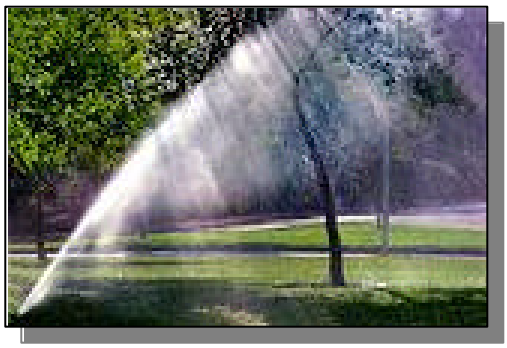
CHAPTER 13
GROUNDS MAINTENANCE

Ski area operations include the maintenance of grounds including on-mountain grounds and landscaping around lodges and common areas. Also, many ski areas have golf courses that operate in the summer months and require maintenance. Environmental aspects of grounds maintenance at ski areas include water use, pesticide use and application, water quality, erosion control, and revegetation. The U.S. Forest Service in cooperation with Sun Valley Corporation and Snowbasin Ski Area created a document titled "Ski Area Best Management Practices, Guidelines for Planning, Erosion Control, and Reclamation." The document focuses on best management practices (BMP) for ski areas related to preventing or decreasing environmental damage and water quality degradation. Specifically, the document covers BMPs related to construction activities, protecting water quality, and land reclamation. For a copy of this document, contact the U.S. Forest Service at (202) 205-1663. Other opportunities for pollution prevention (P2) at ski areas include water conservation and integrated pest management. This chapter discusses P2 opportunities associated with these two topics. Although much of the information presented in this chapter applies to any sort of grounds maintenance, much of the discussion is devoted to golf course operations because many ski areas operate golf courses and golf courses have diverse environmental aspects. This chapter concludes with a discussion of various environmental programs related to grounds maintenance at ski areas.

13.1 WATER CONSERVATION



In grounds maintenance, water is used mainly for irrigation purposes (water use associated with other areas of operations, such as snowmaking is covered in relevant chapters of this notebook). Ski areas nationwide are increasingly faced with water conservation issues because of climatic conditions and limited water supplies in mountain communities. At various locations, local water use restrictions are increasingly likely to be promulgated if they have not been already. It is difficult to estimate irrigation at ski areas, but in an average year, according to Golf Course Superintendants Association of America (GCSAA) survey, an average golf course in the U.S. uses about 28 million gallons of water, and yearly water use at various golf courses ranges from 15 to 100 million gallons. Water conservation practices offer paybacks in terms of decreased labor hours, water bills, and healthier landscape. Several factors affect water conservation practices. These factors, as well as, some techniques and technologies for water conservation are discussed below. For more information on water conservation, visit the web sites of the Soil and Water Conservation Society at www.swcs.org and WaterWiser, a water efficiency information clearinghouse, at www.waterwiser.org. For more information on water management for turfgrasses, visit http://aggie-horticulture.tamu.edu/plantanswers/turf/ publications/water.html.

13.1.1 Factors That Affect Water Conservation

Water use and conservation techniques are unique to the area being irrigated and depend on numerous local climatic, surface, and soil conditions. It is important to understand each of these factors as they relate to water use because opportunities for

> Direct evaporation from sprinklers can account for a 50 percent or greater loss of water in a dry climate.
>
> *Richard Duble*
> *Turfgrass Specialist*

conservation rely on optimizing one or more of these variables. The most important single variable that affects requirements for water is the rate of evapotranspiration (ET), which is the total water loss from soil, including direct evaporation and transpiration, and the loss of moisture through grass and other vegetation. ET is complicated to estimate because it is affected by a number of factors, including:

- Temperature
- Wind
- Vegetation type
- Solar radiation
- Humidity
- Soil conditions
- Irrigation system operating pressure and nozzle diameter

Soil conditions, surface conditions, and vegetation selection factors to consider with respect to water conservation include

Soil Conditions	Surface Conditions	Vegetation Selection Factors
• Soil porosity in the grass root zone • Infiltration • Percolation • Water retention	• Dense thatch • Surface crust • Nonwettable sand	• Water needs • Transpiration rates • Adaptability to the environment

Soil type is also an important consideration with respect to watering and conservation practices because the soil type affects water infiltration and runoff rates and therefore water application rates and techniques.

