# USGA® Green Section RECORD

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# Green Section RECORD



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*Cover Photo:*
*Filling the holes made by aeration is a practical way to prolong the beneficial effects of this operation.*



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*To ensure best results from aerification and topdressing operations, the topdressing must be thoroughly brushed into the aerification holes.*

# AERATION: Needed More Today Than Ever Before

**by ROBERT C. VAVREK, JR.**
Agronomist, Great Lakes Region, USGA Green Section

TRADITIONAL hollow-tine aeration is probably the most unpopular maintenance practice performed on the golf course. From the crew's point of view this operation ranks near repairing an irrigation leak on a bone-chilling morning or redistributing wet sand to the slopes of washed-out bunker faces. From the golfer's point of view, well . . . "expletives deleted."

However, as the amount of play increases at most golf courses, so does the need to address the detrimental effects of wear and compaction caused by concentrated foot traffic, motorized golf cart use, and maintenance equipment. The combination of these factors and the often unreasonable expectations for flawless day-to-day playing conditions exact a toll on the turf and the superintendent. Golfers view superb playing conditions on television each weekend but fail to realize that it has taken months and sometimes years to prepare a course for these events. The number of rounds played at most courses is unlikely to decrease, so the best chance for maintaining a high-quality stand of turf is to provide optimal growing conditions — which is why a sound aeration program is so important.

The ideal growing medium for turf is considered to be 50% mineral matter, 25% air, and 25% water by volume. The amount of large pores should roughly equal the amount of small pores. Large pores, called macropores, drain quickly and ensure the movement of air and water through the soil profile. Small pores, called micropores, hold water against gravity, through capillary action. Most of the water in micropores is available to plant roots.

Traffic compresses the soil and reduces the percentage of macropores, while the percentage of micropores remains unchanged or is slightly increased. The shift in the distribution of pore space limits the infiltration of water into the playing surface and slows the movement of water through the soil. Since air is "pulled" into macropores as water drains through the soil profile, the loss of large pores indirectly affects root growth by limiting the amount of oxygen available for root respiration.

The physical resistance of tight soils to root penetration alters rooting patterns to a point where most root growth occurs close to the surface and is exposed to environmental extremes. Compacted, poorly drained soils warm more slowly than dry soils during spring, another factor that further limits root growth. When the turfgrass root system is compromised, sooner or later the effects are seen on the surface as reduced quality or a limited ability to recover from stress.

Once a significant amount of soil compaction has occurred, the only practical way to reestablish more favorable growing conditions on an established stand of turf is to aerate. For the record, though, there is little scientific evidence that aeration increases the amount of oxygen in the soil between the holes. Therefore, the only portions of the soil that are actually "aerated" are the sidewalls and bottom of the empty holes. A more appropriate term for "aeration" would be hollow-tine, solid-tine, water, drill, etc., cultivation.

There are, however, many well-documented benefits of aeration. The holes and channels accelerate the movement of rain or irrigation water into the soil. The timely removal of excess moisture from the surface equates to fewer delays of play and more consistent playing conditions. The physical removal of cores lowers the bulk density — a measurement directly related to the degree of soil compaction.

The prolific amount of rooting that occurs in aeration holes is apparent when the cups are changed. A dense mass of white, healthy roots often can be seen in aeration holes even during the peak stress periods of midsummer.

The benefits of aeration are not limited to improving the soil's physical properties. Hollow-tine aeration is the most effective way to minimize the undesirable effects of excess thatch accumulation — short of stripping the sod. One pass with a "punch-type" aerifier equipped with ½″ diameter hollow tines on a 2″ × 2″ spacing removes about 5% of the surface area when the cores are broken up and the soil worked back into the playing surface with a brush or dragmat. As done on most tees and fairways, most of the organic material remains on the surface and is easily blown away or collected with the clippings.

*The key to "good greens" is matching the rate and frequency of topdressing application to the growth of the turf. Less-intensive aeration operations are necessary on greens built to USGA recommended specifications when the inputs of fertilizer, topdressing, irrigation, etc. are carefully managed.*

The incorporation of broken cores into a thatchy playing surface modifies the physical properties of this layer and introduces soil microorganisms responsible for organic matter decay. We are in the era of biostimulants, composted microbes, natural extracts, etc., and some manufacturers have claimed or suggested thatch control. Until research proves otherwise, though, the best chance of enhancing the degradation of organic matter is to improve the conditions for the native microbes already present in or under the thatch as described above — and it doesn't cost a cent.

Not too long ago the choices were simple: a pull-behind drum aerifier for the fairways/tees and a punch-type machine for the putting surface. Today there are many choices, and some units have more specific applications than others.

