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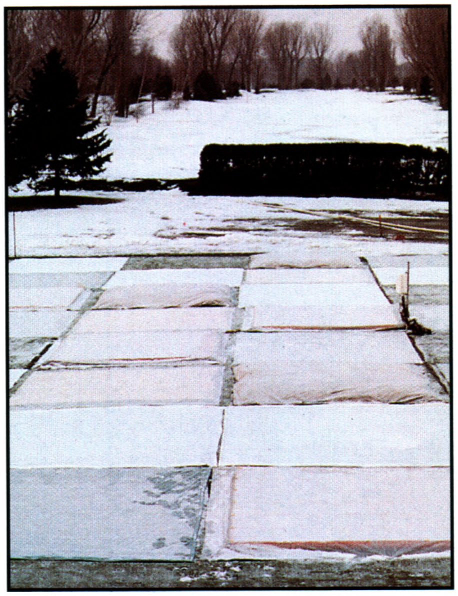
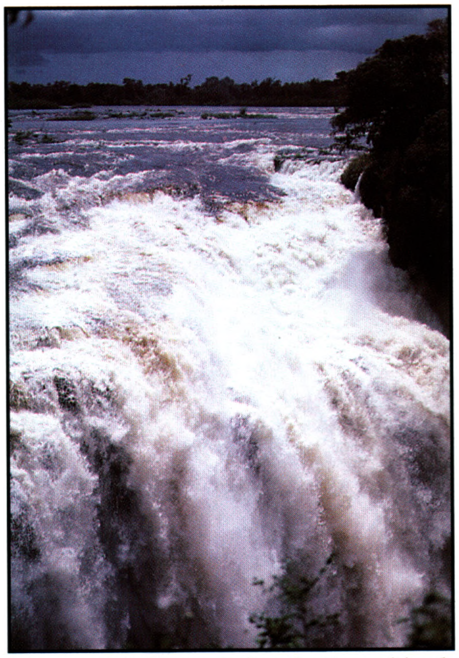
Cover Photo: On-site weather stations and computer controls help the turf manager more precisely determine how much water to apply to the golf course turf.

USGA® GREEN SECTION Record



Winter protection of annual bluegrass golf greens is often a necessity to ensure that extensive winterkill doesn't occur. See page 11.



The availability and distribution of fresh water will be a widely debated issue in the 21st century. See page 14.

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Does Your Irrigation System Make The Grade?

A guide to help evaluate factors influencing irrigation system performance.

by MIKE HUCK

MOST GOLFERS QUICKLY recognize poor irrigation coverage by the obvious — the number and size of both wet and dry areas throughout the course. However, very few understand the many factors that affect an irrigation system's ability to apply water uniformly.

First and foremost, proper design and installation are critical. Hydraulics, head spacing, nozzle selection, control capabilities, and climate all must be considered in the design process. If any one area is lacking, performance suffers. If one is fortunate enough to already have a good system in place, then routine maintenance should sustain acceptable performance. Annual adjustment of pumps, pressure regulators, leveling of low heads to avoid surrounding turf interference with spray patterns, and replacement of worn nozzles or any other damaged components must be ongoing.

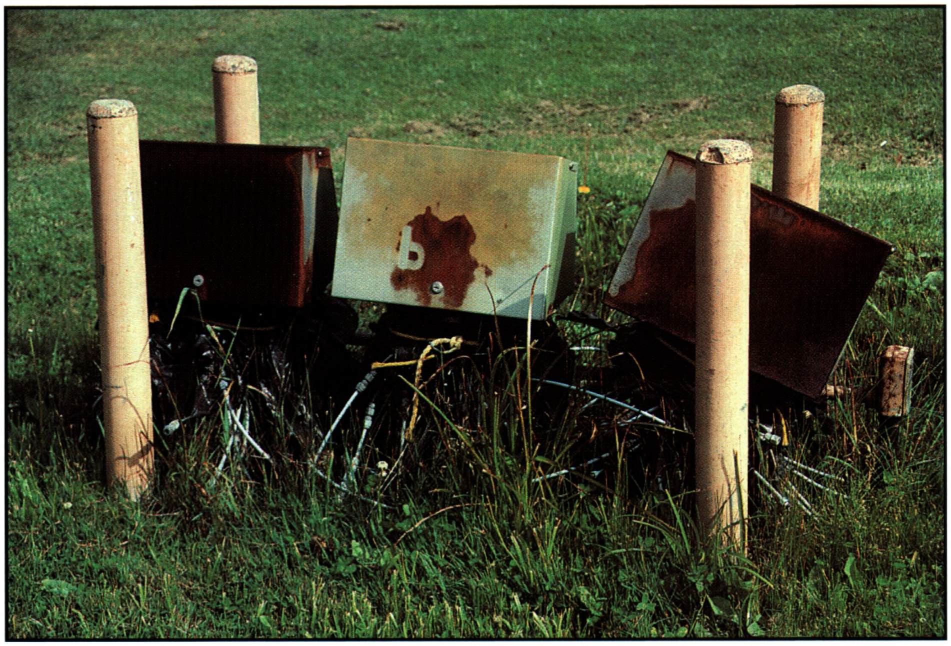
Outdated systems present another set of problems with aging hardware resulting in major failures of pumps, controllers, mainlines, and fittings that can cause large areas of turf loss. To counter such problems, a daily ritual of many superintendents is to spot water, repair leaks, and continually adjust controllers — turning them up to reduce dry spots one day, and down the next to control wet spots. So much time is spent compensating for system inadequacies and inefficiencies that little time is left for other duties and the staff is constantly putting out fires. It is no wonder that irrigation systems are often nicknamed *irritation systems*!

The Report Card Evaluation

Understanding and evaluating factors that influence irrigation system performance is the first step towards improving overall performance. To understand the system's weaknesses and evaluate where improvement is needed, consider completing an irrigation system report card. The report card can help golf course decision makers understand the various factors affecting irrigation system performance and guide them in developing improvement plans. This suggested method 1) identifies a system that will satisfy your needs, 2) considers historical performance of the existing system, 3) evaluates the existing system's condition as compared to a state-of-the-art design, and 4) suggests actions to consider

3) More than one pumping plant or piping system services different segments of the golf course.

A grade average can be determined following each step and appropriate plans to bring the system up to an acceptable grade that will satisfy your overall needs (as identified in step one) can then be developed. Understand that it may not be possible to improve every factor to the highest possible "A" grade, but raising any particular area one or more letter grade can make a difference.



Is this system state of the art or in a state of disrepair? Evaluating your system is the first step in determining where improvements should be made or if the system needs to be upgraded or replaced.

based upon a final grade point average (GPA).

Before beginning the process, assemble a rating team comprised of the golf course superintendent, green committee, general manager, and golf professional. The rating team then will evaluate several specific areas and assign grades from "A," reflecting excellent performance, to "F," indicating failure for each factor listed on the report card, a system we are all familiar with from our school days.

In most cases, one grade for performance of the entire irrigation system will be adequate, but in some cases a hole-by-hole grading may be necessary if:

1) Modifications affecting the irrigation system have been made on individual or various holes.

2) Significant elevation changes occur across the property that affect operating pressures.

Step 1: Determine the Grade of an Irrigation System That Will Satisfy Your Needs

The level of sophistication needed for an irrigation system varies regionally depending upon factors such as: 1) golfer expectations for turf quality and course conditioning, 2) labor and budget resources, and 3) climate. Not every location requires (or can justify) an "A" system that includes all the whistles, buttons, and bells that currently are available. Using the following factors, an average grade can be developed that should satisfy your overall needs.

Golfer Expectations: Golfers' expectations and acceptance of manual watering, wet and dry areas, general turf quality, and playing conditions are summarized as:

• A: Must look and play like the latest televised event. Golfers accept hand watering of greens only.

• B: Excellent conditioning, firm, fast conditions with an occasional wet or dry area. Golfers accept occasional spot watering on greens, tees, and fairways.

• C: Good conditions with moderate numbers of wet or dry spots. Golfers accept daily spot watering of fairways, tees, and greens to minimize problem areas.

• D: Fair to poor conditions, with numerous wet and dry areas developing when relying on sprinklers alone. Many hose-end sprinklers run during the day to maintain acceptable conditions.

• F: Very poor; large wet and dry areas that require manual irrigation of large areas daily. Uniform soil moisture and turf color are only possible with rain.

Labor and Budget: To offset system inefficiencies, use of manual irrigation with hoses and portable sprinklers is often necessary, and this can require significant labor and budget additions. The following criteria can be used to determine the grade of the system needed to provide acceptable conditions based upon budget and labor availability:

• A: Shoestring; must rely on the irrigation system entirely. Only have time to mow and set up the course for play.

• B: Limited; can hand water dry spots on greens and collars. Not much time to spot water tees or fairways.

• C: Moderate; can put out a few roller-base portable sprinklers on tees and fairways and hand water greens and collars as required.

• D: Large; can hide all the inefficiencies of the system with hand watering and numerous portable sprinklers.

• F: Infinite; we can hand water the entire property if necessary.

Climate: The sophistication of the irrigation system needed is directly related to the climate. The length of time between rainfall events and the amount of natural rainfall, along with peak daily ET (evapotranspiration) replacement requirements, must be considered. Based upon the following climate descriptions, the grade of irrigation system needed is:

Peak Daily ET Replacement in Inches	*Climate/ Expected Precipitation*
• A: >0.30	Dry desert climates, with several months between significant rain (<15" annually).

- B: 0.20-0.30 Interior plains and valleys with hot, dry summers. Regular showers are expected every three to four weeks (15"-25" annually).
- C: 0.15-0.20 Transitional regions with high summer temperatures and rain expected every one to two weeks (25"-35" annually).
- D: 0.10-0.15 Coastal climates with considerable fog, and northern temperate regions with moderate temperatures. Weekly rainfall (35"-45" annually).
- F: <0.10 Our course is located in a rainforest; we receive rain just about daily (>45" annually).

Step 2: Historical Performance

After determining the grade of a system that will satisfy your needs, establish an average grade for the overall performance of the irrigation system over the past five years. Ask questions such as: With the existing irrigation system, has the staff been able to a) keep the turf healthy all of the time, b) keep the course green most of the time, c) keep the course firm and playable most of the time? Has the system been reliable and not cost an excessive amount of money to maintain? In short, the irrigation system over the past five years has:

- A: Met or exceeded expectations at all times.
- B: Met expectations most of the time.
- C: Met expectations some of the time.
- D: Consistently fell below expectations.
- F: Never met expectations.

Step 3: Determine the Quality of the Existing System

The intended result of any irrigation system is to apply water uniformly, but it is a mistake to think that only "head-to-head coverage" is needed for uniform coverage. Uniform coverage is the end result of several factors combined, including:

1. Reasonable sprinkler spacing distances specified in the original design.
2. Uniformly installed spacing and proper configuration of sprinklers.
3. Sprinkler and nozzle performance that produces optimum coverage within the system's design parameters (i.e., spacing distance, layout, and system hydraulics).
4. Flexible controls with the ability to manage the amount of water applied based upon varying site requirements (plant and turf species, soil types, shade influence, slope, etc.).
5. Reasonable numbers of sprinklers assigned to control stations.
6. Proper hydraulic design (correct pipe and pump sizes, operating pressures, and flow rates).
7. Properly installed, reliable hardware components (controllers, fittings, thrust blocks, pipe pressure rating, etc.).

In summary, an irrigation system works on the "weakest link in the chain" theory. If any one of the above areas is lacking, undesirable results often occur. In the following section, each of the above areas will be graded against current state-of-the-art design standards.

Sprinkler Spacing Distances: Physics dictates that throwing water a short distance requires less energy (pressure) than discharging water a greater distance. Operating at lower pressures reduces operating costs and minimizes development of fine droplets that, when affected by wind, upset application patterns. This is why new irrigation systems are designed with closer spacing and with sprinklers that operate at lower pressures. Also, application uniformity generally is better when using smaller spacings. Assign a grade for the designed spacing of primary playing areas as follows:

- A: ≤ 65 feet
- B: 66-75 feet
- C: 76-85 feet
- D: 86-95 feet
- F: ≥ 96 feet

Spacing and Configuration Uniformity: Sprinkler spacing should be uniform in distance and configuration (equilateral triangles or squares). Spacing reduced in one direction to compensate for wind generally is not recommended because wind direction and velocity are usually different each day. The following criteria can be used to grade sprinkler spacing and uniformity:

- A: Equilateral triangles or squares, installed within 5% of designed spacing.
- B: Equilateral triangles or squares, installed within 10% of designed spacing.
- C: Uniformly sized non-equilateral triangles or rectangles.
- D: Single row, uniformly spaced (fairways).
- F: Varying spacing with no apparent plan considered.

Sprinkler/Nozzle Performance: If sprinkler and nozzle performance are not matched to the installed spacing and configuration, then application uniformity will never be achieved. To measure sprinkler distribution performance, conduct a catch-can test and evaluate the data. The basic procedure is as follows:

Maintaining level irrigation heads is a basic in sprinkler maintenance. The end result is improved water application uniformity.

1. Bring all sprinklers in the areas to be tested to a level grade.

2. Inspect nozzles of complementing heads. Replace mismatched or unusually worn nozzles.

3. Adjust pressure regulation valves (PRV) to specified operating pressures.

4. Check that sprinkler rotational speed is within the manufacturer's specifications. (Impact heads are controlled by properly tensioned return-spring adjustment, while stator and nozzle combinations control gear rotors.)

5. Place uniformly sized catch-cans five feet apart throughout the test area.

6. Operate each sprinkler influencing the area for 15 minutes.

7. Measure and record the depth of water in each container.

8. Evaluate the data.

Note: Data can be evaluated manually or with computer software to determine distribution uniformity (DU) and/or scheduling coefficient (SC). For additional information regarding these formulas or available software, contact The Center for Irrigation Technology (CIT) at Fresno State University, Fresno, California, (559) 278-2066. Request the references listed at the end of this article or visit http://www.atinet.org/CATI/rese/ .

Where high SC and low DU values result, operating pressure, sprinkler spacing, nozzle selection, and/or nozzle wear should be closely examined as potential problems. Where low SC and high DU values result, yet wet or dry spots persist when operating the system automatically, closer examination of controller programming, operational pressures, flow velocities, pipe sizing, soil compaction, and potential water chemistry problems that affect permeability (SAR and ECw) are warranted. The following criteria can be used to grade catch-can test results:

	SC	DU
• A:	≤ 1.2	> 85%
• B:	1.2-1.3	75-85%
• C:	1.3-1.5	65-75%
• D:	1.5-1.8	55-65%
• F:	> 1.8	< 55%

Automatic Controls: Properly programmed control systems help manage how much, when, and where water will be applied. They also can balance hydraulics, maintain maximum flow velocities, and optimize operating window time frames. The following criteria can be used to grade automatic controls:

• A: Computerized central controls with flow-managing software, solid-state satellites, on-site weather station, and hand-held radio controls.