13.1.2 Water Conservation Opportunities

Water can be conserved using a number of techniques and technologies. The techniques include irrigation techniques, selection of vegetation and turfgrass, alternative water sources, watering schedules, and hand watering. Use of technologies include computerized weather stations, global positioning systems (GPS), and geographic information systems (GIS).

Irrigation Techniques

The manner in which landscape is irrigated depends on the local climate and the growing season. Traditionally, watering practices have been based on the theory that deep, infrequent irrigation is better for root development. In many parts of the country and in places with adequate growing seasons, this watering practice is appropriate. However, research in the semi-arid western states indicates that the quality of vegetation growth is enhanced by frequent, light watering. This practice is known as deficit irrigation. Implementing deficit irrigation involves using a trial-and-error process to determine how infrequently and how lightly to water, and these factors vary for different soil and vegetation types. For example, sandy loam soils, soils with high bicarbonate concentrations, and highly compactable soils are well suited for deficit irrigation. Deficit irrigation will not work well in all areas of the country, but ski areas in semi-arid climates with short growing seasons may be able to save water using this method.

For more information about deficit irrigation on golf courses, visit
http://www.gcsaa.org/resource/environ/watercon.html

Vegetation and Turfgrass Selection

Significant savings in water use are possible with the correct selection of vegetation. Rates of water use differ between types of vegetation. Any vegetation, including turfgrass on golf courses, should be selected based on its water need. Xeric landscaping is both attractive and beneficial because of its low requirements for water. Ideally, vegetation with a water requirement met by the local average rainfall should be selected. For areas with low annual rainfall, xeric plants are available for all landscaping needs, including trees, shrubs, ground cover, vines, and many types of accent plants. Information about xeric landscaping is widely available.

Grasses with poor drought resistance may require three to four times more frequent irrigation then excellent drought-resistant grasses.

For more information about xeriscape, you can visit www.xeriscape.org, www.greenbuilder.com/sourcebook/xeriscape.html, and many other resources on the internet. For further information about turfgrass selection, visit www.ntep.org.

Alternative Water Sources

In the future, use of potable water for irrigation may be restricted; therefore, alternative sources of irrigation water, such as effluent water, should be considered. Effluent is partially treated wastewater from a municipal treatment facility, nearby development complex, or other source. Effluent water is usually cleansed of major pollutants but still contains enough pollutants and bacteria to make it undrinkable. Golf courses are good locations for application of effluent water. Dense, well-managed turfgrass can serve as a filtration system for such water. The thatch layer in the turf traps and holds particulate pollutants in the water and allows them to degrade naturally. Use of effluent water is more viable in hot, dry regions with high requirements for irrigation. Effluent water also contains plant nutrients, resulting in less need for fertilizer, and it is generally less expensive than potable water. Use of effluent water may pose challenges because of high levels of salinity and other pollutants, but these issues can usually be overcome with good management practices. There are two primary pollutants of concern: industrial waste and salinity. Industrial waste may contain heavy metals and toxic contaminants, both of which are good reasons to eliminate a particular source of effluent. The greater ongoing concern is salt. Concentrations of salt increase significantly during the water treatment process, and this can be a major problem in areas where concentrations of salt in fresh water are naturally high. It is also a problem during droughts when salts from effluent can severely damage some grasses. The range of salt tolerances is fairly wide among grass species, but the tolerances of most grasses on golf courses are at the low end of the scale. High concentrations of salt may also damage the structure of soil. High salt concentrations in effluent water can be compensated for by mixing fresh water with the effluent to achieve concentrations that are within tolerances.