**Splicer/Spiker**

A slicer utilizes triangular or rectangular knives mounted on a drum or axle. These units are simple to use and cause very little disruption to the playing surface. This operation is useful for breaking up a surface crust and promoting more rapid infiltration of water into the soil. The severing of stolons or rhizomes can improve turf density as well. Slicers, though, do not bring soil to the surface and have a limited depth of penetration on compacted sites.

**Hollow Tines**

Hollow-tine aeration is the standard against which all other forms of aeration are compared. There are two types of hollow-tine aerifiers: those with tines mounted on a drum, and the "punch-type" units that utilize vertically operated tines.

Drum aerifiers are simple to use, have few moving parts to wear out or break down, and can cover considerable acreage in a relatively short time. Unfortunately, the depth of penetration is highly dependent on the degree of soil compaction and the moisture content of the

*On the other hand, aeration is needed when greens become severely layered due to an excessive accumulation of organic matter that can occur during the "grow in" period or when the greens are topdressed infrequently. Note the "black layer" and the deep penetration of roots through the aeration hole.*

soil, and close spacing is sacrificed for speed. If soil conditions are not ideal, these units tend to ride over compacted sites, producing the least effect where penetration is needed the most. The holes can be quite ragged, which limits the use of most drum units on greens. This type of equipment will continue to perform an important task on many low- to moderate-budget courses.

The vertically operated hollow-tine units are the most versatile aerators on the market. They cause much less surface disruption than the drum or open-spoon type designs, making them well suited for use on greens. There is no better way to overcome the effects of compaction, increase the infiltration rate of water into the soil, encourage deep root growth, and minimize excessive thatch accumulation in one operation.

The price of versatility is a considerable amount of surface disruption — much less than the old designs, but still enough to aggravate golfers, especially on greens. Core removal or breakup has traditionally been a time-consuming, labor-intensive task, but with specialized equipment such as core harvesters, core pulverizers, and highly efficient sweepers, this operation has been greatly simplified. The slow ground speed of punch-type aerators once limited their use on the golf course, but now fairway units have been developed that can remove deep, closely spaced cores at a rate of up to an acre per hour.

The optimal time to aerify is a subject for debate. After hearing all the arguments from superintendents and golfers, it seems that there is no "best" time. They say not to aerify in early spring because soil temperatures are low, turf is not actively growing, and the holes will take a long time to heal. Some don't aerify in late spring because *Poa annua* is germinating and they believe the open holes invite encroachment of this weed. Others can't aerify during summer because the open holes will cause severe wilting. Early fall is out, because of tournaments, and late fall to winter is impossible because of a limited labor force and little chance to dry the cores before breakup or collection.

All might be valid arguments, but the overall benefits of aeration, especially on heavily compacted areas, far outweigh the disadvantages. For example, some *Poa annua* may germinate in the holes during spring, but by relieving compaction and improving drainage the more desirable species have a better chance of competing with and crowding out the *Poa annua*. The potential loss of turf from severe wilt following aeration during midsummer is a concern, especially on a hot, windy day with low relative humidity. Timely irrigation or syringing, though, can prevent serious drought stress.

A variation of hollow-tine aeration not utilized to its full potential on golf courses is "quadra-tine" aeration. Quadra-tines are ¼" diameter tines that penetrate up to 1½" deep on a 1" × 1" spacing. Due to the close spacing, the amount of surface area removed after one pass is only slightly less than the amount removed following ½" diameter aeration on a 2" × 2" spacing. A primary advantage is little surface disruption and fewer golfer complaints.

The close spacing of holes greatly increases the amount of exposed surface area, which accelerates the evaporation of excess moisture from poorly drained, shaded sites. This operation also can relieve surface compaction during periods of heavy play and be a beneficial pre-treatment to the application of wetting agents to relieve localized dry spots.

Several superintendents have had good success overseeding into quadra-tine aeration holes. This is a practical way to introduce new, improved bentgrass cultivars into a green. The depth of penetration can be adjusted to about ½", and a mixture of seed, topdressing, and a little fertilizer can be worked into the holes with a brush or upside-down piece of carpet. The numerous, shallow holes are an ideal place for germination and development of seedlings.

### Solid Tine

There are no cores to collect following solid-tine aeration, and this is perhaps the only advantage to this operation. The use of solid tines is sometimes called "shatter-core" aeration because the jarring effect of inserting blunt tines into the soil, in theory, loosens the soil and relieves compaction. The benefits tend to be short-lived, though, and the operation has little beneficial effect on compaction when the soil is moist. In fact, there is a greater potential to develop a compaction pan when solid tines are used because soil is not removed from the hole. The pros and cons of hollow- versus solid-tine aeration are further discussed in the September/October 1990 issue of the GREEN SECTION RECORD.