• B: Computerized central controls with flow-managing software, electro-mechanical satellites, and access to public weather station data.

• C: Solid-state central control *without* flow-managing software.

• D: Electro-mechanical central and satellite controls.

• F: Satellite control only (no central).

Sprinkler Station Assignments: Reducing the total number of sprinklers controlled per satellite station increases flexibility. Individually controlled heads throughout the tees, fairways, and roughs, along with dual heads at greens (one set of heads directed at the putting surface, with a separate set of heads directed at the green surrounds) to allow more finite management of water have become common with new designs. The following criteria can be used to grade sprinkler station assignments:

• A: Individual sprinkler control throughout greens, tees, fairways, and roughs, with dual heads at green perimeters.

• B: Individual wires to all sprinklers. Individual sprinkler control at greens and tees and dual perimeter heads at greens. Fairways and roughs have not more than three sprinklers per station, with individual wires accessible within control cabinets to allow easy station reassignment.

• C: Single head control at greens, not more than two heads per station on tees, and not more than four heads per station in fairways and roughs. Station assignment wires are permanently spliced underground and require trenching to make changes in station assignments. Fairway and rough station assignments operate parallel to the direction of play.

• D: Two heads per station on greens, no more than five sprinklers per station on tees, fairways, or roughs. Tee, fairway, and rough heads operate parallel to direction of play.

• F: Any kind of control with more than two sprinklers operating per station on greens, or fairway sprinklers operating perpendicularly (from tree line to tree line), as opposed to parallel to fairways.

System Hydraulics, Flow Velocities, and "Operational Windows": To assure optimum operating pressures, efficiency, and the avoidance of water hammer, proper hydraulics must be designed into the system from the start. Hydraulic design and pipe sizing is based upon 1) the number of acres to be irrigated, 2) peak water replacement

This circle of green grass and surrounding brown turf is a classic symptom of poor irrigation coverage. The lack of a good irrigation system often results in the staff spending an inordinate amount of time compensating for the system's weaknesses.

requirements, and 3) the number of hours available to complete an irrigation cycle during peak water replacement.

It is common for sprinklers to be added where deficiencies in the original design are noticed or as golfers' expectations increase. This can result in hydraulically overloading the system or extending the operating window into hours of daylight that interfere with play and maintenance. Overloading system hydraulics must be avoided, as it is similar to operating an electrical circuit with too many appliances. Eventually, something gives out! Overloaded electrical systems generate heat through resistance and blow fuses. Overloaded irrigation systems develop excessive flow velocities that create water hammer. Water hammer eventually fatigues and ruptures pipe. Excessive velocities also cause pressure losses that contribute to poor coverage and require extending the operational window to maintain proper operating pressures.

Therefore, evaluating the operational window is often a fair assessment of potential hydraulic problems, and poor performance in this area warrants consultation with an irrigation designer. To evaluate the overall hydraulics of the system, the operational window required to complete an automatic cycle at peak demand without exceeding flow velocities of 5 feet per second is:

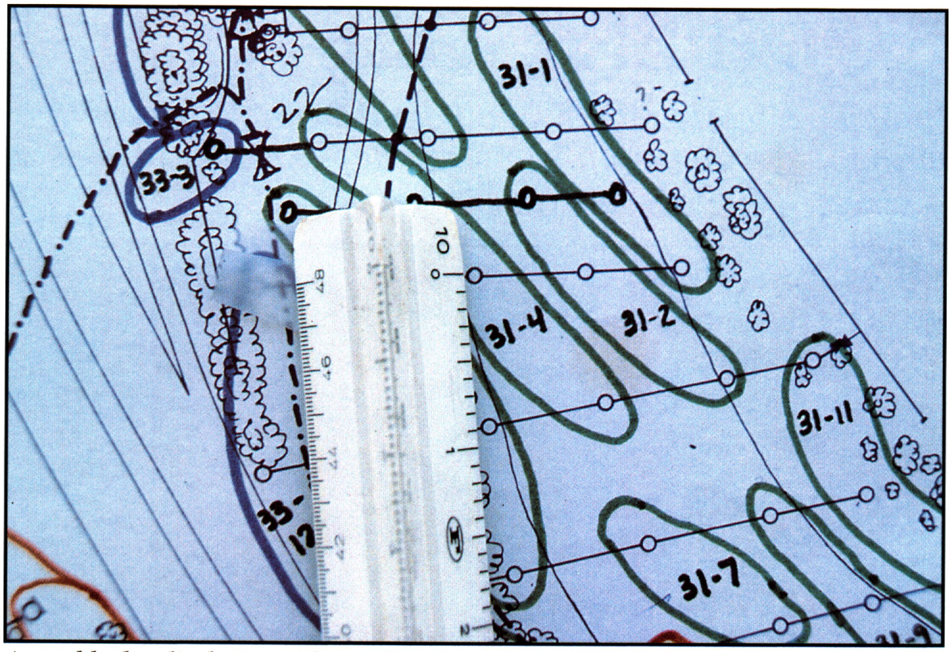
- A: ≤ 7 hours
- B: 7-8 hours
- C: 8-10 hours
- D: 10-12 hours
- F: 12 hours or more

System Reliability: No matter how well a system distributes water, it must also be reliable. Chronic failures of lateral or mainline pipe, fittings, pumps, or control systems can be a sign of poor quality products, incorrect installation techniques, and/or aging components in need of replacement. Normal wear and tear failures should not become an issue until a system reaches more than 20 years of age. Frequent pipe failures occurring sooner can indicate that pipe and fittings of improper pressure rating were used, or pipe was not sized correctly and maximum flow velocities have regularly been exceeded. Additionally, if epoxy coated steel or PVC mainline fittings are utilized, chronic failure can be expected earlier in the life of the system. Their replacement with longer-lasting and far more durable ductile iron components is suggested. System reliability may be ranked accordingly by the number of major failures occurring each season:

- A: Zero to one
- B: Two to four
- C: Five to seven
- D: Eight to ten
- F: Eleven or more

Other Rating Factors: Some sites may require site-specific rating factors to be considered by the rating team. These could include the following:

- Pump output
- Well output
- Lake storage capacity
- Varying soil conditions
- Soil compaction
- Tree influences
- Water chemistry as it relates to permeability



A good hydraulic design with a uniformly spaced and configured sprinkler layout is the first step towards achieving an irrigation system worthy of an "A" grade.

Step 4: Implementing Changes or Seeking Additional Help

Changes to improve performance, such as adjusting pressure regulation valves, lifting and leveling low heads, replacing sprinkler nozzles or control systems, can offer reasonable improvements. Bringing in an irrigation design consultant to perform a more complete analysis is warranted where serious deficiencies are identified. Finally, it is important to understand that irrigation upgrades often require large capital expenditures to offer noticeable improvement. Recommendations based upon the grade point average derived from the various factors evaluated in Step 3 are:

Final GPA

- A: Excellent system; proper maintenance should maintain this status for a number of years.
- B: Good system; possibly beginning to show some age, but proper maintenance should prolong useful life expectancy, maintain efficiency, and possibly offer improvement.
- C: This system needs work, and improvement may be possible, depending upon the problems. The assistance of an irrigation designer may be helpful.
- D: Seek the advice of an irrigation designer for improvement.
- F: Get a good irrigation designer and get out the checkbook; nothing short of complete system replacement can likely help.

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MIKE HUCK *is the agronomist in the Southwest Region, where water use efficiency is of the utmost importance and the arid climate quickly shows an irrigation system with a failing grade.*

AQUIFER GOLF

Imagine a world where a golf course can coexist with a municipal water supply and not be the center of constant protest.

by FRANK A. RENDULIC, CGCS

A self-cleaning screen at the lake intake prevents large debris from entering the system.

THE KITTYHAWK Golf Course is an 800-acre, 54-hole golf complex owned and operated by the city of Dayton, Ohio. The golf course is unique in many ways. First, it is one of the largest municipally owned golf facilities in the country, and it is situated immediately above the Miami Aquifer, one of the largest bodies of underground water in the world and the water source for Dayton and the surrounding area. Second, the Kittyhawk Golf Course is a part of the city's Miami Well Field, which produces as much as 63 million gallons per day (MGD) of water for the residents and businesses of the greater Dayton area.

The concept of a golf course within the well field arose in 1956 when the city of Dayton acquired a large tract of land adjacent to the Great Miami River to act as a buffer zone for the existing Miami Well Field. The well field included a large lake and two recharge lagoons (long, narrow water channels intended to increase percolation into the aquifer). The lake and lagoons were filled naturally through a connection to the Great Miami River and could produce 2 to 4 MGD of recharge to the aquifer. City planners sought to make better use of the newly acquired land rather than allowing it to sit fallow.

The development of a golf facility was considered to be an appropriate dual use of the land. Robert Bruce Harris was contracted to design an 18-hole championship course (Hawk Course) and a par-3 beginner's course (Kitty Course). Construction on the golf courses began in 1960, and the two courses opened for play in 1961. With increasing rounds of golf and additional land available at the Kittyhawk site, the city again hired Robert Bruce Harris to design the 18-hole Eagle Course. The Eagle Course opened for play in 1965, bringing the number of holes available for play to 54.

Time to Sell Water?

From 1965 to the early 1980s, the Kittyhawk Golf Course not only served as a fine test of golfers' abilities, but also fulfilled its role in buffering the well field operations from industrial development. Then, in 1982, the city of Dayton, along with Montgomery County, hired CH2M Hill to study the feasibility of the city of Dayton selling water to the southern suburbs. The results of this study concluded that the well field and treatment facilities were adequate to proceed with the project. The necessary interconnects were created, and the city began selling water to Montgomery County in the mid-1980s.

The added demand, coupled with back-to-back drought years in 1987 and 1988, caused the water table to drop dramatically during that period. The drought had the expected effect on the golf operation, leaving large areas of brown turf in the non-irrigated areas and showing clearly any weak areas in the irrigation system. More important, however, was the impact on the city's ability to provide water to area residents. Modifications to the existing recharge lake and lagoon system had allowed for a maximum aquifer recharge of approximately 29 MGD, but it was clear that additional recharge was needed to insure that future demand could be met.

Enhancing Water Recharge

The services of Camp, Dresser and McKee were engaged to study the feasibility of adding recharge facilities to the Kittyhawk Golf Course. Three possible solutions were studied: horizontal collector injection wells; the typical long, narrow recharge lagoons already in use in the well field; and ponds strategically placed as water hazards on the golf courses. Each of the three solutions would require a pumping system to lift water from the recharge lake near the river to the golf courses' higher elevations.

Following several internal meetings, it was decided that golf water hazards were the most viable solution. Hank Chafin, CGCS, superintendent of the golf course at the time, worked with Abe Martin, well field supervisor, to select approximately 40 possible locations that would serve both the Water Department's and the golf courses' needs. Bowser-Morner, Inc., was contracted to take soil borings at each site to help determine the final locations for the ponds. This work was completed in 1988.

Woolpert LLP was hired to oversee the water hazard construction project. Six new ponds were placed on the Kitty Course, 13 new ponds were added to the Hawk Course, and 11 new ponds were added to the Eagle Course. In addition, one existing pond on the Hawk Course and two on the Eagle Course were reworked to be added to the recharge system. Following the excavation of the ponds, a connection to the aquifer was created by excavating a trench through any clay layers to facilitate movement of water into the aquifer. The resulting trenches were backfilled with clean #4 roofing gravel; #57 gravel and #8 pea gravel were then installed over the roofing gravel to act as a filter. The #8 gravel layer is removed and replaced periodically to ensure maximum recharge of the aquifer.

Water for the recharge system is pumped from the original recharge lake, which had been modified to act as a stilling basin, allowing particulate matter to settle before being pumped into the ponds. The pump station is fitted with five 16"-diameter line shaft turbine pumps driven by 75 HP motors. The total output of the pump station is approximately 39 MGD. Water from the pump station is delivered to the ponds through a 30-inch main that branches out to each pond. The lateral lines servicing each pond range from 8 to 12 inches in diameter, based on the size of the pond being filled. Final output to the ponds ranges from 800 to 1,200 GPM (gallons per minute). Each pond is fitted with a water-level control that maintains preset levels once the ponds fill.

Concurrent with the installation of the recharge pipe network, a 60"-diameter potable water main was installed to deliver water from 14 new production wells located on the golf courses to the water supply and treatment facility. This pipe was installed in a trench alongside the 30" recharge main. The routing of the two mains bisected the Hawk and Eagle courses. (Note: The resulting trench was 20' wide and 20' deep and did have an impact on play.)

Filling freshly excavated ponds or ponds that have had the filter layer replaced is not an overnight process. The initial filling can take up to two months. During this time, the water delivered to the ponds simply flows into the gravel channel and disappears. As groundwater under each pond begins to mound, percolation rates drop to the design levels and the pond begins to retain water. The water-level control structures prevent overfilling of the ponds.

Several factors influence the pond cleaning schedule. Because the ponds are relatively shallow (8' maximum depth), and because the water supply comes through a predominantly agricultural area before reaching Dayton and may contain nutrients as a result of runoff, algae forms more rapidly. In addition, to help meet the needs of the golf operation, water has sometimes been pumped into the ponds when turbidity levels have been higher than planned. The Water Department installed aerators or air diffusers in 20 of the ponds, which helped with the algae problem, but the ponds must still be cleaned every two years. The cleaning involves the replacement of the gravel filter layer.

Replacing the filter layer is no small task. Excavators, loaders, and Terex-style, off-road dump trucks haul the contaminated materials out and bring in fresh gravel. This process takes much of the winter to accomplish. The trucks and other equipment follow prescribed haul roads, but they must cross the playing areas at times. Haul roads have been laid out to minimize effects on golf play, the grounds, and underground facilities.

Ongoing Maintenance

Maintaining a golf course within an operating well field presents special challenges. We stay in almost constant contact with the city's Environmental Protection Office. A copy of our annual plant protection program is forwarded to that office for review every winter. Before and immediately after every application of fertilizer or pesticide, a record of the application is faxed to the Environmental Protection Office so that upcoming groundwater tests can be tailored to look for potential problems. In addition to 16 production wells located on the golf course, numerous monitoring wells dot the landscape. We can proudly say that no golf-course-related materials have ever been found in the groundwater or in soil samples taken around the course.

Also submitted is an annual Regulated Substance Activity Inventory Report (RSAIR) to the city's Environmental Protection Office. This report is required of any business located within the well field protection area. The report lists quantities of regulated substances that may be stored or used on the property during the course of the year. The golf courses store only dry formulation products on site for the plant protective program. All liquid materials are stored in a specifically designed facility at the Madden Golf Course. Liquids are brought on site within 24 hours of use.