Another alternative water source is recycled irrigation water. In this case, the layout and drainage of a golf course are designed in such a way that all runoff and seepage flow into containment areas, and the water collected is reused for irrigation.

For more information on alternative water sources for golf courses, visit www.gcsaa.org or call (800) 472-7878.

Development of Watering Schedules

Independent of any other factors, to decrease ET, grounds should be watered at night when the temperature, solar radiation, and wind speed are lower. Other considerations in developing watering schedules depend on vegetation, soil type, slope, site use, and specific vegetation management practices.[1] For more information about watering schedules, visit aggie-horticulture.tamu.edu/plantanswers/turf/publications/water.html.

Computerized Weather Stations

Weather station systems can save 25 percent of the water used for irrigation.[2] Ski areas can payback computerized weather stations within 2.5 years at locations where substantial irrigation water is used, such as at golf courses.[3] The systems work by gathering data on solar radiation, wind speed, wind direction, and temperature from various sensors strategically located to calculate the ET rate. A computer uses the ET rate to automatically adjust water output at each sprinkler head. With most systems, operators can control the water output of individual sprinkler heads or the entire system through handheld communicators (such as radios and palm pilots) or office or home computers. Even if a weather station cannot be connected to the irrigation system and automated, data from the weather station can be used to manually adjust the irrigation system or to guide hand watering practices.

Computerized weather stations can reduce irrigation water by 25 percent.

Most irrigation system vendors can provide computerized weather station equipment and technical assistance.

Global Positioning Systems (GPSs) and Geographic Information Systems (GISs)

Although their use is not widespread, GPSs and GISs are increasingly being used in ski areas and at golf courses for many aspects of operations, including water conservation. Data collected with a GPS and input into a GIS can be used to manage sprinkler heads, vegetation types, and many other matters related to grounds maintenance. The data collected from a computerized weather station can be connected to GPS data points such as sprinkler heads and used to plan irrigation and control operations. Other GPS and GIS applications beyond water conservation include snowmaking operations, pest management, soil sampling, tree management, maintaining accountability for new construction, and record-keeping. Most irrigation system vendors can provide GPS and GIS equipment and technical assistance.

CASE STUDY: SADDLE ROCK GOLF COURSE

In 1996, during construction of the Saddle Rock Golf Course, located in Aurora, Colorado, the course installed a weather station and computerized irrigation operating system that uses a GPS and GIS to aid in irrigation. Saddle Rock uses a Rain Bird Maxi Sirus operating system. The following table summarizes system costs in 1996 and 2001 dollars.

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[1] Duble, R. L. "Water Management on Turfgrasses." Document obtained on Internet, June, 2001. On-Line Address: www.aggie-horticulture.tamu.edu/plantanswers/turf/publications/water.html

[2] A. Pioppi. "Irrigation Systems More Than Conserve H_2O." *Golfweek's Superintendent News*. Page 8. May 12, 2000.

[3] A. Pioppi. "Technology Takes Guessing Out of Forecasting Weather." *Golfweek's Superintendent News*. Page 11. May 12, 2000.

Component	1996 Cost	2001 Cost
Weather Station	$10,000	$14,000
Computerized Irrigation Controller	$29,000	$40,000
Irrigation Radio Control System	$ 6,800	$ 9,400
Total	**$45,800**	**$63,400**

Because the system was installed during construction of the course, Saddle Rock does not know how much water it would use without the system. Rain Bird conservatively estimates that the system saves about 15 percent compared with a non-computerized system. The total cost for irrigation is calculated as:

Annual Irrigation Costs = Water + Operation and Maintenance (Labor and Equipment)

In 2001, Saddle Rock used about 100 million gallons of water per year for irrigation at $1 per 1,000 gallons. Assuming the system saves 15 percent in water use per year (15 million gallons), Saddle Rock saves $15,000 per year in water use. For operation and maintenance costs, Saddle Rock estimates that it spends 40 hours per week to monitor, operate, and repair the system and pays its staff about $19 per hour (including benefits). Based on his 10 years of experience, the Saddle Rock superintendent estimates that without the computerized system, his staff would spend 100 hours per week monitoring the system (40 hours at about $19 per hour, 40 hours at $15 per hour and 20 hours at $8.50 per hour). Based on a 6-month irrigation season per year (24 weeks) the additional labor cost is $22,560 per year.

