collection audit results for a green surface.

As much of the areas features should be depicted as possible. If the image resolution is of high quality, aerial photographs may also be used as the base image if scaled accordingly. If sprinkler nozzles are not consistent, notate the nozzle information for each individual sprinkler. It is also a good idea to record any issues such as poor drainage or areas of collecting water.

## Step 7. Map Grid Collection Data

To determine the measurement of Distribution Uniformity (DU), the auditor must summarize the data collected using the following formula:

$$DU_{lq} = \frac{\text{Avg. LQ} \times 100}{V_{avg}}$$

where $DU_{lq}$ = Lower quarter distribution uniformity

Avg. LQ = Average of lower 25% of sample

$V_{avg}$ = Average catch can container volume of all containers

The calculation of distribution uniformity utilizing the lower quarter (DUlq) is the most commonly used calculation to determine uniformity of a sprinkler layout.

Multiple factors affect uniformity including sprinkler design, head layout, system design, installation and actual site conditions. As a result, it is not possible to

achieve 100% uniformity in actual field conditions. Most irrigation systems fall with three primary categories as identified by The Irrigation Association's Certified Golf Course Irrigation Auditor's manual:

- 80% distribution uniformity (excellent, achievable)
- 70% distribution uniformity (good, expected)
- 55% distribution uniformity (poor)

## D.2 Using Test Results

How do you use low quarter distribution uniformity (DUlq)?

This percentage value can be used along with the Run Time Multiplier (RTM) chart (Table D-1) to help determine the amount of run time the area needs to run to apply the adequate amount of water to the driest areas within the audited section.

The RTM table clearly illustrates how areas with poor distribution uniformity require the application of more water. Referencing the previous example, an area of sprinklers providing 62% distribution uniformity will require 30% more water to address the driest portions of the area. Any improvement of measured distribution uniformity will reduce water waste and increase system efficiency.

### Example DUlq Calculation Using 20 Catch Cans

**To determine Avg. LQ:**

Take the total number of catch can devices
(20) x .25 = 5

Add the 5 lowest recorded readings from the catch can devices as follows:

20 + 17 + 18 + 16 + 19 = 90

Next, divide the result of the lowest recorded readings by 5 as follows:

90 / 5 = 18

**To determine Vavg:**

Determine the total amount of water measured and collected in milliliters and divide that figure by the number of catch can devices as follows:

27 + 31 + 36 + 40 + 20 + 20 + 17 + 18 + 16 + 19 + 38 + 32 + 37 + 34 + 35 + 36 + 30 + 33 + 42 + 19 = 580 ml

### Table D-1. Run Time Multiplier (RTM) values

| $DU_{LQ}$ | RTM | $DU_{LQ}$ | RTM | $DU_{LQ}$ | RTM |
|---|---|---|---|---|---|
| 94 | 1.04 | 70 | 1.22 | 44 | 1.51 |
| 92 | 1.05 | 68 | 1.24 | 42 | 1.53 |
| 90 | 1.06 | 66 | 1.26 | 40 | 1.56 |
| 88 | 1.08 | 64 | 1.28 | 39 | 1.58 |
| 86 | 1.09 | 62 | 1.30 | 36 | 1.62 |
| 84 | 1.11 | 58 | 1.32 | 33 | 1.67 |
| 82 | 1.12 | 56 | 1.36 | 30 | 1.72 |
| 80 | 1.14 | 54 | 1.38 | 27 | 1.78 |
| 78 | 1.15 | 52 | 1.40 | 24 | 1.84 |
| 76 | 1.17 | 50 | 1.43 | 21 | 1.90 |
| 74 | 1.18 | 48 | 1.45 | 18 | 1.97 |
| 72 | 1.20 | 46 | 1.48 | 15 | 2.04 |

# Appendix E Example Irrigation Schedules

## E.1 Bermudagrass Fairway on a Silty Clay Loam Soil in July

Estimated ET demand..... 0.9”/wk = 0.13”/day

Effective rooting depth..... 6”

PAW per inch of soil ..... 0.22”

Estimated infiltration rate..... 0.5”/hr

Irrigation zone precipitation rate ..... 1.16”/hr

Irrigation zone DU..... 72% or 0.72

### Procedure for developing irrigation schedules:

#### Step 1.

Determine reservoir of water available to the root system at soil field capacity:

Effective rooting depth X PAW per inch
= 6” x 0.22” = 1.32”

#### Step 2.

Next, determine how dry the surface 2-4” of soil can safely become. Remember, soil moisture is depleted from shallow depths first, so a good rule of thumb to minimize wilting potential between irrigations is to allow 60% depletion of PAW.

Days until 60% depletion of PAW
= (1.32” x 0.60) / 0.15” ET/day = 6 days or run irrigation every 6th day to apply 0.8” of water

#### Step 3.

Determine irrigation minutes required to replace 0.8 inches of water (on even the driest parts of the zone due to poor distribution) used each 6 days:

(0.8” / 1.16”) = 0.96 x 60 minutes = 58 minutes

DU of 0.72

#### Step 4.

Finally, determine number of irrigation cycles needed to replace 0.96 inches of water without wasteful runoff. The soil can absorb about 0.5”/hr, so the longest we can run the zone is:

(1.16”/hr x 0.50”/hr) x 60 min = 35 minutes

Soak cycles needed to avoid runoff
= 58 min / 35 min/cycle = 1.65 cycles

#### Step 5.

One approach to using these numbers would be to schedule one 30 minute cycle every 6 days, followed by one more 28 minute cycle on day 7.

We have yet to discuss what time of day these cycles would be scheduled. Late evening to early morning (8 pm to 6 am) is the best time of day to space various zonal and soak cycles to take advantage of four factors: first, wind is usually low providing more uniform head to head coverage; second, no golfers are around to be bothered by the irrigation; third, the larger droplets applied via irrigation actually knocks sugary dew off the leaf, reducing a food source and the leaf wetness period required for best disease development; and fourth, evaporative demand from the sun and wind are minimized providing more efficient soil moisture recharge.

## E.2 Creeping Bentgrass Green on a Sandy Soil in July

Estimated ET demand..... 1.10”/wk = 0.16”/day

Effective rooting depth..... 2”

PAW per inch of soil ..... 0.08”

Estimated infiltration rate..... 4”/hr

Irrigation zone precipitation rate ..... 0.9”/hr

Irrigation zone DU..... 80% or 0.80

#### Step 1.

Determine reservoir of water available to the root system at soil field capacity:

Effective rooting depth X PAW per inch
= 2” x 0.08” = 0.16”

#### Step 2.

Next, determine how dry you can safely allow your surface 0-2” soil to get. Remember, soil moisture is depleted from shallow depths first, so a good rule of thumb to minimize wilting potential between irrigations is to allow 60% depletion of PAW.