The Plant Protective Program is developed as a guide for the golf course superintendent to follow and represents the maximum amount of product that may be applied. Phil Cline, CGCS, golf course superintendent at Kittyhawk, carefully monitors weather patterns and is free to back off the program to meet conditions. A comprehensive inventory is conducted every fall to ensure that excessive amounts of materials are not stored. The program is under constant review, and products are replaced as newer, more efficient, or lower toxicity products become available.

The use of Merit® for white grub control is a prime example of this review process. Merit, which replaced organophosphate materials used in the past, has decreased the potential impact on the environment while providing much better grub control. All improvements in our environmental management program carry over to our other golf courses as well.

Application of materials is a special concern as well. In addition to the bermed pond edges to prevent runoff from adjacent areas, no applications are made within 30 feet of the top edge of any of the ponds to help ensure that materials do not run off. Maintenance of the pond edges is the responsibility of the Water Department well field managers, with many banks allowed to grow rank as a deterrent to Canada geese.

The Kittyhawk Golf Course (along with its sister courses Madden and Community Golf Courses) is a member of the Audubon Cooperative Sanctuary Program and is currently working toward certification. Communicating the purpose of the water features and the need for them to be dry at times is an ongoing process. The Water Department has placed signs at the first tee on each golf course to explain the overall operation of the recharge project. Much of the Water Department equipment on the course (freshwater pumps, lake level control structures, water purifying towers, etc.) has signage explaining how the equipment works.

The Kittyhawk Golf Course is a work in progress, with changes made to the recharge system from time to time. One recent change included the excavation of a creek across the third fairway on the Eagle Course to move water from a purifying tower into one of the lakes. The stream flows at 800 GPM and acts as a hazard on the hole. Work currently in progress includes the creation of a series of waterfalls and meandering streams to connect the ponds on the par-3 Kitty Course.

This project has demonstrated how the city has successfully worked with the community to meet their water needs and provide a recreational facility.

FRANK RENDULIC, CGCS, *is superintendent of Golf Operations (General Manager) for all Dayton Municipal Golf Courses. He has been with the city since 1989, first serving as agronomist for all the golf courses before assuming his current position in 1995. Frank is a Penn State University graduate, with more than 26 years of experience.*

And the Survey Says . . .

Converting to creeping bentgrass fairways should be based on sound economics and environmental consciousness.

by PAUL VERMEULEN

DURING THE LATE 1990s, gray leaf spot quickly spread from Baltimore to Omaha, leaving a path of destruction unequalled in the turfgrass industry. This tragedy of almost biblical proportion has prompted golf courses in the upper transition zone, where perennial ryegrass replaced Kentucky bluegrass in the 1980s, to seriously consider yet another change in fairway turf.

The mindset towards change is not so much a matter of avoiding future catastrophes, but rather a means of reducing annual spending on pesticides. Since the discovery of gray leaf spot, turfgrass pathologists have had the opportunity to screen registered fungicides and determine those that offer the highest level of control. To date, these research efforts have shown that azoxystrobin, thiophanate-methyl, and trifloxystrobin provide good to excellent control. Furthermore, chlorothalonil and propiconazole provide fair to good control when applied singularly and good to excellent control when tank mixed.

When gray leaf spot attacks, protecting perennial ryegrass from devastation necessitates two or more expensive fungicide treatments.

Given all the good news regarding gray leaf spot control, why is it that superintendents are still mulling over change? The answer for Scott Werner, CGCS, of Lincolnshire Fields Country Club in Champaign, Illinois, is tied to sound economics and environmental consciousness. Before perennial ryegrass showed its vulnerability to gray leaf spot, Scott's primary concerns were controlling pythium, brown patch, and dollar spot. These three diseases, while troublesome in their own rights, are fairly predictable and can be controlled with timely fungicide applications. Furthermore, the costs of the products typically used for their control are moderately priced, considering efficacy and treatment intervals.

Since 1998, when gray leaf spot first struck Lincolnshire Fields Country Club, a preventive fungicide program has been required, beginning in July and continuing through October. This rigorous program has been necessary because of the lack of a gray leaf spot prediction model and the inability to achieve an acceptable level of control with a curative program. The bottom line for Scott and other superintendents in the Mid-Continent Region battling against gray leaf spot has been a substantial increase in their fungicide budgets.

From an environmental perspective, the added demands of controlling gray leaf spot leave superintendents questioning their voluntary commitment to reducing pesticide usage. However, not meeting the high expectations for turf quality on courses with perennial ryegrass fairways will create unwanted openings on the starter's reservation sheet and job insecurity.

If perennial ryegrass is no longer the best choice for fairway turf because of the need to make frequent fungicide applications, then what is the clear alternative? In the upper transition zone, where winters are too long and cold for warm-season grasses, the list of alternatives is narrowed to Kentucky bluegrass and creeping bentgrass.

Sentimentally, Kentucky bluegrass is the hands-down favorite among golfers because of its dark green, luxurious appearance. Problems can arise quickly, however, when the demand for mowing heights of less than ¾" induce summer patch and, yes, the invasion of good ol' *Poa annua*. These two problems are what originally inspired many golf courses to convert to perennial ryegrass in the first place. And, until new cultivars prove their advertised superiority in the realm of low mowing, it is unlikely many superintendents will take the risk of revisiting the past.

By process of elimination, that leaves creeping bentgrass as the sole alternative for courses such as Lincolnshire Fields Country Club. To some, this may seem like a consolation of sorts, but it really is not. Creeping bentgrass is actually a good choice for fairway turf. Its list of attributes includes reasonably good disease tolerance, good heat tolerance, excellent recuperative potential, and excellent playability when mowed between 7/16" and 5/8".

The true litmus test, however, is whether or not creeping bentgrass makes good economic and environmental sense when compared to perennial ryegrass. To answer this question, a survey was conducted among 18 courses throughout central Illinois and eastern Iowa. Nine of the courses maintain creeping bentgrass as the dominant species on the fairways, while the other nine maintain perennial ryegrass. The courses had a wide range

Fumigation with Basamid may be the best choice for controlling Poa annua *during a fairway conversion project. The line of* Poa annua *invasion indicates where the operator missed a narrow strip when applying the product with a drop spreader.*

of backgrounds, including public to private, newly established to well established, low to high traffic volumes, moderate to high maintenance standards, and poor to good air circulation and drainage characteristics.

The results of the survey are presented in Table 1 and reveal at least three sobering points that deserve discussion. First, not every course with perennial ryegrass fairways should expect to reduce pesticide usage by converting to creeping bentgrass. As demonstrated in the survey, some perennial ryegrass courses maintain excellent playing conditions for about the same pesticide budget as creeping bentgrass courses. It is important to note, however, that each of these courses has resisted the temptation to overplant trees on both sides of the fairways and is not located where extreme humidity and poor drainage tend to increase disease activity.

Second, and most important if conversion is being contemplated, converting from perennial ryegrass to creeping bentgrass can actually increase pesticide usage. Wait a minute! How can this be, given the stated superiority of creeping bentgrass and the susceptibility of perennial ryegrass to several diseases, including gray leaf spot?

The answer lies in the fact that converting to creeping bentgrass, as done years ago by two of the leading fungicide users in the survey, can bring *Poa annua* into the equation. In other words, the survey showed that creeping bentgrass is king of the hill on highly manicured courses only if it is practically *Poa annua* free. This being the case, courses wanting to convert to creeping bentgrass fairways because they have reached their spending limits on perennial ryegrass, should have an effective *Poa annua* control strategy in place. If not, they could wind up with equally high expenses.

The two control strategies that have worked best in the Mid-Continent Region are 1) to embark on an aggressive herbicide/growth regulator program immediately after the fairways have been treated with RoundUp® and reseeded, and 2) to fumigate the fairways before reseeding. Of these two strategies, fumigation, where possible, would be the preferred choice because it addresses the seed bank of *Poa annua*. By eliminating most of the *Poa annua* seed in the soil, the new turf can establish without competition, and the need for follow-up herbicide/growth regulator applications will be minimized.

The success of fumigation has long been demonstrated on courses that have renovated greens, but rarely has it been performed on fairways. The reason is that the product, methyl bromide, is very difficult to use on a large scale because it requires a plastic cover after it has been injected.

To fumigate the fairways at Geneva Golf Club in Geneva, Illinois, before establishing them with Kentucky bluegrass, Ed Braunsky, CGCS, used a granular product, Basamid (dazomet), that does not require a plastic cover. (Author's note: The choice of Kentucky bluegrass was based on the golfers' preference to play on a tall surface. The

Table 1

Results of a survey taken among 18 courses throughout central Illinois and eastern Iowa. The totals represent actual budget information from the 1999 growing season.

Course	Total Spent on Pesticides Per Fairway Acre	Total Spent on Fungicides Per Fairway Acre	Reported *Poa annua* Percentage	Level of Turf Quality by Golfers
		Creeping Bentgrass Fairways		
No. 1	$ 500	$ 300	30	Moderate
No. 2	$ 668	$ 450	5	Moderate
No. 3	$1,697	$1,108	0	High
No. 4	$2,480	$1,400	1	High
No. 5	$2,800	$1,142	1	High
No. 6	$2,825	$1,500	10	High
No. 7	$3,352	$2,030	35	High
No. 8	$3,461	$2,500	30	High
No. 9	$3,574	$2,833	30	High
Average	$2,373	$1,474		
		Perennial Ryegrass Fairways		
No. 10	$1,208	$ 833	35	Moderate
No. 11	$2,266	$1,433	50	High
No. 12	$2,352	$1,666	10	High
No. 13	$2,640	$2,007	10	High
No. 14	$3,160	$2,400	35	High
No. 15	$3,200	$1,600	25	High
No. 16	$3,382	$2,285	40	High
No. 17	$3,500	$2,333	40	High
No. 18	$3,768	$2,411	5	High
Average	$2,831	$1,885		

Careful planning before renovation projects are initiated helps reduce long-term problems. Fumigating fairways during a renovation project can help eliminate the existing Poa annua *seed bank that acts as a source of contamination once the new turf is established.*

Basamid label is available for reference on the web at www.topprospecialties.com.) This product has recently received renewed interest as a replacement for methyl bromide because of its effectiveness when either tilled into the soil or surface applied with a drop spreader under specific application parameters.

The cost of fumigating fairways has been raised as a possible deterrent; however, the survey showed that the payback in fungicide savings alone when converting fairways could be as short as two years. Take, for example, a course with perennial ryegrass fairways that currently is spending $2,300 per acre annually on fungicides. If it was converted to creeping bentgrass with fumigation and in the process the *Poa annua* population was reduced to 3%, then the cost of controlling fungal pathogens could decrease to between $1,100 and $1,400 per acre annually.

Third, creeping bentgrass fairways, even when they are contaminated with 30% *Poa annua*, can be maintained at a lower cost than perennial ryegrass. What? I just discussed the importance of *Poa annua* control and now I'm contradicting myself. Not really, because here I am referring specifically to situations where it is *not* essential to maintain flawless turf conditions.

In the survey there are three courses that for economic reasons allow the quality of the fairways to decline for short periods without causing complete dissatisfaction or staff turnover. Under these circumstances, perennial ryegrass can no longer prevail as the turf of choice because gray leaf spot has the potential to kill off more than 90% of the stand and wreak havoc on any attempt to reseed during the following fall season. When gray leaf spot attacks, protecting perennial ryegrass from devastation would necessitate two or more expensive fungicide treatments to prevent playing on bare soil. Creeping bentgrass, even when contaminated with *Poa annua*, can recover from disease infections over a period of several weeks.

In closing, deciding when and how to convert perennial ryegrass fairways to creeping bentgrass should be based on sound agronomy and reliable information from as many sources as possible. In presenting the information contained in this article, I would like to thank the superintendents who cooperated in the survey. Without their assistance, formulating renovation proposals based on relevant information would be impossible.

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Winter Protection of Annual Bluegrass Golf Greens

How protective covers can reduce winter damage to putting greens.

by JULIE DIONNE

THE QUALITY of putting surfaces is one of the most important criteria by which golf courses are evaluated. Extensive winter-kill on annual bluegrass golf greens is a major concern in Canada and the northern United States, where damage can disrupt play for many weeks in the spring and result in significant losses of income. Winter damage is caused by a wide range of environmental stresses, including rapid exposure to cold temperatures, prolonged exposure to cold temperatures, desiccation, freeze-thaw cycles, extended snow cover, ice encasement, and disease.

Golf course superintendents utilize various types of protective covers to reduce winter damage to putting greens. The covers can be invaluable tools for protecting golf greens against freezing temperatures, ice encasement, and desiccation injury. There is a wide array of winter covers available for use. However, many superintendents report inconsistent results with the use of the protective covers, and there are few precise recommendations for their use and almost no data comparing their effectiveness in northern climates.

The Horticultural Research Center of Laval University, Quebec City, established a research program to answer some of these questions. The Canadian Turfgrass Research Foundation provided funding for the project. The project's objectives were to evaluate the effectiveness of different winter covers and develop improved protection practices for annual bluegrass golf greens.

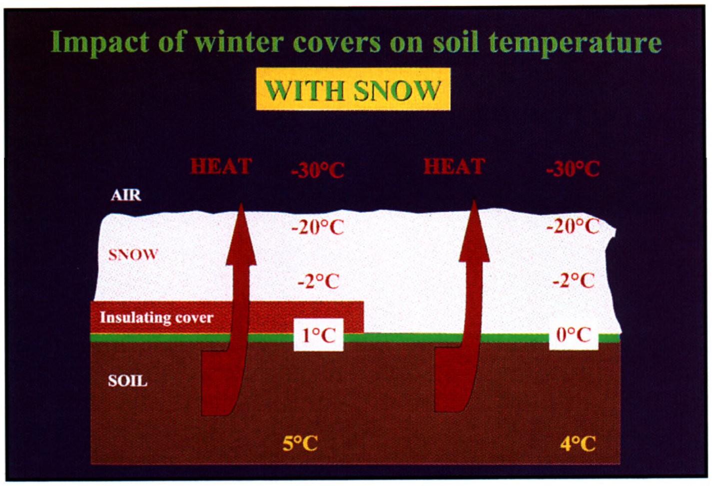
Research Methods

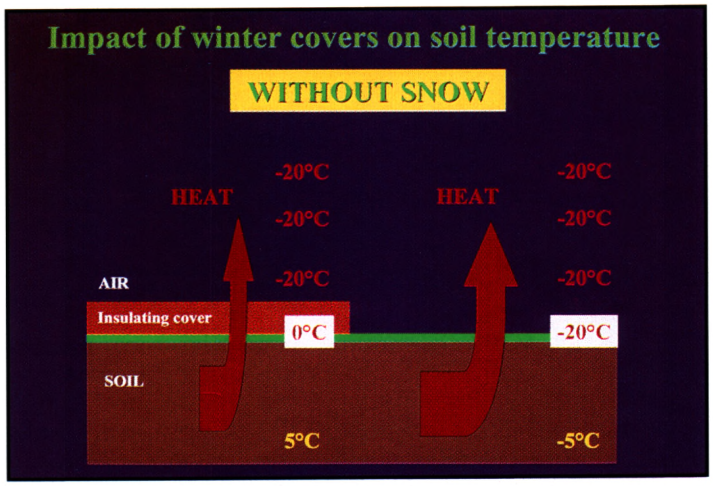
The study was conducted over a seven-year period at Laval University's experimental green located in Quebec City and on greens at Montreal Country Club, Royal Montreal Country Club, and Royal Quebec Country Club. The golf courses were selected in part because of the wide variation in winter climates between sites. The principal objective of this research was to evaluate the impact of different winter protective covers on soil temperature and on winter survival of annual bluegrass on golf greens.