With a capital investment in the system of $63,400 (2001 dollars), the payback period for the system is 1.7 years. Although Saddle Rock's superintendent knew that the system would pay for itself in water savings alone, he indicated that the system's ease and accuracy in estimating water use needs were reason enough to install the system.

13.2 INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) is a sustainable ecological approach to preventing or reducing unacceptable levels of damage by pests. An effective IPM program helps to identify pests and evaluate, select, and implement the best possible management options based on reductions in environmental, economic, and human health risks. The IPM decision-making process determines whether, where, when, and how pest management practices should be applied. A key concept of IPM is to manage vegetation so as to optimize its health and make it more resistant to disease and damage. Ski areas that have an IPM plan should continue to look for opportunities to improve on their plan. Ski areas without an IPM plan are encouraged to write and implement a plan based on their specific needs and goals. For technical assistance in Colorado, call the CDA Division of Plant Industry, at (303) 239-4145.

For information on basic principles guiding IPM and how to develop an effective IPM plan, visit IPM Access at www.efn.org/~ipmpa/

13.2.1 IPM Advantages

The ecological and economic advantages of IPM outweigh the time it may take to develop and implement a course of action. From an ecological standpoint, IPM uses proven biological, mechanical, and cultural controls to reduce chemical pest treatments. Furthermore, because many pesticides are expensive, reducing the amount used and opting for more cost-effective, long-term practices can save money. During preparation of this handbook, four golf courses were visited, and information was gathered on their environmental projects. Table 13.2 summarizes IPM-related case studies for one golf course.

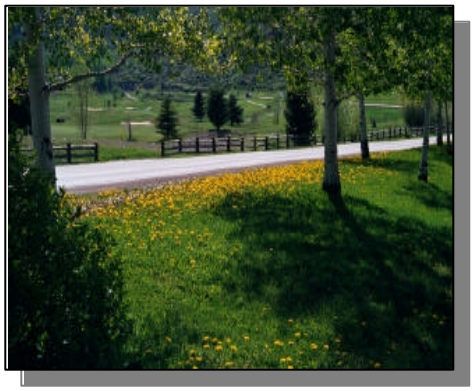


TABLE 13.2

Contact	Practices	Benefits
Lakewood, CO Country Club Chris Swim (303) 233-5507	**Buffer zones around Lakes and Creeks:** grow vegetation higher, and do not apply pesticides in the buffer zones	Reduce the amount of pesticides that come in contact with surface water
	Use of Growth Regulator: apply growth regulator twice every spring and fall	Decrease the amount of mowing required on the course, which decreases labor time, emissions from mowing equipment, use of fuel and oil, and maintenance waste
	Minimized Application of Pesticides: look for opportunities to reduce application of pesticides by using such techniques as weeding by hand and spot-applying nonrestricted-use pesticides; overall, the approach is to treat weeds curatively	Decrease application of pesticides, which saves money and decreases environmental impacts

13.2.2 Know Your Surroundings for IPM Success

Before an IPM plan can be developed, specific knowledge of the ski areas environmental setting is essential. Full consideration should be given to threatened and endangered species in the region, natural and cultural resources, human health and safety, and laws and regulations that apply to ski areas. Familiarity with the local surroundings will aid in identifying common pests and diseases in the area.