Days until 60% depletion of PAW
= (0.16” x 0.60) / 0.10” ET/day = 0.63 days or irrigate every day and supplement with hand-watering and syringe cycles in July.

### Step 3.

Determine irrigation minutes required to replace 0.16" of water (on even the driest parts of the zone due to poor distribution) used every day:

(0.16" / 0.9") = 0.22" x 60 minutes = 13 minutes

DU of 0.80

### Step 4.

Finally, no soak cycles are needed as the sand root zone infiltration rate is estimated to be 4"/hr or greater and we only need to run the heads long enough to supply 0.22" in the areas of heaviest overlap.

## E.3 Summary

In summary, the deep and infrequent irrigation approach for this shallow-rooted creeping bentgrass green will be to irrigate in some manner every day in the heat of the summer. This type of irrigation schedule does not seem to be very "deep and infrequent", but it is what is required to maintain health and responsibly apply irrigation to this shallow rooted-species. The key is to go through this exercise to fine-tune the number of minutes needed each night so that chronic over-watering does not occur; a situation that increases potential for wet wilt and disease development.

# Appendix F Turf and Landscape Nutrient Management Planning

This Appendix emphasizes the actual steps that a certified nutrient management planner will use in developing and implementing a nutrient management plan (NMP). Utilizing the data and recommendations provided in an NMP promotes water quality protection. However, equally important results of an NMP are its value as a comprehensive tool in planning fertilizer selections and application strategies in terms of optimizing plant responses, nutrient use efficiency, and economics. While these criteria were specifically developed for the state of Virginia, the principles will apply to any state in the mid-Atlantic. It should be noted that only planners certified by State of Virginia are allowed to write official Nutrient Management Plans. For more information on certification, contact the DCR or visit the certification website.

### The primary nutrient management planning steps are as follows:

#### Step 1.

Determine reservoir of water available to the root system at soil field. Collect and evaluate information about the overall area to be planned.

#### Step 2.

Determine realistic expectations of planting's performance with known conditions, such as soil fertility levels, and adaptation of plant species to the area and for the intended use.

#### Step 3.

Establish nutrient requirements for the plant species in each area to be planned.

#### Step 4.

Evaluate planting area limitations based on environmental site sensitivity or other plan implementation concerns.

#### Step 5.

Allocate purchased and any onsite nutrient sources, if any, to available planned areas.

#### Step 6.

Identify nutrient timing and placement methods to maximize nutrient use by plantings and minimize environmental losses.

Prior to initiating plan development, it is critical to obtain some information about the current management practices. This process of inventorying resources and needs is critical to developing a sound and implementable agronomical plan that improves water quality.

## F.1 Assessment of Planned Areas

### F.1.1 Land

A planned area is land that will be managed and fertilized as one distinct unit. It will usually be defined by the type of planting it contains, such as turf or bedding plants. How many planned areas will be needed to address various plant species? How much area is in each of these planned areas? What is the present use of these areas? If they are being used for turf or annual or perennial bedding plants, will that use continue or will the areas be renovated to something else?

### F.1.2 Equipment Resources

Once you know what is normally (or expected) to be done in each planned area, knowing what type of equipment, if any, your client has will be helpful when developing recommendations. Does your client have seeding equipment, fertilizer spreaders, aerators, sprayers, or tillage equipment? What are the limitations of these machines? You need to consider the availability of equipment when recommending certain management operations, and if unavailable is there an alternative operation that will be acceptable?

### F.1.3 Past Methods of Fertilizer Application

The use of commercial fertilizer is a similar consideration. You need to know the client's current fertilization program. The rate and timing of applications are important considerations for plan development. Also be certain to determine how much custom application is done and by whom. If the landowner is a steady customer of a particular dealer, his application capabilities and limitations should be considered, if possible, when developing the final plan.

### F.1.4 Soil Resource Assessments

The most important resource to consider when developing a plan is the soil, or combination of soils, and the location within the landscape of each planned area. For undisturbed areas a soil survey is used to determine the predominant

soils in the planned areas. Consider the expected outcomes in trying to grow the various plant species your client wants. If the soils in the planned area have been heavily excavated, what type of soil is present and how deep is it? This may come down to identifying the soil by its texture and physically assessing the soil horizons and any restrictive characteristics that will limit or even prohibit successful plantings. Steep slopes that are prone to erosion or light textured soils subject to leaching are two possible examples. These types of factors obviously affect satisfactory seeding, but are also additional considerations in developing a thorough plan. Of course a current soil test will also be important as part of this evaluation.

## F.1.5 Nutrient Resources

Soil testing is critical to nutrient management planning in determining the plant's likely response to applied nutrients and in determining soil pH for lime needs. The use of water soluble fertilizer, slow release materials, and even manures, waste water, and biosolids needs to be considered in your recommendations regarding timing and rate of applications. You will have preferred materials you would like used; however, your client may have products in stock, or a source of these materials he may need to use. Know the options you have available to use various materials in the following years, educate your client about the advantages and disadvantages of available materials for his operation. Ultimately it will be the client's decision what is used, so to facilitate plan implementation, try to use as many "client preferred" materials as possible.

## F.1.6 Nutrient Requirements for Species in Each Planned Area

Once soils are tested, nutrient recommendations for the plant species in each planned area can be determined by utilizing the tables in *Virginia Nutrient Management Standards and Criteria* (DCR 2005). If the plant species is not contained in Standards and Criteria, use Virginia Cooperative Extension publications or other sources that specifically address management of that species. When a publication is used for this purpose, it should be noted in the Plan Narrative or noted as a recommendation source on the balance sheet of the plan.

## F.1.7 Environmentally Sensitive Sites

The presence of environmentally sensitive sites is an important consideration. An environmentally sensitive site means any managed area which is particularly susceptible to nutrient loss to groundwater or surface water since it contains, or drains to areas which contain sinkholes, or where at least 33% of the area in a specific management area contains one or any combination of the following features:

- soils with high potential for leaching based on soil texture or excessive drainage
- shallow soils less than 41 inches deep likely to be located over fractured or limestone
- bedrock
- subsurface tile drains
- soils with high potential for subsurface lateral flow based on soil texture and poor
- drainage
- floodplains as identified by soils prone to frequent flooding in county soil surveys
- lands with slopes greater than 15%.

Existing BMPs installed to protect such areas should be noted to ensure their protection and maintenance. The plan writer should also consider the need for recommending additional measures to protect water quality whenever necessary. It is critical that an actual site visit be made to all planned areas that will receive any type of nutrient applications. This is necessary to check for environmentally sensitive areas and to check the general terrain of the application sites. Maps in the plan should clearly identify all environmentally sensitive sites.