During the winter of 1994-95, eight different winter protection treatments were tested. Covering systems with different permeability and insulating characteristics were selected. The protection systems in the project included:

- Permeable covers
- Impermeable covers (Evergreen brand covers from Hinspergers Poly Industries Ltd.)
- A curled wood shavings mat (American Excelsior Company) protected with an impermeable cover
- A straw mulch system (consisting of a permeable cover with 15cm

Research plots at Montreal Country Club seven days after the winter protection covers were removed. The type of cover used had a significant influence on soil temperatures and turf injury under severe winter conditions.





of straw covered by an impermeable cover)

- A 3mm felt material (Texel Incorporated) protected by an impermeable cover
- A 10mm felt material (Texel Incorporated) protected by an impermeable cover
- A 5cm air space (created with a wooden frame covered with an impermeable cover)
- A non-protected control treatment

In 1994, winter covers were installed on 3m-by-3m plots on November 24, prior to the first snow cover at Laval University and on November 30 at the Montreal Country Club. A fungicide and rodent repellent were applied before the covers were installed. Winter protective covers were removed on April 7 at Laval University and on March 21 at the Montreal Country Club. Soil temperatures under the covers and climatological data, including air temperature, thickness of snow cover, rainfall, and snowfall, were recorded daily during the winter. Annual bluegrass quality and recovery in the spring were also evaluated.

Soil Temperatures and Turfgrass Winter Survival

Soil temperature is more critical than air temperature for the winter survival of annual bluegrass. Temperatures in the surface soil affect the crown portion of the plant. Surface soil temperature is also a determinant in turfgrass disease development. Winter air temperatures in both Quebec City and Montreal often reach values of -30°C (-22°F). Annual bluegrass cannot tolerate exposure to such low temperatures, and its winter survival is linked to the insulating protection of snow or artificial covers.

Effects of Deep Snow Cover

Snow cover was deep and lasting at the Quebec City plots. Soil temperatures remained around 0°C (32°F) throughout the winter season under the different protective covers and on uncovered control plots. The thick and continuous snow cover was a very good natural insulating material and prevented soil temperatures that could be fatal to the turf. However, the deep snow cover and constant soil temperature also were favorable for snow mold diseases. Consequently, most winter damage observed on the experimental golf green at Quebec City was caused by snow mold rather than by freezing temperatures. These results emphasize the importance of disease management and appropriate use of fungicides prior to installing the covers.

Effects of Intermittent Snow Cover

In contrast to the Quebec City experimental site, the plots at Montreal Country Club had thin snow cover, and, as a result, the soil temperatures were lower, even though air temperatures at the sites were similar. In addition, high rainfall completely melted the snow cover in December 1994 and January 1995. The type of cover used had a significant influence on soil temperatures and the resulting turf injury under these severe winter conditions.

Insulating covers like straw, the curled wood mat, and the 5 cm air space reduced soil temperature fluctuations at the crown level, minimizing the impact of freezing air temperatures and thin snow cover. Minimum soil temperatures at the crown level were recorded at -1°C (30°F) under straw, -2°C (28°F) under curled wood mat, and -6°C (21°F) under the air space. Straw, the curled wood mat, and the 5 cm air space provided adequate insulation, and the annual bluegrass overwintered successfully. Turf quality was excellent immediately upon removal of the straw and curled wood mat covers. Minor damage was observed under the cover that provided the 5 cm air space, but the turf was fully recovered within two weeks following the removal of the covers.

The thick felt material (10mm) cover did not provide as much insulation as straw, the curled wood mat, or air space treatments. The soil temperature at crown level under the felt dropped to a minimum of -10°C (14°F) and considerable winter damage was observed on turf under those covers. Recovery was complete and turf quality was excellent on April 26, more than a month after winter protection removal.

Very cold minimum soil temperatures were recorded under the thin felt material (3mm) covers, permeable and impermeable covers used alone, and on turf without protection. Minimum soil temperature at crown level reached -15°C (5°F) under permeable and impermeable covers and -17°C (1°F) under thin felt material covers and on the uncovered control plots. The cold soil temperatures at the plant crowns and the large temperature variations were responsible for the severe damage observed for the four treatments.

Annual bluegrass under thin felt material, permeable and impermeable covers, and on the uncovered control plots was entirely dead following the removal of the covers. Spring recovery eventually resulted from germination of annual bluegrass seed present in the green soil seed bank.

Annual bluegrass seedlings were apparent on damaged plots in mid-April, and turfgrass quality improved as annual bluegrass growth progressed. Spring turfgrass quality on control plots and under thin felt material, permeable, and impermeable covers remained significantly inferior to that observed under the better-insulating covers for several weeks following the removal of the covers. Annual bluegrass on these severely damaged plots was not suitable for play until May 17, about one month following the Montreal Country Club golf course opening (April 16). From the level of damage observed on these plots and from other winter protection experiments, we have determined that a critical minimum crown level temperature of -10°C (14°F) is required to damage annual bluegrass greens.

Practical Steps For Winter Protection

The use of insulating winter protective covers improved turfgrass quality and surface conditions earlier in the spring in our tests. That may be good news for golf course superintendents and for golfers in northern climates. There are some practical steps for optimizing the winter protection of your golf greens:

- A preventive fungicide for snow mold disease control must be applied before the installation of winter protective covers. Temperature and moisture conditions under covers are very favorable for disease activity, and fungicide protection is therefore imperative.
- Consider local winter conditions and snow cover. It is not necessary to use a heavy insulating material if snow cover is deep and continuous. However, if snow cover is thin, the use of insulating protective covers is highly recommended. They decrease temperature fluctuations at crown level and minimize the impact of freezing temperatures.
- Always use impermeable protective covers to keep the insulating material dry and reduce injury from ice encasement and crown hydration.
- Monitor the temperature profile under winter protective covers. Temperature provides information on the modifications of the insulating properties of the covers and will be helpful for determining when to remove the covers in spring.
- Install and remove the winter protective covers at the right time. Installing covers too early may interfere with hardening of the plant and lead to excessively warm temperatures under the covers. It is important to install covers as late as possible in fall, ideally after the plant has hardened off. Removing covers too early in the spring can expose turf to frost damage and desiccating winds, while late removal could result in snow mold damage because fungicide effectiveness is low at the end of winter.
- Spring permeable covers should be used after the winter protective covers have been removed. These light cover materials provide protection against late frosts and desiccation.
- Winter protective covers are a valuable tool for preventing winterkill of annual bluegrass golf greens. However, the covers will be most successful when used together with a sound turfgrass management plan. Proper mowing practices and a sound fall fertilization program are very important to maximize energy reserves and optimize cold hardening of turf, and consequently improve winter survival of annual bluegrass golf greens. Turf growing in full sun also will reach a greater degree of cold temperature hardiness.

Current Research Programs

The first series of experiments confirmed that winter protective covers are an effective and practical way to mitigate winter damage on annual bluegrass golf greens in northern climates. Additional trials to look at different insulating materials and covering systems also are required. We currently are working on atmospheric composition under winter protective covers, particularly under impermeable covers. These covers are very effective in preventing excess water at the plant crown level and keeping insulating materials dry, thereby increasing plant tolerance to winter stresses. However, annual bluegrass winter damage not related to low temperatures has been observed under impermeable covers on certain golf greens. It is hypothesized that this damage may result from the modification of the atmosphere at the plant level due to the presence of the covers.

We have recently documented that CO_2 concentration under covers increases as a result of oxygen consumption, exposing plants to anoxic conditions for long periods of time during winter. The objectives of our ongoing research on winter protection are to identify soil and/or plant factors associated with the occurrence of anoxia under winter protective covers, and to evaluate passive or forced ventilation systems for reducing anoxic conditions and toxic gases on recurrent winter-damaged annual bluegrass golf greens.

Principal Collaborators on the Project

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Michel Tardif, Superintendent, Royal Quebec Country Club

This research is funded by the Canadian Turfgrass Research Foundation

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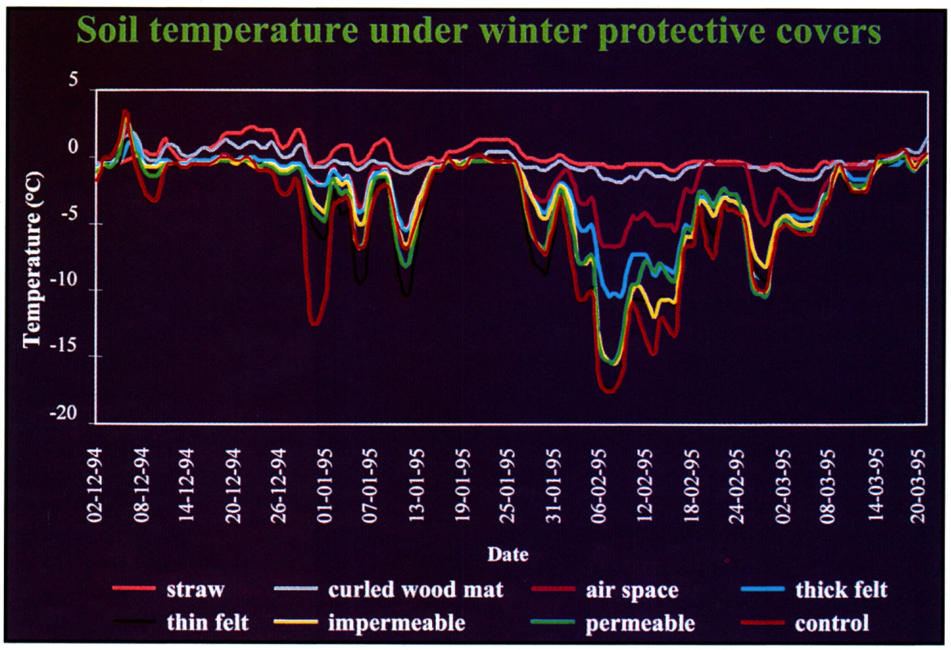


Fairbanks Ranch Country Club (Rancho Santa Fe, California) successfully demonstrates that, with careful maintenance practices, a quality golf course can be achieved despite having been built on a salt lake bed.

Understanding Water Quality and Guidelines to Management

An overview of challenges for water usage on golf courses for the 21st century.

by R. R. DUNCAN, R. N. CARROW, and M. HUCK

WITH GLOBAL demand for fresh or potable water doubling every 20 years, competition for this valuable resource will increase in the 21st century. Potable water reserves comprise only 2.5% of the total available global water supply, with groundwater reserves averaging about 1.7% of that total. For groundwater, only 45% is fresh water, and this source supplies 30% of the human and industrial users, with the remainder from surface water resources. This potable water dilemma will result in turfgrass managers having no choice but to irrigate with recycled and other non-potable alternative water resources of lesser quality that contain increased levels of dissolved salts.

Several overriding issues will change 21st-century turfgrass management strategies. A primary concern is water quality and the consistency of that water quality. Non-potable water can be referred to as brackish, effluent, recycled, wastewater, reclaimed, regenerate, or grey water. Water released from sewage plants can vary from primary to secondary to tertiary treatment levels, and quality will be partially dictated by the 1) quality of the original source prior to potable use, 2) salts and solids added by first-time users (e.g., discharges from factories or by-products of other manufacturing facilities), and 3) contamination of salts and solids added via surface runoff into treatment facilities.

Quality factors include the presence of:

1. Solids (sand-silt-clay and organic particles) that potentially can clog the irrigation delivery system, plug soil micropores, and cause excess wear on sprinkler nozzles and pumping components.

2. Biological (nematodes, weed seeds, algae, fungal spores) and chemical

(pesticides, fertilizers, other salt residues, pollutants) materials that can affect turfgrass performance.

3. Salt-related problems such as total salinity, sodium permeability hazard (impact on soil structure), specific toxic ions, and nutrient balance.

Water quality variability is site-specific and can change seasonally or, in extreme cases, on a daily basis. The focus of this article is on assessment of water for these salt-related problems.

Water Quality Assessment

Water quality assessment is one of the most confusing and complex problems facing turf managers. The types and quantities of chemicals that are applied to the turf system through irrigation water have a dramatic influence on soil chemical/physical aspects and turf performance. Variable levels of salts and extreme environmental conditions (high prolonged heat and humidity, severe drought, and traffic) magnify water quality problems. Water samples submitted to laboratories for analysis often come back with data in confusing units or with no reference points. Do you have a problem with the water on your course? How do you assess the data? What are the critical points to look for? How can you adjust your management to prevent a potential future problem? These are all valid questions that will be addressed in this article.

Problems

Four critical problem categories must be considered from the data presented in a water analysis report: *total salt content, sodium permeability hazard, specific ion toxicity,* and *critical nutrient levels.* Each category is a salt problem but differs from the other three problem areas in specific effects on soil traits and turf performance. In addition to these salt problems, inorganic or organic suspended solids need to be consistent. The four problem areas can result in many different combinations and degrees of stress.

High total salts or total salinity concentrations will often reflect the potential for a saline soil problem to develop. Saline conditions inhibit water uptake by turfgrasses and cause a salt-induced drought stress. This is the most common salt-related water issue that occurs and must be managed on golf courses. Total salinity problems are site-specific and must be assessed on that basis, and management strategies involving grass selection, cultivation, and irrigation scheduling must be developed accordingly.

Continuous use of saline water sources without leaching the soils can lead to serious salt accumulations and ultimately turfgrass decline.

High sodium concentrations, especially in conjunction with high bicarbonates and relatively low calcium (Ca^{+2}) and magnesium (Mg^{+2}) levels identified in the water analysis, can potentially cause a *sodium permeability hazard*. This hazard must be assessed, and high values have the potential for developing serious soil structural deterioration and water infiltration problems. Assessment and management strategies must be 1) based on site-specific soil and water conditions and 2) aggressively monitored and frequently adjusted to address specific constraints involving grass selection, amendments to the water and/or the soil, regular cultivation, and careful irrigation scheduling (leaching).

Specific toxic ions must be assessed as to their level of toxicity and their potential impact on the turf root system as well as foliar damage. Finally, *nutrient load* in the irrigation water is a fourth problem that can contribute a substantial amount of fertilizer to the turfgrass and can often induce deficiencies of other critical nutrients in salt-challenged turfgrass systems.