Government agencies and universities, such as the U.S. Department of Agriculture (USDA), Agriculture Research Service (ARS) (www.ars.usda.gov/), and Colorado State University (CSU) Cooperative Extension (www.ext.colostate.edu/), provide research-based knowledge and information about diseases, pests, maintenance, treatment options, species selection, and new cultivars.

The National Park Service manages over 80 million acres of land, 45,000 buildings, and cultural landscapes ranging from cropland to historic rose gardens; therefore, it has many pest problems. Since implementing an IPM program in the early 1980s, the National Park Service has reduced pesticide use by over 60 percent while improving the effectiveness of its pest management efforts.

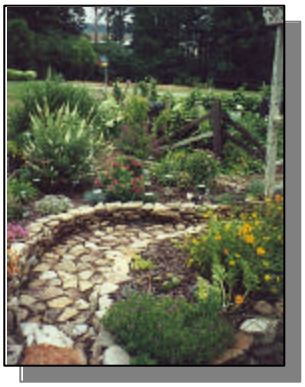
Key elements of this success were formal training and provision of printed and audiovisual materials. One of the program's products is an IPM manual that is now available in a second edition. It provides descriptions of the biology and management of 21 species or categories of pests. The manual is available at www.nature.nps.gov/wv/ipm/manual.html.

For more information on common insect pests, diseases, and weeds, visit the Colorado State University National IPM Network at www.colostate.edu/Depts/IPM/csuipm.html.

13.2.3 Thatch and Mat

Excessive thatch (greater than ½ inch thick) is an issue of concern at golf courses. Thatch is an organic layer of intermingled dead and living shoots, stems, and roots that develops between surface soil and green vegetation. Thatch is created when organic matter is developed faster than it is decomposed. Mat is thatch that contains mineral matter. Thatch and mat provide an ideal environment for insects that damage turf, such as white grubs and billbugs that feed beneath the layers and sod webworms that nest between the layers. Although some thatch and mat are desirable, excessive thatch prevents the infiltration of water and can create localized dry spots and minimize the movement of air and fertilizers, thereby weakening the turf and making it more susceptible to pests and disease. Thatch reduction is a long-term process but can be accomplished by following proper cultural practices; for example, by avoiding use of pesticides that harm earthworms and fungicides that reduce microbial populations. Earthworms aerate and break up thatch and mat, and microbes feed on thatch and mat. More information on thatch and mat can be found at www.colostate.edu/Depts/IPM/index.html.

13.2.4 Management of Pests and Diseases



Pests and diseases are managed through a variety of controls intended to reduce or eliminate them. Pest and disease controls are either preventive or curative in nature. Common preventive controls are cultural or genetic modifications and are usually the most cost-effective and long-lasting. Curative controls generally involve mechanical, biological, or chemical pest and disease management. Some examples of pest and disease controls are provided below.

PREVENTIVE

- **Cultural:** Modifying fertilization, fertigation, irrigation, thatch management, cultivation, seeding, or mowing practices or lawn and landscaping equipment maintenance and sanitation; renovating landscapes to include disease- and pest-resistant plants; or choosing a less toxic pesticide
- **Genetic:** Choosing pest- or disease-resistant vegetation

CURATIVE

- **Mechanical:** Physically disrupting the area where pests or diseases are located by means of tilling, hoeing, hand-pulling, mowing, aeration, burning, or barriers
- **Biological:** Introducing organisms such as earthworms, microbes, or plant pathogens into soil to disrupt weed, disease, and thatch development Grazing livestock are another form of biological control

- **Chemical:** Applying herbicides, insecticides, fungicides, and plant growth regulators. Growth regulators can both (1) reduce growth rates by inhibiting cell division and (2) suppress development of weed seed heads

For more information on any of these pest and disease controls, visit www.colostate.edu/Depts/IPM/index.html and www.gcsaa.org.