## F.1.8 Allocation of Nutrients to Planned Areas

After considering nutrient needs for each planned area and environmentally sensitive areas, fertilizer applications should be made to meet nutrient needs or to supplement deficiencies in meeting the nutrient needs when other sources of nutrients have been applied first.

Plans should be written on a nitrogen and phosphorus basis. It is important that nutrient applications be prioritized to meet plan requirements. Nitrogen recommendations should not exceed the need determined by *Virginia Nutrient Management Standards and Criteria* (DCR 2005) or other appropriate resource as discussed. Soil test levels should be used to make phosphorus and potassium recommendations.

## F.2 Background Information

An initial visit is important because the complete and detailed information collected at this time will reduce the number of return visits or calls needed. Plan ahead and be organized. Make an appointment with your client and let him know this will take may take several hours or more so he can schedule the time. Also let him know what information you will need so he can have it ready when you arrive. The following pages contain an example of an approach for collecting background information. It may not be necessary in all cases but could be helpful when working with a client for the first time.

### General Information

Date of Visit ____/____/____

Owner Name _____ Phone _____

Manager/Superintendent _____ Phone _____

Address _____

City/State/Zip _____

Extension Agent _____ Phone _____

Fertilizer Supplier _____ Phone _____

Salesman _____ Phone _____

Consultant _____ Phone _____

Are you scheduled to receive biosolids or other organic nutrient sources? ❑ Yes ❑ No

If yes, Supplier _____

Field Representative _____ Phone _____

Who takes soil samples? ❑ Client ❑ Fertilizer Dealer ❑ Consultant ❑ Other

At what interval are soil samples taken? ❑ 1 yr ❑ 2 yrs ❑ 3 yrs

Do you have current samples of all areas to be included in Plan? ❑ Yes ❑ No

What lab is used? ❑ VT ❑ $A_{\&}L$ ❑ Spectrum ❑ Waters ❑ Other

Who makes recommendations? ❑ Extension ❑ Laboratory ❑ Fertilizer Dealer ❑ Consultant ❑ Yourself

Are tissue samples taken? ❑ Yes ❑ No

What plant species? _____

### General Nutrient Application for Each Plant Species (lbs/acre plant food)

| Plant Species | Rate/Month | Rate/Month | Rate/Month | Rate/Month |
|---|---|---|---|---|
| Bermuda | | | | |
| Turftype tall fescue | | | | |
| Flowering Annuals | | | | |
| Other | | | | |

## Management Area Information

Owner_____ _____ Date_____

Operation Name_____ Location _____

| Management Area Designation ID | Sq Ft or Acres | Present Plant Species | Renovate to New Species | Last Lime Application Rate Month/Yr. |
|---|---|---|---|---|
| | | | | |
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## F.3 Components of a Nutrient Management Plan (NMP)

A complete NMP is designed for proper management of nutrients using proper application rates and timing specific for the species of plant in each management area. Following the plan will result in a cost effective and environmentally sound use of plant nutrients. A plan may also be used to document the proper rate and timing of nutrient applications. This documentation is used to report the urban community's progress in protecting and improving water quality. A description of the components of a NMP is outlined in the Nutrient Management Training and Certification Regulations (4 VAC 5-15). The following information offers a brief outline and explanation of the various parts of a plan. All plans must be written to the criteria set forth in the regulations.

### F.3.1 Plan Identification Sheet

The plan identification sheet is just what it sounds like. It is a page at the front of the plan which contains information such as the client's name and address, planner's name and certificate number and county and watershed code for the operation. Information about the square footage or acreage of each plant species are included to give a snapshot view of the plan.

### F.3.2 Narrative

Use this section to describe the operation, and to assist with tailoring the plan to the individual. Describe the type of operation, (athletic field, golf course, recreation area, etc.). A description of the location naming common landmarks, route numbers, will be helpful to identify the operation on a map, or for another planner to drive to the operation.

A general description of the management of each plant species in the operation should be included in the narrative.

Make note of the proximity of fields to streams, erosion control, environmentally sensitive areas, etc. and what precautions address each issue. Give directions on where additional help can be obtained for other operation management and water quality objectives that are beyond

the scope of this plan. Write statements that are clear, concise, and to the point. If some information is already included on the balance sheet (e.g., timing, testing, renovation) it is not necessary to include it in the narrative.

### F.3.3 Plan Map

Use a copy of an aerial photograph whenever possible. Generally these photographs will show established planned area boundaries, and should be a good reference to identify these areas as they are listed in the plan. If aerial photos are not available, take the time to draw a clear, neat map. This map should show planned area identification designations, environmentally sensitive areas (i.e., wells, erosion control structures, drainage ways) and anything else you feel is important to minimize the impact of nutrient application to the environment.

A legend should explain any symbols used on the plan map. It can be on the map itself or included on a separate sheet directly following the map.

### F.3.4 Soil Map

Soil maps for the operation should be included when there is considerable acreage in the plan and the land for the most part is undisturbed. Delineate the outside boundaries of the operation matching those used on the plan maps.

### F.3.5 Nutrient Application Window

Timing of nutrient applications is very important. Virginia Tech has two publications which give the client a quick view of when various operations in turf maintenance should be occurring throughout the year. This information may be helpful when clients are putting together a plan implementation strategy.

### F.3.6 Organic Nutrient Sources

Calculating nutrient availability from land applied organic materials is an important component of a NMP. Most organic materials will either be animal manures or biosolids. A detailed discussion and examples of calculating nutrient availability is covered in *Virginia Nutrient Management Standards and Criteria* (DCR 2005 pp. 109-110 and 117). Refer to this section to become familiar with the formulas and proper coefficients to be used on each planned management area receiving organic nutrient sources. Once the plant available N, $P_2O_5$, and $K_2O$ have been calculated, the nutrients supplied from the organic material application are deducted from the Nutrient Needs for the plant species to which the material was applied, and subsequent residual N credit is given to following spring plant species nitrogen needs.

### F.3.7 Nutrient Worksheet

The nutrient worksheet on the next page was developed in order to provide the client with a ready reference regarding nutrient management recommendations.

### F.3.8 Assistance Notes

Use this sheet to record what transpired during your first and follow-up client visits. Write about such things as alternatives you provided, decisions made based on unusual circumstances, progress on plan implementation, or unusual circumstances anyone should be familiar with when visiting the client. These notes will help you and your successor understand what has already been discussed and what needs further discussion. These notes should only be kept in **your** copy of the NMP.