Calculations and Unit Conversions

Development of an effective management program starts with collection of a representative water sample and submission of that sample to a reputable analytical laboratory for analysis. What data should you ask for, and in what specific units should these data be presented?

Quality Factor	*Preferred Units*
Water	pH
Carbonates and Bicarbonates	mg/L, ppm, or meq L^{-1}
Total Salinity (impact on plant growth from higher total salts)	
Electrical conductivity (EC)	dS/m
Total dissolved salts (TDS)	ppm
Ion Toxicity (impact on root and foliar contact)	
Na	meq/L and ppm
Cl	ppm
B	ppm
Na Permeability Hazard (impact on soil structure)	
Sodium adsorption ratio (SAR)	meq/L
Adjusted SAR (adj SAR)	meq/L
Residual sodium carbonate	meq/L
Nutrients	ppm and meq L^{-1}

Often, the laboratory analysis comes back with confusing units for some of the data values. The conversion factors can be found in Table 1.

Table 1. Conversion factors

		To convert ppm to meq/L, multiply by:	To convert meq/L to ppm, multiply by:
Sodium	Na^{+1}	0.043	23.0
Calcium	Ca^{+2}	0.050	20.0
Magnesium	Mg^{+2}	0.083	12.2
Chloride	Cl^{-}	0.029	35.4
Potassium	K^{+1}	0.026	39.0
Sulfate	SO_4^{-2}	0.021	48.0
Carbonate	CO_3^{-2}	0.033	30.0
Bicarbonate	HCO_3^{-}	0.016	61.0

Note: 1 mg L^{-1} = 1 ppm

For example, to convert 220 mg L^{-1} Na^+ to meq L^{-1}:
(220 mg L^{-1}) × (0.043) = 9.46 meq L^{-1} Na^+

	Convert ECw	Multiply by:
Electrical Conductivity of Water	mSm^{-1} to dSm^{-1}	0.01
	dSm^{-1} to mSm^{-1}	100
	$mScm^{-1}$ to mSm^{-1}	100
	mSm^{-1} to ppm	6.4
	dSm^{-1} to ppm	640
	$mScm^{-1}$ to ppm	640
	ppm to dSm^{-1}	0.0016

Other Conversion Factors:

1 mmhos cm^{-1} = 1 dSm^{-1} = 1,000 umhos cm^{-1} = 0.1 Sm^{-1}

1 umhos cm^{-1} = 0.001 dSm^{-1} = 0.001 mmhos cm^{-1}

1 ppm = 1 mg L^{-1} (solution) = 1 mg kg^{-1} (soil)

1% concentration = 10,000 ppm

1 mmolc L^{-1} = 1 meq L^{-1}

1 ECw (dSm^{-1}) = 640 ppm (TDS = Total Dissolved Salts)

TDS (ppm) = ECw × 640; TDS (lb./ac.-ft.) ≈ TDS (ppm × 2.72)

ppm = grains per gallon$^+$ × 17.2
(grains/gallon is still used by domestic effluent water purveyors to report hardness)

Sum of cations and anions (meq L^{-1}) ≈ EC (dSm^{-1}) × 10

Total Salinity

The most common salt problem on turf is accumulation of high total salts leading to a saline soil condition. Saline soils can cause salt-induced or physiological drought. Turfgrass symptoms include reduced growth, discoloration, wilting, leaf curling, and eventually leaf firing or desiccation. Drought or water stress symptoms can occur a) if salt from irrigation water is allowed to accumulate within the rootzone, b) if accumulated salts in the rootzone (previously added by salt-laden irrigation water) rise up into the active rootzone by capillary action, or c) when both occur simultaneously during hot, dry periods.

In USGA greens, the perched water table zone, located below the normal rootzone, is an area of potential salt accumulation where salts could rise by capillary action into the rootzone during high ET periods. To avoid capillary rise, sufficient surface water must be applied to break tension in a USGA-type green and periodically flush out excess salts. In a native soil, a net downward movement of salts beyond the active turf rooting area must be maintained by ample irrigation.

Excess salts inhibit water uptake by turfgrass roots and cause wilting. Salts literally prevent water uptake even in a moist soil, and the turf can change color rapidly (sometimes overnight) to a yellowish brown and purplish color, depending on turf species. Salt crystals may actually form on the soil surface, especially in bare-soil areas. Salts that contribute to total salinity include calcium, potassium, magnesium, sodium, chloride, sulfate, nitrate, ammonium, and bicarbonate.

Electrical conductivity (ECw) is the extent to which water conducts electricity, which is directly proportional to the concentration of dissolved salts. ECw is used to estimate the total dissolved salts (TDS) in water (TDS ÷ 640 = ECw). TDS will occasionally be referred to as total soluble salts (TSS) or total dissolved solids (TDS) by analytical laboratories. Irrigation water containing high total salts such as sewage effluent can lead to saline soil conditions and poor turfgrass performance. Most sewage effluent ranges from 200 to 3,000 ppm TDS or ECw = 0.30 – 4.7 dSm^{-1} (Feigin et al., 1991).

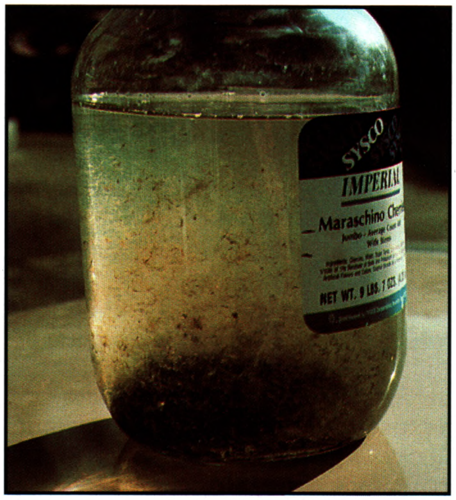
Irrigation quantity, leaching duration and frequency, drainage requirements, and turf species/cultivar selection requirements increase as ECw or TDS increases (Table 2). Water quality monitoring must be used to predict future soil salinity problems and to adjust management strategies to minimize deterioration of turfgrass performance.

Management Strategies for Total Salinity

Indicators of total salinity impact on turfgrass growth will be ECw and TDS, and both measurements are interrelated. When a water analysis indicates that total soluble salts (> 0.75d Sm^{-1} ECw or > 500 ppm TDS) are the primary problem, *irrigation scheduling* and *cultivation plus leaching* become the predominate management options. Sodium (Na), chlorine (Cl), and boron (B) levels may be high, and if ECw > 1.50 dSm^{-1} and TDS > 1,000 ppm, selection of salt-tolerant turf species and specific cultivars within that species becomes increasingly important.

Drainage requirements also increase since leaching frequency and the water quantity needed for leaching escalates as the total salinity hazard increases. Leaching directly affects nutrient availability, particularly with mobile ions such as potassium (K), magnesium (Mg^{+2}), nitrate (NO_3^-), iron (Fe), and manganese (Mn). Fertilizer programs must be adjusted accordingly, and this topic will be discussed in the section on "Nutrient Variability."

The success or failure of the management strategy for dealing with high total



Excess suspended solids can plug water-conducting pores at the soil surface. Low-quality effluent irrigation sources are notorious for containing high loads of suspended organic solids.

Table 2. Total salinity hazard classification guidelines for variable quality irrigation water based on ECw and TDS (Carrow and Duncan, 1998)

Salinity Hazard Class	ECw (dSm^{-1})	TDS (ppm)	Management Requirements
Low	< 0.75	< 500	No detrimental effects expected
Medium	0.75 - 1.50	500 - 1,000	Moderate leaching to prevent salt accumulation
High	1.5 - 3.00	1,000 - 2,000	Turf species/cultivar selection, good irrigation, leaching, drainage
Very High	> 3.00	> 2,000	Most salt-tolerant cultivars, excellent drainage, frequent leaching, intensive management

salts is predicated on one key aspect of turf management, namely *water management*. In particular, good irrigation scheduling and adequate volumes that promote leaching are essential. Cultivation is an integral part of regular management in salt-affected environments, encompassing both deep aeration (8-12 inches) once or twice each year and shallow aeration (3-6 inches) as needed, depending on soil texture. Infiltration, percolation, and drainage will dictate how effectively total salts are moved away from the turfgrass root system and are not allowed to build up in subsoil layers where they could potentially rise to the rootzone during periods of inadequate leaching.

Theoretically, sandy soil profiles are easier to leach than heavier clay soils. However, both soil types often require regularly scheduled deep and shallow cultivation followed by adequate leaching to move the excess salts downward. If aeration is regularly performed, but irrigation is scheduled for only 5-10 minutes daily (i.e., light, frequent irrigation), salts can move back up through the soil micropores by capillary action, form a concentrated layer in the rootzone, and limit water uptake or even kill the turf root system. This usually occurs when evapotranspiration (ET) exceeds the amount of water applied to the turf during prolonged high temperature or windy conditions. Also, if large diameter aeration holes are not backfilled with topdressing sand prior to leaching, large volumes of water can run into the holes and beyond the surface, while leaving behind a salt-laden zone between holes.

High salt levels from even low volume total salt applications (TDS = 600-800 ppm) can build up in subsoil layers over time in sand-based greens during prolonged dry periods. These salt layers usually can be found at depths corresponding to how deep the irrigation water percolated into the sand profile. If only a low volume (< 0.50 inch) of irrigation water is applied, the salt accumulation zone is often located just below the root system at about 6-8 inches depth, unless total salts are leached deeper by a periodic heavy flushing from rainfall or irrigation. Any zone of salt accumulation on sandy soils should be at least 12-16 inches deep, and on fine-textured soils, at least 16-24 inches deep to limit a possible rapid capillary rise of salts when irrigation volume is not sufficient for net leaching.

At shallower depths, salts can rise within two or three days through capillary action and evapotranspiration during extreme hot and prolonged dry, windy conditions. The salts may have been added through irrigation water at 600-800 ppm levels (which is normally not a problem), but the subsurface salt accumulation zone will be at much higher concentrations that can quickly desiccate and kill the turfgrass root system. Thus, net downward water movement is essential to avoid salt layers near the turfgrass rootzone. A heavy nighttime leaching program followed by an afternoon hand-watering of localized dry areas on sand-based greens may be necessary to prevent turfgrass collapse when temperatures exceed 90-95°F for one to two weeks or more. *The rule of thumb to minimize salt accumulation is to increase water volume applied by 12.5% for each 640 ppm rise in total dissolved salts (TDS) in the irrigation water.*

Additionally, high total salts can have a growth regulator effect on turfgrasses because water uptake is limited. Regardless of the level of salt tolerance, all turfgrass cultivars will experience some growth reduction from high salt accumulations. The most salt-tolerant cultivars (for example, seashore paspalum cultivars Sea Isle 1, Sea Isle 2000) have high inherent growth rates so that they maintain adequate growth for recovery from injury and for long-term performance when under persistent salt stress. Less salt-tolerant cultivars can be significantly affected when other stresses such as low mowing height (< ¼ inch), high salt-index soluble fertilizers, shade, and excessive traffic/wear/compaction negatively affect long-term turf performance. Sites continually irrigated with salt-laden irrigation water should restrict cart traffic on the golf course to cart paths only, especially on turf species and cultivars with low salt tolerance.

Sodium Permeability Hazard

The sodium concentration in conjunction with the quantity and type of other salts in irrigation water have a major influence on a) water infiltration into and percolation through soil profiles by directly affecting soil permeability, b) the leaching fraction, or the quantity of water required to leach excessive Na or other salts, c) whether the water should be treated prior to application to enhance infiltration/percolation into the soil, and d) the options available to adjust management scenarios to maintain or enhance turf performance. Two key water component relationships must be determined before management decisions can be made: Sodium adsorption ratio and bicarbonate/carbonate levels.

The SARw, or sodium adsorption ratio, is used to assess the sodium status and permeability hazard (Table 3). Sodium, calcium (Ca), and magnesium concentrations (in meq L^{-1}) are used to compute SARw:

$$SARw = \frac{Na}{\sqrt{(Ca + Mg)/2}}$$

When bicarbonate (HCO_3^-) and carbonate (CO_3^{-2}) concentrations are > 120 and 15 ppm, respectively, calculate adj SARw and *residual sodium carbonate* (RSC) according to Table 4.

Table 4. Calculation for adjusted sodium adsorption ratio and residual sodium carbonate

adj SAR or adjusted sodium adsorption ratio

a) adj SARw = SAR $[1 + 8.4 - pH_c]$
(refer to Carrow and Duncan 1998, and Ayers and Westcot 1985)

b) adj SARw is also calculated by the Hanson et al. (1999) method

RSC or residual sodium carbonate

RSC = $(CO_3 + HCO_3) - (Ca + Mg)$, in meq L^{-1}

Table 3. Sodium permeability hazard and specific toxic ion reference points
(Adapted from Harivandi and Beard, 1998; Carrow and Duncan, 1998)

Irrigation Water Components		**Degree of Problem**		
Sodium permeability hazard (Na^+-induced soil structural deterioration, and low water/oxygen permeability)				
SARw or adj SARw (sodium adsorption ratio) by clay type (ppm)				
		Low	**Moderate**	**High**
Clay type unknown		< 10	10 - 18	> 18
Montmorillonite (2:1)*		< 6	6 - 9	> 9
Illite (2:1)*		< 8	8 - 16	> 16
Kaolinite (1:1)**		< 16	16 - 24	> 24
Sands with ECw > 1.5 dSm^{-1}		< 10	10 - 18	> 18
Sands with ECw < 1.5 dSm^{-1}		< 6	6 - 9	> 9
RSC (residual sodium carbonate)		< 1.25	1.25 - 2.50	> 2.50
Specific Toxic Ions				
Sodium Content		**Low**	**Moderate**	**High**
Toxicity to roots	SARw	< 3	3 - 9	> 9
	ppm	< 70	70 - 210	> 210
Toxicity to leaves	meq L^{-1}	< 3	> 3	
	ppm	< 70	> 70	
Chloride Content				
Toxicity to roots	meq L^{-1}	< 2	2 - 10	> 10
	ppm	< 70	70 - 355	> 355
Toxicity to leaves	meq L^{-1}	< 3	> 3	
	ppm	< 100	> 100	
Residual Chlorine (Cl_2)	ppm	< 1	1 - 5	> 5
Boron toxicity on roots	ppm	< 0.7	0.7 - 3.0	>3.0
Bicarbonate content	meq L^{-1}	< 1.5	1.5 - 8.5	> 8.5
	ppm	< 90	90 - 500	> 500

*2:1 clays are shrink-swell clays
**1:1 clays do not shrink (crack) on drying or swell on wetting
Other 1:1 types are Fe/Al oxides and allophanes

Sodic and Saline-Sodic Soil Formation

The relative quantities of soil Ca, Mg, and Na are extremely important. Calcium is the primary ion that stabilizes soil structure. Magnesium offers secondary structural stability. When excess Na (> 200 ppm) is applied through irrigation water, the Na content builds up over time and eventually will displace the Ca^{+2} ions that are the building blocks and that enhance the structural integrity of the clay fraction in the soil profile. This "push-and-shove" relationship, which is dominated by a larger Na^+ ion with a weaker force or charge for holding clay particles together, eventually results in soil structure breakdown. The result is a sodic soil. It is sometimes referred to as *black alkali*, since the excess sodium precipitates out the organic matter fraction in the soil, which in turn rises to the soil surface. The deposit on the surface is black with a slick, oily appearance. Where excess Na^+ and high total salts are both present, it is called a saline-sodic soil and is characterized by having both white salt deposits and black decomposed organic matter deposits on the surface.