13.2.5 Biopesticides

For biopesticide fact sheets and related information, visit EPA's Office of Pesticide Prevention biopesticide web site at www.epa.gov/pesticides/ biopesticides/.

Misapplication of toxic chemicals can be hazardous to native plants and animals and to human health. As an alternative, biopesticides may be applied. Biopesticides are natural materials or organisms that can act as pesticides for unwanted insects and plants. Biopesticides can be plants, animals, bacteria, or minerals. A major concern regarding pesticide application is the effect that it can have on nontarget species. Biopesticides may be less harmful than conventional chemical pesticides and, when used correctly, may affect only the target pest. Additionally, biopesticides may be less costly because they can be effective in small quantities and decompose quickly. As with all the pesticides, biopesticides must be applied in accordance with the U.S. Environmental Protection Agency (EPA)-approved label directions. According to National Turfgrass Evaluation Program (NTEP), biopesticide is limited to preventive applications within a management system; biopesticides are not suitable for use as curative controls.

13.2.6 Pesticide Runoff

Another important part of IPM is protection of waters such as ponds, wetlands, and streams. Runoff occurs when water is applied to soil faster than it can enter the soil. Runoff containing pesticides can cause direct injuries to nontarget species, harm aquatic organisms in streams and ponds, and lead to groundwater contamination. Many approaches for controlling pesticide runoff borrow from the pest and disease management controls discussed in Section 13.2.4. Although the quickest, most cost-effective way to protect waters is reduction of pesticide use, this may not always be a viable option. Some BMPs for reduction of pesticide runoff are listed below

- Reduce the volume of runoff and sediment through subsurface drainage system installation (tile drainage), tillage of soil, use of buffer strips, or contour planting
- Reduce pesticide migration to surface water through use of structural landscaping such as terraces, buffer strips, and grassed waterways
- Reduce pesticide losses by diluting the concentrations of pesticides applied to greens
- Apply pesticides under optimal weather conditions; that is, avoid applying pesticides when a heavy rainfall is predicted
- Use pesticides that are less susceptible to infiltration and runoff losses, such as Fenaxoprop, Prodiamine, Cyfluthrin, or Permetrin

For more information about pesticide runoff reduction techniques, visit www.ctic.purdue.edu/KYW/TipsAndHints/Page22.html. For more pesticide runoff information related to golf courses, visit the Water Quality and Golf Course Superintendents web site at www.ces.ncsu.edu/TurfFiles/pubs/wqwm154.html, and read "Best Management Practices and

Integrated Pest Management for Protection of Natural Resources on Golf Course Watersheds" at www.epa.gov/owowwtr1/watershed/Proceed/peacock.html.

13.3 ENVIRONMENTAL PROGRAMS

Part of the challenge of increasing environmental performance is finding out about the opportunities available. Involvement in environmental programs is a good way to learn more about environmental opportunities. The importance of interacting with these programs cannot be overstated for golf courses that seek to improve environmental performance and demonstrate environmental leadership. This section discusses the environmental resources listed below.

Golf Course Resources	IPM Resources
• Audubon Cooperative Sanctuary (ACSP) • GCSAA • U.S. Golf Association • NTEP • Colbert-Thein Environmental and Evaluation Management System	• CSU National IPM Network • Database of IPM Resources • Radcliffe's IPM World Textbook • IPM Almanac • IPM Practitioners Association

13.3.1 Golf Course Resources

Audubon Cooperative Sanctuary Program

Audubon International created a number of education and certification initiatives for different habitats (golf courses, businesses, schools, and backyards) collectively referred to as the Audubon Cooperative Sanctuary Program (ACSP). ACSP addresses environmental concerns at golf courses while maximizing opportunities to provide open-space benefits. ACSP provides education and certification in six environmental areas:

- Environmental planning
- Wildlife and habitat management
- Water conservation
- Water quality management
- Outreach and education
- Chemical use reduction and safety

ACSP participants are widely regarded as "benchmark" golf courses in terms of environmental stewardship and conservation.