## Nutrient Application Worksheet

Name_____ Management Area Identification _____

Turf Species_____ Prepared ____/____/____ Expires ____/____/____

Square Feet_____ Landscape Plants_____

| Nutrient Needs Lbs/1,000 Sq. Ft. $N\text{-}P_2O_5\text{-}K_2O$ | Application Month/Year | Fertilizer Material $N\text{-}P_2O_5\text{-}K_2O$ / Lbs/1,000 Sq. Ft. | % Slowly available N |
|---|---|---|---|
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

| Nitrogen Lbs/1,000 Sq. Ft. | $P_2O_5$ Lbs/1,000 Sq. Ft. | $K_2O$ Lbs/1,000 Sq. Ft. | Lime Recommendation Lbs/1,000 Sq. Ft. |
|---|---|---|---|
| | | | |
| | | | |
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| | | | |

**Notes:**

## Worksheet Header Columns Description

### Name

Owner's name, the date the plan was prepared and the date it expires are in the first column of the header.

### Managed Area Identification

The second column in the header has the identification of the managed area and the area as per 1,000 square feet or per acre. The managed area identification designation needs to exactly match the labeling as the areas appear on the plan map. They can be grouped in any order which you feel best suits the client's operation. Separate recommendations should be made for each individual planned area, unless two or more areas are managed similarly and soil test levels are similar.

### Turf Species

The third column in the header identifies the plant species in the management area for which the recommendations are being made as either turf or landscape materials.

## Worksheet Table Columns Description

### Note

All recommendations should be designated on a per 1,000 square feet or acre basis.

### Nutrient Needs

The nutrient needs represent the total N, $P_2O_5$, and $K_2O$ for an annual application. Recommendations should be based upon soil test results for phosphorus and potassium for each plant species. Nitrogen recommendations should be based on those contained in Standards and Criteria or a referenced resource document.

### Application Month/Year

There may be several applications of nutrients per year depending on the species being fertilized. This column allows the planner to designate the months in which the nutrient applications should be applied. This column allows the planner to use the worksheet in two ways:

- If the management areas are small and will be receiving the same applications for each year of the plan, only the month for the application needs to be entered and then a note on the worksheet explaining that this annual application program is applicable for all the years of the plan.
- If the recommendations will vary from year to year, then the month and year can be entered in this column in a calendar year type sequence. This will probably increase the number of worksheets in the plan, but is acceptable when needed to convey the specific applications needed to achieve desired soil fertility levels in the management area.

### Fertilizer Material N-$P_2O_5$-$K_2O$

This column identifies the fertilizer material and rate which should be applied at the designated time period.

### % Slowly available N

This column is used to identify the amount of slowly available nitrogen in the material recommended (Note: slowly available N is defined in Chapter 8 of this manual).

### Nitrogen (lbs/1,000 square feet or lbs/acre)

This is the amount of plant-available nitrogen supplied by the designated fertilizer material application.

### $P_2O_5$ (lbs/1,000 square feet or lbs/acre)

This is the amount of plant-available phosphorus, expressed as phosphate, which is supplied by the designated fertilizer material application.

### $K_2O$ (lbs/1,000 square feet or lbs/acre)

This is the amount of plant-available potassium, expressed as potash, which is supplied by the designated fertilizer material application.

### Lime Recommendation (lbs/1,000 square feet or lbs/acre)

This is the amount of lime recommended for the management area. Most times this recommendation may be the only material application designated and thus it will have it own Application Month/Year as it will probably be applied at a different time than fertilizer materials.

### Notes

Special considerations regarding nutrient application, special conditions in the managed area, tillage practices, etc. can be footnoted here.

## F.3.9 Personal Plan Notes

This is where **your** personal notes and calculations should be recorded. This will be important and very helpful to you because in some cases you may not be updating plans for two or three years, depending upon the expiration date of the plan. You may need some reminders of how and why you wrote the plan. You should keep a record showing details of how the recommendations were derived. Any special condition or unusual circumstances that existed at the time the plan is written should be documented so that it can be referred to when reviewing the plan at a later date, or to justify specific recommendations during an inspection.

# F.4 Sample Nutrient Management Plan

This section provides an example NMP and discussion of the sample plan.

## NUTRIENT MANAGEMENT PLAN IDENTIFICATION

**Owner**

*Amherst Golf Course*

*Route 151*

*Clifford, Va 24533*

**Land Manager**

John Smith

**Watershed Summary**

Watershed: JM29

County: Amherst

**Nutrient Management Planner**

John Smith

Courthouse Plaza

Suite #5

Hanover, VA 22555

Certification Code: 100

**Acreage Use Summary**

Total Acreage in this plan: 36.1

Greens: 1.5

Fairways: 15

Tees: 2

Maintained Rough: 15

Other Turf: 2.5

Planting Beds: .1

*Plan written 3/18/10*

*Valid until 3/18/13*

Planner Signature: _____

## Narrative for Amherst Golf Course Amherst, VA

Amherst Golf Course is located north of the Town of Amherst, on Rt. 151, about 1 mile from Rt. 29. The 9-hole golf course is open year round and is very busy. Course conditions are maintained at a high level with a relatively small budget with the greens receiving the most attention.

The greens are sand based with Pencross and L93 bentgrass. Tees are topped with sand and have Vamont Burmudagrass that is overseeded in the winter. Fairways are Vamont Bermudagrass and are not overseeded. The golf course maintains about 10 yards of rough around the fairways and greens. These areas are a mixture of tall fescue and bluegrass. The fairway and rough areas are various remnants of clay loams and loams. Most areas of the course that are not improved soils were disturbed when the course was shaped. All of these areas receive irrigation regularly. The rest of the turf area on the course is not fertilized and is mowed as needed. Some areas of the course are "naturalized" and harvested for hay or mowed at 6" height for aesthetic appearances 1-2 times per year.

The club also maintains about 2.5 acres of clubhouse grounds and a small perennial bed. These areas are not irrigated but are fertilized and maintained to a high level.

A buffer area is maintained around the water features on the course. Fertilizers are not applied within 25-50 feet of the creek, pond and lake on the left of hole 7. The 8$^{th}$ tee is within 10 feet of the lake, and is fertilized carefully with a rotary spreader equipped with a side guard to ensure no fertilizer is applied to the rough surrounding the tee surface. About a 5 foot buffer of 6-8 inch grass is maintained along the edge of the lake with several feet of pond grasses planted along the bank.

In order to save money for this low budget course, soil tests were taken on every third hole for the tees, fairways and rough. Holes 1, 4 and 7 were sampled. All greens were sampled.

The course has equipment to apply fertilizers to large areas, but does not buy in bulk. All fertilizers used in the plan are available in 50 lb. bags.