Very few turfgrasses can survive these sodium hazard conditions since the soil structural breakdown results in a sealed soil with little or no water permeability. Classic symptoms on golf courses are heavily compacted areas, areas with long-standing puddles, and dead turf. A secondary symptom can be surface algae and black layer formation caused by the constant moist conditions and the lack of oxygen in the turf root system. Sodium adsorption ratios (SAR or adj SAR) exceeding 6 meq L^{-1} indicate that the Na^+ levels are high enough to cause structural deterioration in some soils.

A more subtle symptom often occurs in sand-based greens or on fairways and tees where clay soil profiles have been capped with sand. On greens, short duration (5-10 minute) daily irrigation scheduling when using high Na irrigation water may eventually result in a layer forming in the sand profile. This layer normally will be as deep as the water percolates downward each day (usually somewhere between 4 and 12 inches deep). While sands often contain few clay colloids, Na^+ can cause organic matter of colloidal size to migrate to this depth and start to seal the soil pores, eventually leading to black layer formation. High sulfur or sulfate concentrations in the water will enhance the process.

The salts and excess Na congregate in this zone and, with normal evaporation, the salt concentration will gradually increase. When evapotranspiration exceeds irrigation, coupled with prolonged hot, dry, and/or windy conditions, these concentrated salts will move back up into the turf rootzone, cause salt-induced drought, root dessication, and may even kill the turf. The turfgrass will turn purple or yellow to yellowish-brown to brown, usually within 24 hours, depending on the turf species.

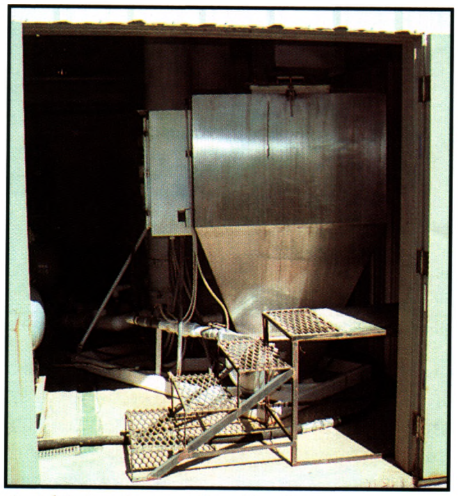
A similar scenario can develop on fairways, roughs, or tees where sand (4-10 inches in most cases) is used to cap a heavy clay soil. The high Na irrigation water will usually result in a concentration of excess Na ions at the interface of the sand cap and clay. Unless the excess Na^+ moves laterally under the sand cap (drainage lines can help), it will eventually break down the clay structure and the subsoil will seal off. Symptoms during wet periods will be continuously damp, boggy areas with possible standing water. In dry periods, salts may rise into the rootzone.

The type of clay soil has a profound influence on the amount of Na that will eventually cause soil structural deterioration. Soils that crack open when they dry (montmorillonite, illite) tolerate a much lower Na concentration before soil structural deterioration, mainly because Na^+ easily enters between clay platelets, and because of the increased exposure of the clay particle exchange sites to excess Na as these soils expand and contract. Soils that have non-swelling clays (kaolinite, Fe/Al oxides) tolerate much higher Na concentrations before structural breakdown because the Na ion has more difficulty migrating into these non-expanding soils and in-between clay platelets.

Regardless of clay type, once a soil has deteriorated into a sodic condition, turning this condition around will require a program of aeration, application of Ca^{+2} source amendments, high-volume leaching, and careful turfgrass selection. Calcium amendments should be applied immediately following aeration to avoid acceleration of permeability problems in the soil profile at the depth of the aeration treatments. This scenario is the most complex and difficult salt stress to overcome and may take several months to several years to accomplish. With poor quality, salt-laden water as the only irrigation source, management at a high level will have to be constant to prevent the sodic soil condition from reoccurring.

Bicarbonate and Carbonate Influence

Another set of water data factors is also important in influencing Na^+ activity — namely, relative levels of bicarbonates (HCO_3^-) and carbonates (CO_3^{-2}) in relation to Ca^{+2} and Mg^{+2} concentrations (Tables 3 and 4). When high HCO_3^- and CO_3^{-2} levels (> 120 and 15 ppm, respectively) are applied through the irrigation water, these ions react with Ca^{+2} and Mg^{+2} to form insoluble $CaCO_3$ and $MgCO_3$. The decreased levels of Ca^{+2} and Mg^{+2} from this reaction process reduce the amount of these ions that can compete with Na^+ for exchange sites on the clay particles. As the Na^+ content increases through daily irrigation applications, the Na^+ dominates these exchange sites and causes soil structural breakdown. The soil becomes sealed, water does not percolate into the soil profiles, and the turf eventually dies. The insoluble Ca/Mg carbonate forms precipitate out into the soil, and remaining bicarbonates reduce the effectiveness of gypsum or sulfur treatments to the soil.



Acid injection and sulfur burners can be used to treat water with excess bicarbonate levels. Acidifying irrigation water to a pH of 6.5 reduces bicarbonates by approximately 50%.

The sodium permeability hazard in irrigation water is usually assessed by SARw values when HCO_3^- is < 120 ppm and CO_3^{-2} is < 15 ppm. The SARw value incorporates the influence of Na^+, Ca^{+2}, and Mg^{+2} concentrations. Above these levels, adj SAR is preferred since these values incorporate the influence of HCO_3^- and CO_3^{-2}.

Residual sodium carbonates (RSC) also are used to assess the sodium permeability hazard, and this value includes the influence of HCO_3^- and CO_3^{-2} as compared to Ca^{+2} and Mg^{+2} (Tables 3 and 4). As a general rule, whenever HCO_3^- exceeds 120 ppm, it is a good idea to calculate RSC. *It is not the absolute levels of HCO_3^- and CO_3^{-2} present in the irrigation water that are important, but the relative concentrations of HCO_3^- and CO_3^{-2} compared to Ca^{+2}, Mg^{+2}, and Na^+ levels.*

When HCO_3^- and CO_3^{-2} concentrations exceed soluble Ca and Mg concentrations, water acidification may be needed if residual sodium carbonate and adjusted sodium adsorption ratios (adj SARw) exceed 1.25 and 6 meq L^{-1}, respectively (Table 3). If HCO_3^- and CO_3^{-2} concentrations are < 120 ppm, RSC < zero, *and* adj SARw < 6 meq L^{-1}, then acidification of irrigation water should not be needed. *Know all three values before deciding to purchase a sulfur generator or acid injection system for water treatment!* (Carrow et al., 1999)

If the RSC is > 0, indicating residual carbonates remain above those removed by Ca and Mg precipitation, another option is to add gypsum or a soluble Ca^{+2} source to prevent Na^+ accumulation in the soil. One meq L^{-1} Ca must be added for each meq L^{-1} HCO_3. However, any previously precipitated Ca and Mg tied up by the excess bicarbonates (positive RSC value) will not be active or available. Thus, acidification will remove the bicarbonate and will make available the Ca and Mg contained in or added to the irrigation water to react with the excess Na adsorbed to soil CEC sites. Additional Ca could be supplied by adding gypsum or a soluble Ca source. The amendments are intended to improve soil water infiltration and percolation. (Refer to Carrow et al., 1999, *Green Section Record*, 37(6):11-15 for more information on water treatment options to improve infiltration.)

SAR/ECw Interaction

The interaction of SARw and ECw on soil water infiltration is presented in Table 5. High total (salt) electrolyte concentrations in the irrigation water can counteract the adverse effects of Na on causing soil deterioration. When irrigation water is very low in salts (ECw < 0.5 dSm^{-1}), permeability problems can arise at the soil surface even at low SARw (1-10 meq L^{-1}). All irriga-

Table 5. Interaction of sodium adsorption ratio (SARw) and electrical conductivity (ECw) on soil water infiltration
(Harivandi and Beard, 1998)

SARw and ECw	Salt-Laden Irrigation Water (dSm^{-1}) Influence on Soil Permeability* No Restriction	Slight to Moderate Restriction	Severe Restriction
SARw =	0 - 3	0 - 3	0 - 3
ECw =	> 0.7	0.7 - 0.2	< 0.2
SARw =	3 - 6	3 - 6	3 - 6
ECw =	> 1.2	1.2 - 0.3	< 0.3
SARw =	6 - 12	6 - 12	6 - 12
ECw =	> 1.9	1.9 - 0.5	< 0.5
SARw =	12 - 20	12 - 20	12 - 20
ECw =	> 2.9	2.9 - 1.3	< 1.3
SARw =	20 - 40	20 - 40	20 - 40
ECw =	> 5.0	5 - 2.9	< 2.9

*Soil permeability = ability of water to infiltrate into the soil and percolate/drain. Gas exchange is reduced by low soil permeability.

tion water should contain at least 20 ppm or 1 meq L^{-1} Ca and have a minimum ECw = 0.5 dSm^{-1} to prevent soil dispersion (Petrie 1997). At high ECw (> 3 dSm^{-1}), the high electrolyte (salt) concentration can function in maintaining soil permeability even with a high SARw (15-30 meq L^{-1}). Thus, a high Na hazard in the soil can be reduced by irrigation water with a high ECw (see Table 3).

(Refer to Duncan and Carrow, 1999, *Golf Course Management*, May: 58-62, or Carrow and Duncan, 1998, for the gypsum requirements to reduce soil exchangeable sodium percentage.)

Specific Ion Toxicity

Irrigation water may contain toxic levels of certain ions that affect turfgrass in 1) root tissues due to soil accumulation, 2) shoot tissues due to uptake by the turf roots and accumulation in leaves, and 3) directly on the foliage of landscape plants due to sprinkler irrigation. *The ions that cause toxicity problems include Na, Cl, B, HCO_3, and pH (H^+ or OH^- ions).* As total salinity increases in irrigation water, the potential for specific ion toxicity also increases. Germinating seed, young seedlings, and sprigs are especially vulnerable because of their juvenile root systems.

The specific ion toxicity guidelines (Table 2) apply to sensitive turf and landscape plants, but soil accumulation of these ions can eventually cause damage to even tolerant turfgrass. Over time, sodium can become toxic to turf roots, since it accumulates in the soil and leaves of susceptible turf genotypes at SAR > 3 meq L^{-1} or 70 ppm. Chloride (Cl) can accumulate at potentially toxic levels for roots and leaves at 2-3 meq L^{-1} or 70-100 ppm, and can restrict N uptake. Excess Cl normally accumulates in the tips of leaves. In turf, regular mowing plus collection and disposal of clippings removes these high concentrations from the turf and soil system. But leaf removal is normally not a management option for landscape plants, or may be limited on turf under non-mowed conditions, such as in naturalized roughs.

Residual chlorine (Cl_2) that is used to disinfect wastewater becomes toxic at > 5 ppm. HCO_3 concentrations are not toxic at > 8.0 meq L^{-1} or 500 ppm, but can cause unsightly deposits on leaves and equipment and can contribute to excess Na^+ deterioration of soil structure.

Depending on the source, some irrigation effluent can contain high levels of heavy metals and other ions (Carrow and Duncan, 1998). Maximum concentrations of selected heavy metals Zn (2.0 ppm) and Cu (0.2 ppm) are noteworthy since these ions can restrict uptake of iron (Fe) (Table 4). The maximum concentrations for Fe (5.0 ppm) and Mn (0.2 ppm) are important to know since these elements tend to be deficient in salt-affected and highly leached turfgrass systems. These maximum guidelines are based on the potential to achieve toxic levels over time with long-term use of the water.

Soil and Water pH

Water pH and soil pH are additional management considerations. The key reference points are pHs < 5.0 (H^+ dominates on the acidic level) and > 8.5 (OH^- dominates on the alkaline level). When pHs are at or beyond these specific extremes, management levels must be increased accordingly to minimize deterioration in turf performance (Carrow and Duncan, 1998).

The effect of water pH on altering soil pH is often short term because the buffering capacity (CEC) of most clay and loam native soils is so high that many years of irrigation will be required before a significant change will occur. Soils with lower CECs (sands, decomposed granites, crushed lava rock) should be monitored closely for pH changes. Accordingly, acidifying water for the sake of pH modification is questionable when cost analyses are considered. However, when high bicarbonates are supplied in combination with excess Na in the water source (which ties up the Ca/Mg needed to counter the Na), water acidification would be justified. Additionally, when the water pH is in the 8.0-8.5 range, use of acidifying fertilizers (sulfur-based sources) to dissolve some of the free calcium carbonate (lime) can counter some of this alkaline soil pH reaction.

Be aware that extreme water pH and high salt concentrations, when used in the sprayer mix with fungicides, herbicides, or insecticides, can have an effect on efficacy. This is particularly true with organophosphate and carbamate chemistries. Consult with manufacturers regarding each particular product when confronted with this problem.

Critical Nutrient Considerations

All irrigation water will contain a certain level of nutrients in its composition, and wastewater may contain elevated levels of certain nutrients. Due to the nutrient load in effluent irrigation water, fertility programs must be adjusted to maximize turfgrass performance and to minimize environmental impact (King et al., 2000).

Nutrient guidelines in irrigation are compared in Tables 5, 6, and 7. Key ratios to calculate include Ca:Mg, Ca:K, and Mg:K (Table 8), especially in salt-affected sites that are irrigated with salt-laden water. When dealing with these conditions, certain management considerations should be considered.

- Because of the high mobility of K^+ and the propensity of Na^+ to displace K^+ on soil exchange sites, a regular K^+ application may be needed every 2-4 weeks to maintain a nutritional balance in the turf plant.
- Due to high leaching events with salt-laden irrigation water, Fe and Mn may be needed on a regular basis in spoon-feeding format.
- Highly soluble nitrate sources [$Ca(NO_3)_2$] are recommended in a spoon-feeding approach to maximize turf uptake and utilization in a salt-challenged environment.
- Less soluble, slow-release products with lower salt indexes may be more appropriate when planning soil-applied fertilization programs to reduce the total salt load in the turf rootzone.
- Avoid unnecessary sulfur applications (except when in conjunction with lime to form gypsum) because they can lead to black layer and anaerobic problems in turf.
- If P, PO_4^-, and P_2O_5 concentrations are in the normal range, do not apply additional P-based fertilizers since this nutrient is one of the least mobile of nutrients in the soil and can contribute to algal blooms in holding ponds or contamination in surface and subsurface water resources.
- Avoid foliar calcium applications since this element is the least mobile of nutrients and is an element that is more effectively taken up by roots than through foliar tissue.