Audubon International also offers the Audubon Signature Cooperative Sanctuary Program (Signature Program). The Signature Program offers planning and educational services to help new golf courses protect natural resources on and off site during course development.

For more information about ACSP for golf, call Joellen Zeh at (518) 767-9051, extension 14, or visit www.audubonintl.org/programs/acss/golf.htm.

GCSAA

GCSAA is dedicated to serving its members, advancing their profession, and enhancing the enjoyment and growth of golf. Its 21,000 members are organized according to classifications such as superintendent, assistant superintendent, student, educator, affiliate, and retired. The association has 102 affiliated chapters with members from 65 countries. GCSAA's foundation is educational programming that provides its members the opportunity to keep current on practices for maintenance and upkeep of golf courses. One of its educational features is an Environmental Management Program that focuses on six specific areas of study (employee safety and right-to-know; golf course development; IPM; storage, disposal, and recycling; water quality and application; and habitat development and management) as well as technician training to upgrade field skills.

GCSAA provides many communication tools and programs, including

- *Golf Course Management* magazine
- GCSAA Online (www.gcsaa.org)
- Annual International Golf Course Conference and Show
- GCSAA News Weekly (a weekly electronic newsletter)
- Leader Board (quarterly newsletter)
- Greens & Grassroots (a publication that provides regular updates on federal and state legislative and regulatory actions that affect golf course management)

In May 2001, GCSAA and *Golf Digest* announced the Environmental Leaders in Golf Awards to recognize the environmental achievements of golf course superintendents and their facilities as well as significant work to promote environmental initiatives by communities and individuals. The award program blends GCSAA's Environmental Steward Awards and *Golf Digest*'s Environmental Leaders in Golf Awards. The first winners of the Environmental Leaders in Golf Awards announced in February 2002.

An independent panel of judges from national environmental groups and the golf industry evaluates applications for awards in six categories:

- Resource conservation
- Water quality management
- Integrated pest management
- Wildlife and habitat management
- Habitat development and management
- Education and outreach

Criteria for each category include sustainability, criticality (improving the surrounding environment in a fundamental way that another land use would not), originality, and technology use and implementation.

GCSAA also has information regarding IPM on its web site. For more information about environmental programs at GCSAA or IPM, call (800) 472-7878 or visit www.gcsaa.org.

U.S. Golf Association

In 1995, the U.S. Golf Association (USGA) Green Section began its Environmental Education Program, which is dedicated to environmental outreach to golf courses. The Green Section works in cooperation with ACSP to

- Fund research, management, and education for the Wildlife Link Program, which focuses on projects related to wildlife management issues at golf courses
- Support the Turfgrass Environmental Research Program
- Maintain a list of environmental publications for the golf industry

For more information about environmental programs at USGA, call (908) 234-2300 or visit www.usga.org/green/index.html.

NTEP

NTEP is a cooperative program between USDA; Beltsville Agricultural Research Center; and the National Turfgrass Federation, Inc. NTEP identifies and evaluates grasses to meet various needs, including the need for reduced inputs (applications of pesticides and water), at golf courses. Currently, more than 600 grasses and 17 species are being tested at about 75 sites across the U.S. and Canada. NTEP researches turfgrass and turfgrass systems that will better survive diseases, insects, drought, and traffic, and its produces annual progress reports for each of the species tested.

For more information about NTEP, call (301) 504-5125 or visit www.ntep.org.

Colbert-Thien Environmental and Evaluation Management System

Beginning in 1999, the Colbert Hills Golf Course was constructed in a 312-acre area of native grassland near Manhattan, Kansas, the site of perhaps the most extensive environmental research evaluation ever conducted for a golf course. The purpose of the project was to determine the impact of converting native grassland into a golf course and to develop guidelines for the golf industry in order to minimize negative impacts of golf course construction, operation, and use. The Colbert Hills project was used to develop a system called Colbert-Thien Environmental and Evaluation Management (CTEEM). CTEEM is (1) a system for identifying environmental conditions that need remediation and (2) a source of management strategies for improving those conditions. The CTEEM system has the following five implementation steps:

The construction of Colbert Hills Golf Course near Manhattan, Kansas.