The worksheets in this plan represent recommendations for each management area for the next three years. Applications will be repeated each year at the same designated times. Lime recommendations are only for one application, and designated date includes the

year to be applied. This plan is written for a three year period and will need to be revised at that time to remain current. Revising a plan takes some time, so the process should begin at least four weeks or more prior to the plan expiration date.

**The following management practices should be used where appropriate to protect water quality and enable the client to better implement a nutrient management plan.**

1. Soil samples should be analyzed at least once every three (3) years for pH, phosphorus, potassium, calcium, and magnesium in order to maximize the efficient utilization of nutrients. A representative soil sample of each management area should be comprised of at least 20 cores randomly sampled throughout the area. Soil sampling core depth will be six inches deep from the surface. Soil pH should be maintained at appropriate agronomic levels to promote optimum plant growth and nutrient utilization.
2. Spreader calibration is extremely critical to ensure proper application rates.
3. A protective cover of appropriate vegetation should be established and maintained on all disturbed areas. Vegetation such as trees, shrubs, and other woody species are limited to areas considered to be appropriate such as wind breaks or visual screens.
4. This nutrient management plan should be revised **at least once every three (3) years** to make adjustments for needed renovations, re-establishment of turf around construction projects, and updated soil test information.
5. If clippings are collected they should be disposed of properly. They may be composted or spread uniformly as a thin layer over other turf areas or areas where the nutrient content of the clippings can be recycled through actively growing plants. They should not be blown onto impervious surfaces or surface waters, dumped down stormwater drains, or piled outside where rainwater will leach out the nutrients creating the potential for nutrient loss to the environment.
6. Iron applications (particularly foliar applications) may periodically be used for enhanced greening as an alternative to nitrogen. These applications are most beneficial if applied in late spring through summer for cool season grasses and in late summer/fall applications for warm-season grasses.
7. Do not apply fertilizers containing nitrogen or phosphorus to impervious surfaces (sidewalks, streets, etc.). Remove any granular materials that land on impervious surfaces by sweeping and collecting, and either put the collected material back in the bag, or spread it onto the turf and /or using a leaf blower etc. to return the fertilizer back to the turfgrass canopy.
8. These conditions do not override any local or county ordinances that may be more restrictive.

# Amherst Golf Course Soil Test Summary Report

**Lab: Virginia Tech**

**Sample Date: March 9, 2010**

| Managed Area I.D. | Area Square Feet | $P_2O_5$ - lbs/ac | $K_2O$ - lbs/ac | Soil pH | Buffer Index | Turf Species | Nutrient Needs |
|---|---|---|---|---|---|---|---|
| G 1 | 7,000 | 22 / M | 54 / L | 6.1 | 6.89 | Bentgrass | 6-1.5-2.5 |
| G 2 | 8,000 | 27 / M | 39 / L | 6.0 | 6.88 | Bentgrass | 6-1.5-2.5 |
| G 3 | 7,500 | 59 / H | 6 / L- | 6.1 | 6.89 | Bentgrass | 6-.75-3 |
| G 4 | 6,500 | 65 / H | 3 / L- | 6.0 | 6.89 | Bentgrass | 6-.75-3 |
| G 5 | 8,500 | 75 / H | 46 / L | 6.1 | 6.89 | Bentgrass | 6-.75-2.5 |
| G 6 | 7,000 | 19 / M | 53 / L | 6.5 | 6.91 | Bentgrass | 6-1.5-2.5 |
| G 7 | 6,000 | 65 / H | 35 / L | 6.3 | 6.90 | Bentgrass | 6-.75-2.5 |
| G 8 | 7,500 | 25 / M | 47 / L | 6.3 | 6.90 | Bentgrass | 6-1.5-2.5 |
| G 9 | 7,000 | 29 / M | 17 / L | 6.2 | 6.89 | Bentgrass | 6-1.5-2.5 |
| T 1 | 10,000 | 263 / H+ | 258 / H | 7.2 | N/A | Bermuda/rye | 5-0-.75 |
| T 4 | 10,000 | 277 / H+ | 275 / H | 7.3 | N/A | Bermuda/rye | 5-0-.75 |
| T 7 | 10,000 | 98 / H+ | 304 / H+ | 7.6 | N/A | Bermuda/rye | 5-0-0 |
| F1 | 87,120 | 27 / M | 417 / H+ | 6.5 | 6.31 | Bermuda | 4-1.5-0 |
| F 4 | 65,340 | 34 / M | 393 / H+ | 6.0 | 6.18 | Bermuda | 4-1.5-0 |
| F 7 | 43,560 | 29 / M | 420 / H+ | 6.2 | 6.22 | Bermuda | 4-1.5-0 |
| R 1 | 43,560 | 22 / M | 365 / H+ | 6.5 | 6.33 | Fescue/Blue | 3-1.5-0 |
| R 4 | 43,560 | 7 / L | 303 / H | 5.9 | 6.14 | Fescue/Blue | 3-2.5-.75 |
| R 7 | 43,560 | 6 / L | 421 / H+ | 6.4 | 6.25 | Fescue/Blue | 3-2.5-0 |
| Flowers | 4,000 | 14 / M- | 78 / M- | 6.0 | 6.21 | Perennials | 1.25-1-1 |
| Clubhouse | 108,900 | 10 / L | 73 / L | 5.8 | 6.14 | Tall Fescue | 3-2.5-2.5 |

## Nutrient Application Worksheet

Name Amherst Golf Course  Management Area Identification Fairways

Turf Species Bermudagrass  Prepared 3 / 18 / 10  Expires 3 / 18 / 13

Square Feet 15 acres  Landscape Plants -------

| Nutrient Needs Lbs/1,000 Sq. Ft. $N\text{-}P_2O_5\text{-}K_2O$ | Application Month/Year | Fertilizer Material $N\text{-}P_2O_5\text{-}K_2O$ / Lbs/1,000 Sq. Ft. | % Slowly available N |
|---|---|---|---|
| 4-1.5-0 | 5/15 | 46-0-0<br>1.0 lb/1,000 | 0% |
| | 6/1 | 18-46-0<br>3.26 lb/1,000 | 0% |
| | 7/1 | 34-0-0 | 30% |
| | 8/1 | 34-0-0 | 30% |
| | 9/1 | 34-0-0 | 30% |

| Nitrogen Lbs/1,000 Sq. Ft. | $P_2O_5$ Lbs/1,000 Sq. Ft. | $K_2O$ Lbs/1,000 Sq. Ft. | Lime Recommendation Lbs/1,000 Sq. Ft. |
|---|---|---|---|
| 0.4 | 0 | 0 | - |
| 0.6 | 1.5 | 0 | - |
| 1 | 0 | 0 | - |
| 1 | 0 | 0 | - |
| 1 | 0 | 0 | - |

**Notes:** Initial application should coincide with sustained bermudagrass greenup, after last killing frost. Repeat all applications yearly for the duration of the plan.