Total Suspended Solids

Suspended solids are inorganic or organic materials (sand, silt, clay, plant debris, algae) that do not dissolve in water and can only be removed by filtration. While total suspended solids (TSS) is normally not considered a salt problem, it is an important water quality characteristic. Low quality effluents are notorious for containing high volumes of organic solids. The overall effect on hydraulic conductivity is governed by particle size and quantity of suspended inorganic and organic solids. Organic materials include humic substances such as fulvic acid and humic acid that exhibit both soil aggregating and anti-aggregating properties. Excess suspended solids, and particularly sand contamination, often contribute to premature wear or plugging of sprinkler and pumping components as well as increasing the potential for plugging micropores, which conduct soil surface water.

Suspended solids generally have little or no impact on native soils (fairways, roughs, landscaped areas) or pushup soil tees and greens, because the added solids normally are similar in particle size to the native soil. In this case, solids added through the irrigation water in small amounts provide a light topdressing to the native soil.

The primary concern with suspended solids is their effect on newly constructed sand greens that can potentially be contaminated by these fine-particle-size solids delivered during seed germination, establishment, and grow-in. If significant amounts of suspended soil fines are applied at this stage, soil surface micropores can become plugged, function like a layer of

Table 6. Nutrient guidelines in irrigation water (ppm)

Nutrient	Low	Normal	High	Very High
P	< 0.01	0.1 - 0.4	0.4 - 0.8	> 0.8
PO_4^-	< 0.3	0.3 - 1.21	1.21 - 2.42	> 2.42
P_2O_5	< 0.23	0.23 - 0.92	0.92 - 1.83	> 1.83
K	< 5	5 - 20	20 - 30	> 30
K_2O	< 6	6 - 24	24 - 36	> 36
Ca	< 20	20 - 60	60 - 80	> 80
Mg	< 10	10 - 25	25 - 35	> 35
N	< 1.1	1.1 - 11.3	11.3 - 22.6	> 22.6
NO_3^-	< 5	5 - 50	50 - 100	> 100
S	< 10	10 - 30	30 - 60	> 60
SO_4^-	< 30	30 - 90	90 - 180	> 180

Table 7. Reclaimed water guidelines — recommended maximum values
(Adapted from L. J. Stowell, 1999. Pointers on reclaimed water contract negotiations. Fairbanks Ranch meeting. June 7, 1999.)

TDS (ppm)	960	Cl (ppm)	250
ECw (dSm^{-1})	1.5	Na (ppm)	200
SARw	5.7	Fe	5.0
adj SARw	11.6	Mn	0.2
RSC (meq L^{-1})	< 1.25	Zn	2.0
HCO_3 (ppm)	250	Cu	0.2
B (ppm)	0.5	Ni	0.2

Table 8. Nutrient ratios in irrigation water and potential deficiencies*

Ca:Mg	< 3:1	Ca deficiency
	> 8:1	Mg deficiency
Ca:K	< 10:1	Ca deficiency
	> 30:1	K deficiency
Mg:K	< 2:1	Mg deficiency
	> 10:1	K deficiency

*Irrigation water with nutrient concentrations outside these ranges can be used; the fertility program must be adjusted to avoid deficiencies.

foreign soil or incompatible topdressing, and inhibit water infiltration and percolation. If the irrigation water is salt-laden, the fines can settle at the bottom of the wetting zone and develop a layer where excess salts accumulate and concentrate. If ET is higher than the volume of irrigation that is applied, the concentrated salts can rise through capillary action into the turf rootzone to cause salt injury.

Unfortunately, no specific guidelines have been published for predicting the level at which TSS becomes a hazard. Interpret TSS data based on common sense and the potential impact that contaminants may or may not have on soil structure and irrigation system components. Use the following method to evaluate the TSS hazard:

1) The water quality test reports TSS in parts per million (ppm) or milligrams per liter (mg L^{-1}).

2) Multiply the value by a conversion factor of 2.72. The resulting value is equivalent to the pounds of solids per acre-foot (325,852 gallons), or the volume of solids applied to each acre with 12 inches of irrigation water.

For example:

1) Water quality test reports 22 ppm TSS.

2) 22 ppm × 2.72 = 59.84 or 60 lbs. of solids applied per acre-foot of water applied to the turf.

3) Is this a problem? Not likely, since this amount (60 lbs./acre-foot) is equivalent to one bag of cement spread over the golf course with each acre-foot of water applied. Sand, silt, and clay particle residue from a windy day would provide more solids than this water source (Kopec, 1998).

4) If the TSS was 735: 735 ppm × 2.72 = ~2,000 lbs. or 1 ton of solids per acre-foot. This volume of fines could be a problem on sand greens. Filtering the water or providing settling ponds would be options to consider.

Summary

Steps in assessing water quality to determine turfgrass management options:

1. Check for bicarbonates and carbonates in the water. If concentrations are greater than 120 ppm and 15 ppm, respectively, calculate adj SARw and RSC to verify the degree of impact that these ions will have on Ca and Mg activity. Adj SARs > 6 meq L^{-1} and RSCs > 1.25 may indicate that acid treatment plus lime or gypsum applications are needed.

2. Check Na content and calculate SARw or adj SARw and RSC to assess impact on soil structural deterioration (Na permeability hazard). Also, evaluate ECw in conjunction with SAR or adj SAR to estimate the permeability hazard (Tables 3 and 5). Knowledge of the clay type will be useful. These values will determine the level of aerification, amendments, and leaching that will be needed.

3. Check ECw and TDS for their impact on turfgrass (Table 2). High total salinity values in conjunction with low Na^+ and HCO_3^- values would indicate the potential to create a saline soil condition and will determine the degree of aeration and leaching needed as your primary management options.

4. Check S and/or sulfate levels in the water. If S > 60 ppm or SO_4 > 180 ppm, you may need to use lime as an

This patch of seashore paspalum is surviving better than the surrounding bermudagrass in this poorly drained, high-salt-content soil.

amendment. The high sulfates (sulfur) in the water will combine with lime to form gypsum. Removing the excess sulfur and sulfates will help minimize anaerobic problems and black layer formation when regular aeration and leaching are used in management protocols.

5. Check actual Na, Cl, and B values for their specific ion toxicity potential (Table 3). These ions normally will affect landscape plants and susceptible turf cultivars, but continued accumulation can eventually influence even tolerant species. Plants tolerant to high total salinity also are generally tolerant to high levels of these specific ions.

6. Check levels of actual nutrients and make appropriate adjustments in your fertility program to account for nutrient additions or any induced deficiencies (Tables 6 and 7). Calculate Ca:Mg, Ca:K, and Mg:K ratios and adjust the fertility program accordingly (Table 8). Watch for deficient levels of Fe and Mn. With very high Cl^- levels, you may need to increase N by 10-25%. P and K are critical to maintenance of a good root system in a salt-challenged ecosystem. Annual P and K rates may need to be increased 25-50% above non-salt-affected sites, but with a spoon-feeding application regime. High Ca and Mg applications to replace excess Na can depress K uptake. High Na also depresses K uptake. $N:K_2O$ ratios should be maintained at 1:1 up to 1:1.5 by light, frequent applications.

7. *Aerate, aerate, aerate* followed by *leach, leach,* and *leach*. Keep the salts moving!

Without proper management, sodium, in combination with bicarbonates, can cause crusting and sealing of the soil surface.

Glossary of Terms

Acid injection: Used to treat water with high HCO_3 and CO_3 content. Adding an acid evolves the HCO_3 and CO_3 off as CO_2 and water. Commonly used sources include sulfuric, urea-sulfuric, and SO_2 gas from sulfurous generators.

B: Boron, a micronutrient, essential at very low concentrations. Can become toxic at soil concentrations of 0.5-6.0 ppm. Most turfgrasses have a good tolerance to boron, while some ornamental species are very sensitive.

Bicarbonate: HCO_3 ion.

Ca: Calcium is an essential plant nutrient and cation responsible for good soil structure.

$CaCl_2$: Calcium chloride, a very soluble calcium salt that can be dissolved in irrigation water to lower the SAR or increase the ECw.

$CaCO_3$: Calcium carbonate (lime), insoluble form of calcium precipitated by water high in Ca, HCO_3, and CO_3. Sometimes naturally occurring in calcareous/caliche soils in arid regions. Insoluble until reacted with an acid.

$CaCO_3 \cdot MgCO_3$: Calcium/magnesium carbonate (dolomitic lime), insoluble calcium/magnesium combination precipitated from water high in Ca, Mg, HCO_3, and CO_3. Sometimes naturally occurring in calcareous/caliche soils in arid regions. Insoluble until reacted with an acid.

Carbonate: CO_3^{-2} ion.

$CaNO_3$: Calcium nitrate, a highly soluble source of calcium and nitrogen that can be dissolved in irrigation water to lower the SAR or increase the ECw.

$CaSO_4$: Calcium sulfate, commonly referred to as gypsum. An amendment used to displace sodium from the soil exchange sites and can be added to irrigation water (usually as a suspension) to increase ECw or the ratio of Ca/Na, thereby lowering SAR.

CEC: Cation exchange capacity, the sum total of exchangeable cations that a soil can absorb.

Cl: Chloride is required in small amounts as a plant nutrient; it is a highly soluble salt and toxic in larger quantities (70-100 ppm). Trees and ornamental plants are often more sensitive to chloride than turf, and accumulation is first noted in leaf tips. Most plants are generally more sensitive to chloride salts than sulfate salts.

Cl_2: Chlorine, used by water treatment plants to disinfect water of various pathogens. Excess or residual chlorine (> 5.0 ppm) can cause toxicity.

CO_3: Carbonate, combines with Ca (calcium) and Mg (magnesium) to form $CaCO_3$ and $MgCO_3$ (calcium carbonate and magnesium carbonate) forms of insoluble lime or calcite.

Cu: Copper, an essential micronutrient, but if concentrations are excessive (> 0.2 ppm) can restrict the uptake of iron.

dS/m_{-1}: Decisiemens per meter, the standard measurement used to report electrical conductivity of water (ECw).

ECw: Electrical conductivity of irrigation water. This is a measure of the total salinity or total dissolved salts. 640 ppm TDS = 1.0 dS/m ECw.

ESP: Exchangeable sodium percentage, used to classify sodic and saline-sodic soil conditions. The degree of saturation of the soil exchange complex with sodium as compared to other exchangeable cations occurring from irrigation with sodium-dominated water.

ET: Evapotranspiration, the total amount of water loss from soil evaporation and plant transpiration.

Fe: Iron, essential plant nutrient that tends to become depleted in highly leached, salt-affected soils.

H_2SO_4: Sulfuric acid, either forms in soil when acidifying amendments/fertilizers are used such as soil sulfur (S), ammonium sulfate, etc., or is injected into irrigation water via a sulfurous generator or acid injection and products such as urea sulfuric acid (NpHURIC).

HCO_3: Bicarbonate, combines with Ca (calcium) and Mg (magnesium) to form $CaCO_3$ and $MgCO_3$ (calcium carbonate and magnesium carbonate) forms of insoluble lime or calcite. Can also cause unsightly deposits on ornamentals.

K: Potassium, an essential nutrient that influences rooting, drought, heat, cold, and disease tolerance. Potassium can be displaced by sodium at the cation exchange site.

meq/l: Milliequivalents per liter. Parts per million (ppm) divided by equivalent weight equals milliequivalents per liter.

mg L^{-1}: Milligrams per liter, equals parts per million.

Mg: Magnesium, an essential plant nutrient and cation associated with good soil structure, providing it is not available in excessive quantities in relationship to Ca.

$MgCO_3$: Magnesium carbonate, insoluble form of magnesium precipitated by water high in Mg, HCO_3, and CO_3. Sometimes naturally occurring in calcareous/caliche soils in arid regions. Insoluble until reacted with an acid.

Mn: Manganese, essential plant nutrient that tends to become depleted in highly leached, salt-affected soils.

Na: Sodium, non-essential as a nutrient, a "small" cation with a large hydrated size that disperses soils, thereby affecting infiltration and soil aeration. Can displace potassium on soil exchange sites.

Na_2SO_4: Sodium sulfate, a soluble salt formed when gypsum is used to treat soils with high sodium content.

pH (water): A logarithmic measurement of relative alkalinity or acidity. Water with low pH often reflects higher quantities of sulfates or iron, while high pH tends to reflect high bicarbonates or sodium.

ppm: Parts per million. Milliequivalents per liter multiplied by equivalent weight = parts per million.

RSC: Residual sodium carbonate, like the adj SARw, it is used to determine whether Na will cause soil structure problems. The RSC compares the concentrations of Ca and Mg to HCO_3 and CO_3 and determines when calcium and magnesium precipitation can occur in the soil and result in additional sodium domination of soil cation exchange sites. RSC = $(CO_3 + HCO_3) - (Ca + Mg)$. This calculation is done with all measurements in meq/l.

RSC Value	Potential Irrigation Use
< 1.25	Generally safe for irrigation
1.25 - 2.5	Marginal
> 2.5	Usually unsuitable unless treated

S: Sulfur, a secondary plant nutrient used as a soil amendment to modify pH in alkaline soils. Also used in calcareous and caliche soils (containing high lime) to convert lime into gypsum.

SARw: Sodium adsorption ratio of irrigation water. SARw is used to determine whether sodium (Na) levels of water will cause soil structure to deteriorate. Unadjusted SAR (SARw) considers only Na, Ca, and Mg.

Adj SAR: Adjusted sodium adsorption ratio of irrigation water. Adj SARw predicts the increased influence of sodium (Na) upon soil structure due to the influence of carbonates and bicarbonates.

SO_3 Generator: Sulfurous generator, also known as a sulfur burner. Equipment used to treat irrigation water containing high carbonates and bicarbonates. Burns sulfur at high temperatures to produce sulfurous gas that when combined with water becomes sulfuric acid. This evolves the HCO_3 and CO_3 off as CO_2 and water. This is another method of acid injection.

SO_4: Sulfate, when combined with lime while in an acid form creates gypsum. May also combine with other cations to form various soluble salts.

TDS: Total dissolved salts, normally reported as parts per million (ppm).

TSS: Total suspended solids, organic and inorganic materials (sand, silt, clay, algae, plant debris, etc.) that do not dissolve in water and must be removed by filtration or settling.

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BACK TO BASICS: *Restoring Playability and Native Wildlife Habitats*

Is your golf course planning to undertake a renovation or restoration project? Now is the time to plan for environmental and wildlife enhancements.

by FRED YARRINGTON

DURING 1998, the Hole-in-the-Wall Golf Club (Naples, Florida) was closed for nearly six months during a complete renovation of the golf course playing surfaces and restoration to first-class playing conditions. While the golf course was closed and there was no concern about turf damage, we took advantage of special equipment, time, and the general disruption to undertake several wildlife habitat enhancement projects. The following year we continued to fine-tune the work we had begun the previous summer. The result has been not only a great improvement in playability and aesthetics, but enhanced native plant communities and wildlife populations.