1. Identify natural functions (reactions, processes, and cycles) critical to sustaining ecosystem function; for example, carbon sequestration of soil because it affects many soil properties.
2. Select informative, measurable, and economically feasible indicators to evaluate the critical functions; for example, soil organic matter content to measure carbon sequestration.

3. Measure indicator status. Measurement may include use of historical data, weather station data, or in the case of soil organic matter, for instance, laboratory analysis.

4. Establish control chart indices or acceptable limits for the critical functions-for example, a minimum soil organic matter content of 1 percent.

5. Transform multiple indices into environmental quality evaluation graphs. Indices from any number of quality control charts are normalized on "spider radar" graphs as visual representations of environmental quality.

CTEEM system advocates are currently developing the capability to provide appropriate environmental responses for indicators that fall outside acceptable limits and to monitor the indicators over time. The system is easily customized for individual golf courses. By adopting an environmental evaluation program, superintendents can identify problem areas, be guided toward remediation, and demonstrate progress toward sustainability.

For more information about the CTEEM system, visit www.usga.org/green/record/01/mar_apr/multiple.html.

13.3.2 IPM Resources

CSU National IPM Network

CSU maintains the National IPM Network at www.colostate.edu/Depts/IPM/csuipm.html. The web site contains up-to-date information on pests, weather conditions, and market conditions; IPM information links, and a search engine.

Database of IPM Resources

The Database of IPM Resources (DIR) is a collaborative effort of the Consortium for International Crop Protection (CICP), the University of Illinois, the Integrated Plant Protection Center, Oregon State University, the National IPM Network, North Carolina State University, the IPM Collaborative Research Support Program, the Office of International Research and Development, and Virginia Polytechnic Institute and State University.

DIR is an information retrieval and referral system and a compendium of customized directories of worldwide IPM information resources accessible through the internet. With DIR, one can quickly find the way to thousands of IPM information sites. The DIR covers a wide array of crops, pests, control tactics, regions, organizations, and related topics. It is located at www.ipmnet.org:8140/DIR/.

Radcliffe's IPM World Textbook

Radcliffe's IPM World Textbook is a web site cosponsored by the University of Minnesota and CICP. It is an electronic textbook of IPM featuring chapters contributed by internationally recognized experts. The purpose of the web site is to provide an electronic alternative or complement to printed textbooks on IPM. Specifically, the objectives for the web site are to provide (1) a venue for easily maintaining and updating "state of the art" information from the world's leading experts on all aspects of IPM; (2) a resource that can be freely downloaded and used by students, teachers, and IPM practitioners; (3) a forum for international presentation of practical information and theory on

IPM; and (4) links to the vast and rapidly growing IPM resources available on the internet, including photographs and decision-support software. Radcliffe's IPM World Textbook is located at http://ipmworld.umn.edu.

IPM Almanac

The IPM Almanac is a web site that provides information and tools for IPM planning and implementation. It contains resources such as IPM basics, IPM plans, a glossary, checklists, tip sheets, search engines, and links to IPM Solutions Newsletter. The IPM Almanac is located at www.ipmalmanac.com/.

IPM Practitioners Association

The IPM Practitioners Association (IPMPA) is a nonprofit organization founded in 1989 to facilitate use and understanding of IPM in primarily nonagricultural resource settings. It maintains a web site called IPM ACCESS at www.efn.org/~ipmpa/. IPM ACCESS is a networking and information service web site that gives IPM practitioners and other interested people the opportunity to find, share, and develop effective, economical, and environmentally sound approaches for management of vegetation and pests, primarily in nonagricultural resource settings.