## F.4.1 NMP Sample Plan Discussion

The following discussion is NOT part of an actual plan; it is to help the reader understand what information was used to write this plan and the reasoning behind some of the recommendations.

The pages are a short example of how a plan should read. All areas outlined in the soil test summary should have their own application worksheet. Like areas can be combined as was done with the fairways. While soil tests will not always be the same, work to meet the needs of the best soil test with a program for all areas. A particular green, fairway, or tee may need additional lime, $P_2O_5$ or $K_2O$ applications which can be outlined a separate worksheet for that area.

Soil testing is recommended for each individual green, tee or fairway as management practices and environments differ. But in cost saving efforts it is allowable for every third hole to be sampled. For roughs, the maximum area to be represented by a single sample is 20 acres. When using one sample to represent multiple areas, be sure to group areas which are managed similarly and have similar soils.

When you begin to work with clients, they may have some fertilizer materials on hand they want to use before buying other products. So you may be forced to use some analysis that does not exactly match your recommendations. Try to use as few of products as possible to make the plan a little easier for your client to follow. You will also want to discuss fertilizer preferences with your clients; they may be partial to a particular product, granule size, or release mode. Give the property manager plenty of opportunities to make suggestions/changes before the plan is finalized. The more they feel the plan is "theirs", the more likely it is to be implemented. To aid in understanding the recommendations in the example plan the following specimen labels were used.

For all turf areas, the nutrient needs were determined using the *Virginia Nutrient Management Standards and Criteria* (DCR 2005). The nitrogen program follows the highest levels allowed for golf courses found (DCR 2005, p. 100). Flexibility is important in golf course planning. Weather conditions, disease pressure and budgetary concerns all can influence the amount of nitrogen to be used in a particular year. Building flexibility into a plan gives the land manager options, making it easier and more likely for the plan to be followed. The phosphorus and potash recommendations are from soil test results. Recommendations for golf courses can be found in *Virginia Nutrient Management Standards and Criteria* (DCR 2005 page 102).

Lime applications are shown on the worksheets as well. It was easy to just list the lime material and show the application rate in the far right column. If you find that lime needs vary greatly, a separate lime application table maybe used listing how much lime is needed for each area to reach its target pH. Discuss target pH with your client. In today's golf courses, everything is micro managed. While optimal pH for turfgrass may be between 5.5 and 6.5, your client may have a specific pH in mind.

Since the recommendations for each year of the three year plan are similar, one worksheet was developed for each managed area and labeled to be good for three years - see "Prepared and Expires" dates in the first column of the header section of the worksheet. If the managed areas would have had significantly different fertility for each of the three years, then the planner may choose to develop a worksheet for each management area for each year. Using the worksheets for either option is acceptable; fill them out so that it is clear to the client what needs to be done and when.

The recommendations for the flower bed area shows a nitrogen application and the phosphorus and potash recommendations based on a soil test. While perhaps not necessary, this adds to the plan in that the planner is addressing possible fertilizer applications to all managed areas of the property. Again talk with your client about what they do in these areas and how satisfied they are with their performance and/or appearance.

Although you may find they do not have any formal program in place, your interest in managing such areas, will improve the overall appearance of the property, which increases the value of your service to your client. Recommendations for landscapes are not addressed in the standards and criteria. When making recommendations on these areas use information from reputable sources and include any resources used to determine fertility needs with the plan.

A map of the property showing the various features described in the nutrient management regulations is required to be part of the plan. The soils map and legend may be useful information in the plan, but the soils map and legend needs to be information contained in the client's office file. These maps were omitted from our example.

The following labels, as stated earlier, may not be part of a plan you would take back to your clients. They are provided here as a reference to help in your understanding of how to interpret the information contain in them to make recommendations.

**46 – 0 – 0**
**GUARANTEED ANALYSIS**
**Total Nitrogen (N) ..... 46.00%**
**Available Phosphoric Acid ($P_2O_5$) ..... 0.00%**
**Soluble Potash ($K_2O$) ..... 0.00%**
**PRIMARY NUTRIENT DERIVED FROM .....Urea**

**34 – 0 – 0**
**GUARANTEED ANALYSIS**
**Total Nitrogen (N) ..... 34.00%**
34.00% Urea Nitrogen*
**Sulfur (S) ..... 10.50%**
10.50% Free Sulfur (S)
**Iron (Fe) ..... 5.00%**
0.05% Water Soluble Iron (Fe)
**DERIVED FROM**
Polymer Coated Sulfur Coated Urea, Iron Sucrate

**18 – 46 – 0**
**GUARANTEED ANALYSIS**
**Total Nitrogen (N) ..... 18.00%**
18.00% Ammoniacal Nitrogen
**Available Phosphate ($P_2O_5$) ..... 46.00%**
**DERIVED FROM ..... Diammonium Phosphate**

## F.4.2 Plan Implementation

After the initial plan has been delivered, the client should begin to implement its suggestions. The degree to which it is implemented will depend on several factors. The most obvious is whether it will be of benefit to the client either in cost savings or improved appearance of the managed area(s). Secondly, how easily can changes suggested in the plan be adapted to the client's current methods of operation? If the recommendations in the plan are similar to what is already being done, the client is more likely to follow them. A well written plan which addresses the specific needs of a property, with a practical and realistic approach, is also more likely to be successfully implemented. Finally, the client's acceptance of the plan, willingness to change, and trust in the plan writer will strongly affect the degree of plan adoption.

For those plans (or portions thereof) which are adopted, three tasks are important to its ongoing success: future nutrient testing, equipment calibration, and application and maintenance record-keeping.

### F.4.2.1 Future nutrient testing

The soil and tissue testing, where appropriate, as described earlier are key tools to managing the application of nutrients. Without these measures of nutrient availability balanced with plant needs, it will be difficult to accurately determine plant nutrient needs and to develop relevant, justifiable recommendations. The client should be strongly encouraged to maintain this test-critical information. Not only is it needed for developing credible nutrient management plans, it is also important in the operation management decision making process.

### F.4.2.2 Equipment calibration

Equipment calibration represents another area critical to plan implementation. The plan recommendations will do little to save money and protect water quality if they cannot be followed due to inaccurate nutrient application. Calibration of all application equipment should be checked on a regular basis, especially if your client owns application equipment. Without the necessary adjustments indicated by calibration, the result may be to apply either too little or too many plant nutrients. The first may result in an unacceptable turf durability and turf/landscape appearance. The latter may be costly, not only because of the unnecessary expense, but also because of a negative impact upon water quality. Equipment calibration is detailed in *Virginia Nutrient Management Standards and Criteria* (DCR 2005, Chapter 10).