Based on our experience at Hole-in-the-Wall, we highly recommend to anyone considering major course restoration that they plan to incorporate wildlife and habitat management projects at the same time. It definitely will pay dividends at the minimum expense possible for this type of work.

Removing Exotic Invasive Species

Florida is a haven for exotic, invasive plant species that are wreaking havoc on our native ecological communities. Our golf course is host to some of the worst offenders, including melaleuca and Brazilian pepper.

Our exotic plant removal program began a number of years ago and has won general acceptance by the mem-

Lakeside planting and an osprey platform enhance wildlife diversity and aesthetics at the Hole-in-the-Wall Golf Club, Naples, Florida.

A concerted effort was made to remove exotic, invasive plant species during a scheduled golf course renovation period. The end result enhanced the beauty of the golf course natural areas.

bership and support of the board of directors, but removing exotics a little here and a little there whenever it can be worked into the regular maintenance routine yields slow progress. During the early stages of the course renovation, our golf course superintendent, Russ Geiger, pushed hard for exotic plant removal and had the opportunity to show the restoration committee examples of the advantages generated by such work. Through the support of club president Bill Harvey, who approved the work and expanded the budget to accommodate it, we were able to accelerate our efforts and removal is now 60-70% complete.

With the golf course closed, extensive removal of Brazilian peppers was undertaken on the east side of the lake on the fifth hole and in the general area bordering the fifth hole, the sixth tee, and on through the woods to the 16th fairway. Normally, work of this nature could not be done in this area without significant turf damage caused by heavy equipment. The golf course renovation project proved to be the perfect time to take action.

The improvement in the area for both wildlife and golfers is astounding. The pepper removal by the lake and modest replanting along the banks with ferns has opened up a very attractive cypress and native plant vista. We undertook more extensive replanting with native vegetation in the area west of the fifth green and planted a small butterfly garden around the restrooms. This area has a very attractive grove of native pine, which was formerly totally obscured by the heavy growth of peppers.

In addition, we removed several ornamental plant hedges on the golf course and replaced them with native plant material. The same type of material was used to create badly needed buffers between several existing holes.

In the summer of 1999, a significant number of melaleucas were removed from the course by the 12th hole and the 13th fairway. These areas were replanted with oaks, sable palms, and other native plant material, with much of the cost covered by a memorial fund for former club president Jerry Doyle.

Also included in the renovation program was a continuation of exotic removal between our sixth hole and the 16th tee and along the entire right side of the second hole. Both of these projects involved improving turf conditions by opening up the areas to increase air circulation and light. The substitution of native plant material for the exotics enhanced the visual attractiveness of both these areas.

Naturalizing Out-of-Play Areas

Another exciting project we undertook during course renovation was to eliminate one of the largest out-of-play areas on the course. For several years we have considered a number of ideas for naturalizing the area between our fourth and 18th fairways, but here again, we couldn't have done what we did without incorporating it into our renovation work.

Course restoration required a source of fill, so we capitalized on the situation and created an attractive lake with an island/peninsula at one end. By destroying a large cluster of Brazilian pepper, we opened up a beautiful area of large sable palms and other native trees on the island. Thus, we solved our naturalization problem, created a new golfing feature, saved money on the cost of fill, and opened up a whole new wildlife habitat area.

Documenting Positive Results

Major golf course restoration had multiple benefits for Hole-in-the-Wall. Playing surfaces have improved dramatically and new turf areas have eliminated the need for overseeding, thus substantially reducing chemical and fertilizer use. Documentation and observations indicate that Hole-in-the-Wall has a stable population of birds and reptiles and a sufficient food supply to support them. Osprey and bald eagles are regularly seen, and we've also had a hatch of more than ten alligators beside the 18th tee. Based upon the wildlife activity on the property, it is obvious that given adequate acreage, good turf management practices can be very compatible with maintaining an environment for wildlife on the golf course.

Now that the work is done, we're all glad to take a break from intensive and expensive renovation and get on with simply enjoying the golf course. If your course is thinking about renovation, take the time now to plan habitat improvements too. Such a back-to-basics plan for enhanced playability *and* wildlife habitat will prove satisfying and worthwhile for the entire golf course community.

Longtime Hole-in-the-Wall member FRED YARRINGTON *spearheads Audubon Cooperative Sanctuary Program efforts in cooperation with golf course superintendent Russ Geiger. Hole-in-the-Wall Golf Club achieved certification as an Audubon Cooperative Sanctuary in 1994.*

Eb Steiniger Receives Piper & Oakley Award

EBERHARD "EB" STEINIGER, CGCS, the legendary, longtime superintendent of the Pine Valley Golf Club in Clementon, N.J., has been named the sixth recipient of the USGA Green Section's Piper & Oakley Award. The Piper & Oakley Award was established in 1998 to recognize persons who have so generously contributed to the programs and activities of the USGA Green Section. Drs. Charles V. Piper and Russell A. Oakley were among the earliest scientists to conduct studies in the fields of turfgrass science and golf course management, and served as the first Chairman and Co-Chairman, respectively, of the USGA Green Section. They were men of great character, keen vision, and remarkable achievement, characteristics that pertain equally well to Eb Steiniger.

Eb's contributions to the Green Section dramatically underscore the reasons for his selection for the award. Beginning his career at Pine Valley in the 1920s, Eb met Dr. Oakley prior to Oakley's untimely death in 1928, and thereafter served as friend, confidant, and advisor to generations of Green Section agronomists and directors, including Dr. John Montieth, Dr. Fanny-Fern Davis, and Dr. Fred Grau. He was especially close to Al Radko, the longtime Northeast Region Director and National Green Section Director, and he helped mold the careers of agronomists such as Holman Griffin, Billy Buchanan, and Stanley Zontek. Officially, he served on the USGA Green Section Committee from 1972 to 1990 and the USGA Green Section Award Committee from 1974 to 1989. Eb was also extremely generous in sharing his experiences with other golf course superintendents by writing articles for the *Green Section Record* and serving as toastmaster and speaker at many a Green Section education conference. His enthusiasm for his profession and his boundless curiosity in trying to find a better way to maintain his golf course made him a magnet for visits from Green Section agronomists, and he never failed to have something new to show them. On behalf of the many Green Section agronomists whom you have counseled over the years, we salute you, Eb!

The Piper & Oakley Award was presented to Eb in early July by Jim Snow, National Director of the Green Section, at a luncheon with some of Eb's longtime friends near his New Jersey home.

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The following laboratories are accredited by the American Association for Laboratory Accreditation (A2LA), having demonstrated ongoing competency in testing materials specified in the USGA's Recommendations for Putting Green Construction. The USGA recommends that only A2LA-accredited laboratories be used for testing and analyzing materials for building greens according to our guidelines.

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*Revised July 2000. Please contact the USGA Green Section (908-234-2300) for an updated list of accredited laboratories.

Perfection Is Not Attainable!

However, setting reasonable goals can allow for an objective evaluation of course conditions.

by KEITH HAPP

MANY GOLFERS comment that a well-struck shot should be rewarded. For example, when a well-struck shot from the teeing ground finds the fairway, the player then should have the opportunity to reach the green on a par-4 hole or the landing area of a par-5 hole with the next stroke. However, it seems that no matter where the golf balls may land, many golfers want to have a perfect lie from which to play. It is alarming that having level tees, great greens, and healthy, consistent fairway turf is not enough. It seems that there is an increasing emphasis placed on eliminating small blemishes in the rough or finding the perfect bunker sand that will minimize the potential for a challenging shot. Whatever happened to the saying, "Hit it, go find it, and hit again"? Isn't that what this game is all about?

We often hear the question, "What can we do about the condition of our rough? When my ball lands there I can't play a recovery shot."

I want to respond by asking the question, "What type of recovery shot are you trying to play?" After all, doesn't the lie of the ball dictate the type of shot that is to be played? Where is it stated that there should be no penalty for hitting a shot into the rough? Sometimes a great recovery shot is one that simply positions the player for the next shot to the hole.

As an example, perfection also seems to be a requirement for bunkers. When an errant shot finds a bunker, golfers expect the lie of the ball to be perfect. There also seems to be an increasing demand for absolute consistency from one bunker to another. In many instances, simply raking the sand will never elevate bunker playability to a satisfactory level. Sand may have to be removed, drainage installed, bunker contours may need to be altered, and then new sand can be positioned and readied for play. This is time consuming and, for some, cost prohibitive. Budgetary constraints must be considered so conditioning priorities can be established. However, establishing priorities is only the first step. Developing realistic and obtainable priorities is the challenge, and this task further identifies the fact that golf course operations are different. Just as the lie of the ball dictates shot selection, economic resources dictate course preparation. All too often an apples-to-oranges comparison is made regarding course conditioning. The manner in which one course is prepared may not be affordable for every course.

Establish maintenance standards for the golf course. These guidelines provide direction to achieve conditioning goals. Guidelines will vary for day-to-day versus tournament play.

For those courses that have focused on elevating playability, agronomic strategies used on greens have been expanded to tees, fairways, and even rough. Tees are fertilized more heavily and are overseeded on an as-needed basis. Fairways are being topdressed so that they are firm and better able to support play, no matter what weather conditions are presented. Rough is being topdressed with composts to improve the quality of the soil in which the turf is grown. Now, all of these strategies improve the health of the turf, but they come at a cost. Not all course operations have the same budget under which to operate, so once again priorities must be established.

It is not possible to achieve the same level of conditioning every day of the year. There are too many uncontrollable factors involved in turfgrass management. Budgetary constraints factor into the programs that can be used throughout the property. Weather patterns impact turf growth as well as course grooming activities. If funds are limited, the scope of what is an "important-to-play area" must be clearly defined. In other words, this may necessitate learning a few different shots when playing from the rough or learning how to play a bunker shot from a less-than-perfect lie.

What are perfect conditions for the game of golf? Webster defines perfect as "satisfying all requirements." This definition suggests that "the committee" needs to provide a clear, well-defined description of the desired course setup. Doing so could allow for a fair evaluation of the course and the manner in which it plays. More importantly, course maintenance resources could be evaluated to determine if playability requirements could be satisfied. If the committee constantly changes conditioning goals, then course conditioning standards will never be met. All things considered, no matter how high the bar is raised, expectations will continue to climb and this is further evidence that perfection is impossible to achieve.

KEITH A. HAPP *is an agronomist in the Mid-Atlantic Region, visiting courses in the states of Delaware, Maryland, West Virginia, Virginia, and Pennsylvania. Recently, Keith opened a sub-regional office in the Pittsburgh, Pennsylvania, area, bringing him closer to courses in the western portion of the Mid-Atlantic Region.*

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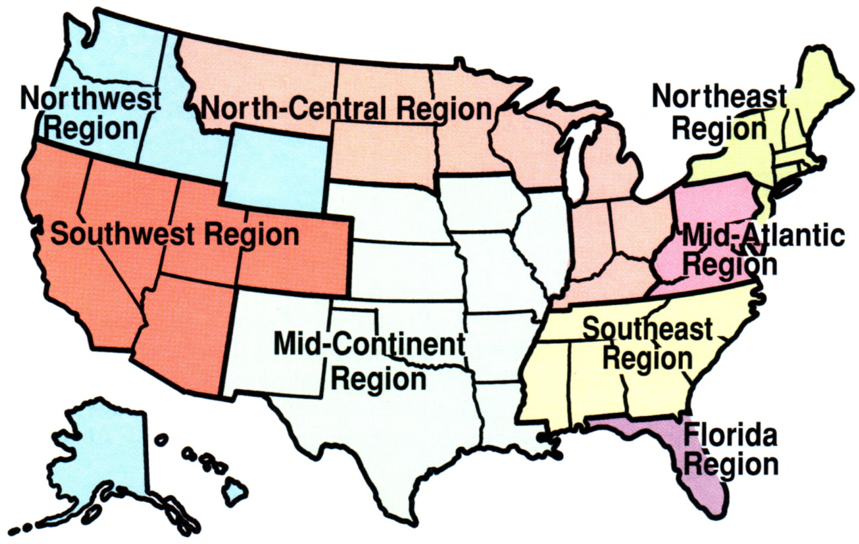

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TURF TWISTERS

DON'T DELAY

Question: The last couple of years I've heard several references to the Green Section Internship Program. I would love to spend a week traveling with a Green Section agronomist. How do I apply? (Indiana)

Answer: The process starts with each university nominating one student from its turfgrass management program to the corresponding Green Section Regional Director. The internship program is limited to juniors, seniors, and graduate students in four-year turfgrass management programs. A stipend and all expenses are paid. The USGA regional agronomists interview the candidates, and one or more students are selected to participate in the program. Nominations for the 2001 program are due back from the university on November 30, 2000. Your starting point is to let your turfgrass professor know that you would like to be considered for the program.

ADDRESS

Question: As an assistant superintendent, one of my least liked tasks is determining when our greens should be opened during a frost condition. The decision is easy, but what I don't like is having to go into the pro shop and "face the music" of irate golfers. Any tips on how to handle this situation? (Washington)

Answer: Above all, *do not* avoid the unpleasant task of going into the pro shop and directly facing the complaints. Let's face it, the people behind the counter receive plenty of complaints daily. *Look at this as an opportunity to hone your communication skills with golfers!* Explain that your decision is based on sound agronomic principles and you are trying to protect their investment. Although it is sometimes difficult, try to do this with a smile on your face while educating the golfers that a little patience now will serve the greens, tees, and fairways well in the future. For those who simply refuse to listen, a handy photo taken on the course showing the telltale black footprints of frost damage can be very convincing. If they still won't listen, remember that the world is full of CAVE people — Citizens Against Virtually Everything!

THE SITUATION AT HAND

Question: Our course recently experienced vandalism on two of our greens. The greens were damaged by the tires of a car. Additionally, gasoline was poured in several areas and lit on fire. From a playability perspective, a large portion of the greens was affected. However, actual turf damage was limited to about 10 percent of the turf. What is the best method for repairing this damage? (Delaware)

Answer: Repair of vandalism on greens is both time consuming and tedious. Sod is the obvious solution for repairing the damage. However, the method is important. First, if possible, obtain sod from a nursery green or practice green to minimize visual impact from turf differences. New sod will work too, although the appearance of the sodded area will often last several years. When sodding on such a small scale, it is important to use narrow sod strips. Six- to 8-inch strips of sod can be obtained using a hand sod cutter. The small strips make the job time consuming; however, they allow for surface contours to be maintained. Wider strips of sod can lead to irregular areas that take many topdressing applications to address. Vandalism is unfortunate, but careful repair can minimize the impact on playability.