### F.4.2.3 Application and maintenance records

A final area to emphasize during plan implementation is recordkeeping. Without good records, it is impossible to know what has been done, and if any progress or improvements are being made. Examples of important information to retain are soil tests, spreader calibration settings, dates of fertilizer application rates, seeding or renovation of specific areas and any usual stresses on the areas due to disease, drought, etc., which would also impact the health and appearance of the turf. This information provides the background needed for the fine tuning in future plan updates or revisions.

## F.4.3 Plan Revision

Several factors can, and will, result in the need for revising the nutrient management plan. The most obvious is that the life of the plan has expired. Plans can be written up to a three year period. Start working with clients will ahead of the expiration date so that your client will have a current plan in place at all times.

Even the best written plan can be refined to take advantage of what has been learned in the last season. For that reason, plans will always be going through some degree of evolution. Some specific factors may result in the need for significant revisions. Changes in the predominant land use on (or adjacent to) the managed areas may require modification of the existing plan. If managed areas are dramatically changed by renovations to the landscape or construction of new buildings, roads, etc., such changes may require the plan to be revised.

## F.4.4 Summary

The number of factors that can alter a nutrient management plan are substantial. For that reason, a sincere effort on the part of the client, who manages a sizeable operation, may need to reassess decisions made when the plan was first developed. Follow-up visits are important to the success of the planning process. Because the performance of various managed areas vary due to season conditions, it is important to continue to follow-up until the client is comfortable with his plan implementation. Once the client has an understanding of the concepts, and is capable of interpreting the plan himself, the amount of support required should be significantly less. Having your clients increase their understanding and importance of nutrient management creates a desire do their best to follow the plan. More importantly, it indicates you are delivering a good and beneficial service to your clients.

# F.5 References

VA DCR, Virginia Nutrient Management Standards and Criteria. 2005. Department of Conservation and Recreation, Division of Soil and Water Conservation. Richmond, VA. http://www.dcr.virginia.gov/documents/StandardsandCriteria.pdf

4 VAC 5-15, Nutrient Management Training and Certification Regulations. http://dcr.virginia.gov/documents/nmtraincertregs.pdf

# Appendix G VDACS Office of Pesticide Services Site Inspections

Virginia has no specific regulations or specifications for a storage or mix-load facility. However, pursuant to the Virginia Enforcement Regulation (1986): 2 VAC 20-20-10 through 20-220 (VAC is the Virginia Administrative Code): "No person shall handle, transport, store, display, or distribute pesticides in a manner which may endanger humans or the environment, or food or feed or other products…" In addition, all pesticide products must be used in accordance with the pesticide label. This includes any product specific storage and mix-load requirements.

VTPP's minimum specifications for a storage area are: secure, dry, well-lit, well-ventilated, protected from extreme heat and cold, set up so pesticides may be stored properly (eg., separate areas for herbicides, fungicides, insecticides, large containers on lower shelves, bags placed where they won't tear or decompose), have a warning sign, emergency contact information, and an inventory and a MSDS for each product on hand—remember that neatness counts!

VDACS investigators check to confirm the storage area is dry, well-ventilated, well-lit, that there are labels on containers, the area can be locked or otherwise secured, and has a sign identifying it as a storage facility or area.

- **Status of applicator's certificates (and pesticide business license, if applicable):** For a golf course, confirm that all pesticide applicators/handlers are properly certified.
- **Application records:** Nine required data elements. Application records are required for all pesticide applications including both general use and restricted use products.
- **Equipment:** VDACS OPS investigators realize that application equipment is not in use during an inspection. However, they give it a general look-over to check for obvious signs of damage, poor maintenance, etc.—things that would result in leaks in transport or improper application when in use.
- **Backflow prevention:** Use of a specific device or air gap
- **Mix-load site:** This may be minimal if handlers and applicators mix and load in the field/on a job site and more involved if there is a mix-load or equipment wash pad at your office/shop.
- **Transportation:** If you transport pesticides in secondary containers or in application equipment, they will want to see service container labels.
- **PPE:** Items required by labels of products in use should be available in sufficient quantity and in good condition; should NOT be stored with pesticides. (If respirators are used, are they stored properly? Are cartridges changed regularly?)
- **Spill kit(s):** You should have one in/near your storage area, at the mix-load site, on each truck that transports concentrates or end-use dilutions; can be "homemade".
- **Container management:** Do you triple rinse or jet rinse plastic containers? (If jet rinse, equipment/nozzle must be installed and functioning properly.) Inspector will ask how you dispose of empty containers.
- **Registration status of products in use:** Products used are checked to ensure they are currently registered w/ EPA and w/ VDACS for use in VA, and labeled for the site(s) where they are used.

VDACS views inspections as compliance assistance opportunities; however, Pesticide Investigators will document any objectionable conditions or violations observed during the inspection. You may be subject to enforcement actions for violations of the Act or Regulations. Most inspections take 30-60 minutes, depending on the size of the operation and the number of employees.

Questions regarding compliance with the Act or Regulations or about using any pesticide should be directed to VDACS OPS before making a pesticide application.

## The following VTPP-produced documents may be helpful:

- Recordkeeping data elements and sample form
- Overview of the legal obligations of certified applicators in VA
- A "generic" checklist of things to do before using a pesticide. (Note that this checklist is not the official one VDACS pesticide business inspector's use. If you find it useful, you can obtain an e-copy from VTPP and customize it for your operation.)

Source: Douglas Edwards, VDACS OPS / Enforcement & Field Operations

Compiled by: Pat Hipkins, VT Pesticide Programs

Date: December 2010

# Appendix H Example Pesticide Application Record Form

**Note:** The Commonwealth of Virginia requires records of pesticide applications to be kept for two years.

| Name, Address,and Telephone Number of Property Owner | Address and Location of Application Site *(if different)* | Certified Applicator's Name and Certificate Number | Date (Day, Month, Year) | Type of Plants, Crops, Animals, or Sites Treated |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
| | | | | |

| Principal Pest to be Controlled | Acreage, Area, or Number of Plants or Animals Treated | Brand or Common Name of Pesticide | EPA Product Registration Number | Total Amount of Product *and* of Diluent (if used) | Type of Application Equipment |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

Prepared by Virginia Cooperative Extension and VDACS Office of Pesticide Services, 2008

# Appendix I Spill Kill Materials

All courses should purchase or assemble a spill cleanup kit. Keep it close at hand whenever you handle pesticides, other hazardous products, or their containers. Plan ahead! If a spill occurs, you will not have the time or the opportunity to find all of the items in a timely manner so you can respond to the incident! See Section 9.6 of this document for more information on emergency preparedness and spill response.

## The basic components of spill kit for small spills are:

- chemical-resistant gloves, footwear, apron, and chemical resistant coveralls
- protective eyewear
- an appropriate respirator, if required by any of the labels of pesticides or other hazardous materials used
- containment tubes ("snakes") to confine a leak or liquid spill
- water in a mist or spray bottle to moisten the surface of fine-textured dry material—for instance, a wettable powder or dust formulation pesticide—to keep the spilled material from "drifting"
- absorbent materials, such as spill pillows, absorbent clay, sawdust, pet litter, activated charcoal, vermiculite, or paper for liquid spills
- a sweeping compound for dry spills
- a shovel, broom, and dustpan (if you will carry the kit in a bucket, purchase a foldable shovel and small broom)
- heavy-duty detergent
- fire extinguisher rated for all types of fires
- other personal protective equipment (PPE) and spill cleanup items specified on any of the labels of products you use regularly
- sturdy plastic bags to contain contaminated materials. You must be able to close them securely. They must be large enough to hold the contents of the largest container in use plus any absorbent or sweeping compound.

Store all of these items in a sealed, sturdy plastic container so that they will be available, clean, and in working order if needed. Dedicate the kit for spill remediation ONLY. Do not allow parts and pieces to be used for other routine activities, lest they be missing when needed.

## Other items to have on hand:

- emergency telephone numbers
- telephone
- product labels and Material Safety Data Sheets
- water
- warning tape, cones, and signs (to restrict access to area)

Customize your spill kit by reading the labels and Material Safety Data Sheets for all of the products you use and store.

# Appendix J Sample Pesticide Application Checklist

## General

- ❑ Study the product label. Use it as a guide before, during, and after handling a pesticide!
- ❑ Never use pesticides that are not in a properly-labeled container!"
- ❑ Read the MSDS for information re: hazards and emergency response.

## Pesticide / Pest:

- ❑ What pesticide product(s) will you be applying?
- ❑ Is the site listed on the label and recommended/ effective for the pest?
- ❑ Is it the right time to make this application?
- ❑ Will your management tactics be effective at this stage in the pest's life cycle?
- ❑ Do you know the proper mixing ratio/rate?
- ❑ How much pesticide mixture will you need?

*Use the label to calculate the amount to use and calibrate your equipment, if necessary, for the job.*

## Personal Safety:

- ❑ Do you know the product's characteristics and specific hazards?
  - ❑ How toxic is this product?
  - ❑ What hazards does it pose to handlers and the environment?
  - ❑ What special precautions are called for?
- ❑ Do you have the PPE the label tells you to use?
  - ❑ Is it clean and usable?
- ❑ Do you have what you need in case of an accident (e.g., to clean up a spill)?
- ❑ Do you have personal decontamination materials and a first-aid kit?
- ❑ Are others that work with or for you trained to know emergency procedures?

## Application Equipment:

- ❑ Do you have the proper application equipment consider site, formulation)?
- ❑ For liquid applications, are you using the right kind/ size nozzle?
- ❑ Is equipment in good working order and properly calibrated?

## Environmental Safety:

Have you inspected the treatment area to locate:

- ❑ sensitive areas (such as water wells)
- ❑ nontarget organisms (such as livestock, pollinators)
- ❑ potential hazards
- ❑ Do you have a plan to protect yourself and other people working or living in or near the treatment area? livestock and pets? environmentally-sensitive areas such as wells or streams? honeybees and othe beneficial insects?

## Mixing / Loading:

- ❑ Do you have a safe and easy to use mix / load site?
- ❑ Will spills be contained?
- ❑ Do you have personal decontamination and spill cleanup materials?
- ❑ Do you have what you need to measure the pesticide and, if a liquid, mix the spray solution or suspension?
- ❑ Do you have clean water to use to mix / dilute liquid concentrates? Do you know the water's pH?
- ❑ Do you know the rate? For liquid applications, do you know how much pesticide and how much water to put in your sprayer?
- ❑ Do you have a set-up for rinsing containers, so the rinsate is added to the spray tank?

*Rinse pesticide container as soon as you empty them!*

- ❑ Do you have the right adjuvant(s), if their use is directed by the label?
- ❑ If you plan to tank mix this pesticide with others, or with fertilizer, are tank-mixing instructions on the label? If not, have you done compatibility testing?
- ❑ Do you have a place to store rinsed, empty metal or plastic containers until they may be recycled or properly disposed of?

## Transportation:

- ❑ How will you move the pesticide to the application site safely?

## Application Site:

- ❑ Do you know the exact location and boundaries of the area to be treated?
- ❑ Have you inspected the treatment area to identify sensitive areas nearby?
- ❑ Do you have a plan to protect yourself, your co-workers, and other people working or living in or near the treatment area; sensitive areas?
- ❑ If this is a field application, do you know the soil type? This may be important for use rate and for pesticide efficacy.

## Weather Conditions:

- ❑ Is the weather suitable for application? Is rain in the weather forecast? Will fog or mist impair visibility?
- ❑ Have you checked the label for temperature or wind restrictions?

## Application:

- ❑ Have you established an application pattern?
- ❑ Do you check your application rate (dose)?
- ❑ Are you able to apply the pesticide in a uniform manner?

## Clean-Up:

- ❑ Do you have a place, method, and time to decontaminate your PPE and application and handling equipment?
- ❑ Do you have a place to store clean PPE and other equipment until you will use them again?

## Disposal:

- ❑ Do you know how and where to dispose of empty pesticide containers?
- ❑ If you mix too much, do you know what to do with the leftover mix?

## Storage:

- ❑ Do you have a safe place to store pesticides?

***Minimum*** *storage specifications: secure, dry, well-lit, well-ventilated, protected from extreme heat and cold, set up so pesticides may be stored properly (for example: separate areas for herbicides, fungicides, insecticides, large containers on lower shelves, bags placed where they won't tear or decompose), warning sign, emergency contact information, inventory, MSDSs. Neatness counts!*

## Follow-Up:

Will you inspect the treated area to:

- ❑ evaluate and record the application efficacy?
- ❑ identify off target movement (if any)?
- ❑ look for unexpected results or problems?

## Emergency Response:

- ❑ Do you know what to do in case of an accident?
- ❑ Do you have spill containment and cleanup materials on hand?

## Recordkeeping:

- ❑ Do you know what your record-keeping responsibilities are? If you're required to record an application, do you know what information is necessary, how long you have to make a record, and how long the record must be kept?
- ❑ Do you have a record-keeping system or forms, and a place to file and keep your records?



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Virginia Chapter
GCSAA
GOLF COURSE SUPERINTENDENTS ASSOCIATION OF AMERICA