*The ever-increasing amount of play at most golf courses necessitates the use of aeration on a wider scale.*

## Verti-Drain

Routine use of hollow-tine aeration can create a layer of compaction called a cultivation pan located just beyond the depth of tine penetration. Evidence of a cultivation pan is a soil core that breaks apart about 4″ deep when cups are changed. A cultivation pan slows the movement of water through the green and restricts root penetration. An effective way to minimize the effects of this kind of compaction is by deep-tine aeration.

A Verti-Drain deep-tine aerator utilizes ½″ to 1″ diameter solid or hollow tines that penetrate up to 12″ deep. When fully inserted, a "kicking action" is imparted on the tines which fractures the surrounding soil profile. The depth of penetration and amount of kick are adjustable to minimize surface disruption. The kick has more effect when the soil is a little on the dry side because dry soil fractures more readily than wet soil — not too dry, though, because the tines then lift and tear the sod.

Many superintendents hire contractors to perform deep-tine aeration because the contractors have experienced operators and because a Verti-Drain is expensive and requires the use of a high-powered tractor. Usually, only greens and perhaps tees are aerated to keep rental costs to a minimum. Those fortunate enough to own the equipment have found that this operation is effective on fairway soils and cart-trafficked rough areas as well.

Never assume that the least amount of disruption will occur when the smallest diameter tines are used. Arrange a demonstration using several tine sizes on the practice green before making a decision. You may be surprised to find that the use of ¾″ diameter solid tines may be less disruptive than ½″ tines because there is less chance of bending or bowing the heavier tines in rocky or heavily compacted soil. Furthermore, the large holes are more easily filled with topdressing than small holes. Taking the time to fill holes with sand or a suitable mix prolongs the beneficial effects of this operation by preserving the integrity of the holes. A similar argument can be made for removing the cores and filling the holes with topdressing after hollow-tine aeration on greens and tees. More material is required, but the long-term benefits are usually worth the added cost.

### Floyd-McKay Deep Drill

The deep drill also is capable of reaching beyond the depth of standard aeration tines. It is a self-propelled unit that utilizes two sets of carbide-tipped drills to bore holes up to 10 inches deep. The operation deposits a small amount of soil on the playing surface, and cleanup is usually required on greens. There is no kicking action, so the beneficial effect on subsurface compaction is probably less than that achieved with deep-tine aeration. Similar to deep tine, deep-drill aeration provides the most benefit where permeable soil exists below the layer of compaction.

Relatively few problems have been observed in the field with either operation. As mentioned above, a notable exception is a lifting or tearing of shallow-rooted turf when these operations are performed under dry soil conditions. This effect also is observed when standard aeration is performed under similar conditions.

### Water Injection

Water injection is an innovative method of aerating, and is in its first season of use on most golf courses. High-pressure jets of water are utilized to produce deep, irregular channels into the soil. The primary benefits are the variable depth of penetration and the absence of surface disruption under most conditions.

Initial research was performed at Michigan State University on a sandy loam soil where water injection was compared to hollow-tine aeration. Various soil physical properties, such as bulk density, porosity, and saturated hydraulic conductivity (percolation rate) were measured, as were rooting, clipping yield, and turf quality. Water injection generally performed as well or better than standard aeration, and the results were similar on either bentgrass or Kentucky bluegrass turf. Only hollow-tine aeration, though, limited thatch accumulation, because water injection neither removes thatch nor is it supposed to bring soil to the playing surface.

This study is a promising indication that water injection is an operation well suited to relieve compaction on fairways and tees. It provides the unique opportunity to relieve compaction and improve drainage during midsummer without disrupting play. Current research is investigating the potential benefits of mixing additives such as phosphorus or wetting agents with the injection water.

Its effect on high-sand-content greens built to USGA recommended specifications is not well understood. Neither is the effect on old native-soil greens which have been topdressed with sand for a number of years.

Many greens have received water injection treatments this season with positive results — deeper root penetration, improved drainage, etc. A few problems have occurred on greens having a substantial accumulation of sandy topdressing above the original construction mix of coarse sand, peat, and soil. Contamination of the topdressing with back-washed silt and clay and the deposition of fine gravel on the putting surface have been observed on a few greens.

Whether or not these isolated cases are cause for concern has yet to be determined. As superintendents become more familiar with water injection, the appropriate uses will become evident. The prudent course of action is to proceed slowly with any new equipment until the more common problems are discovered and addressed.

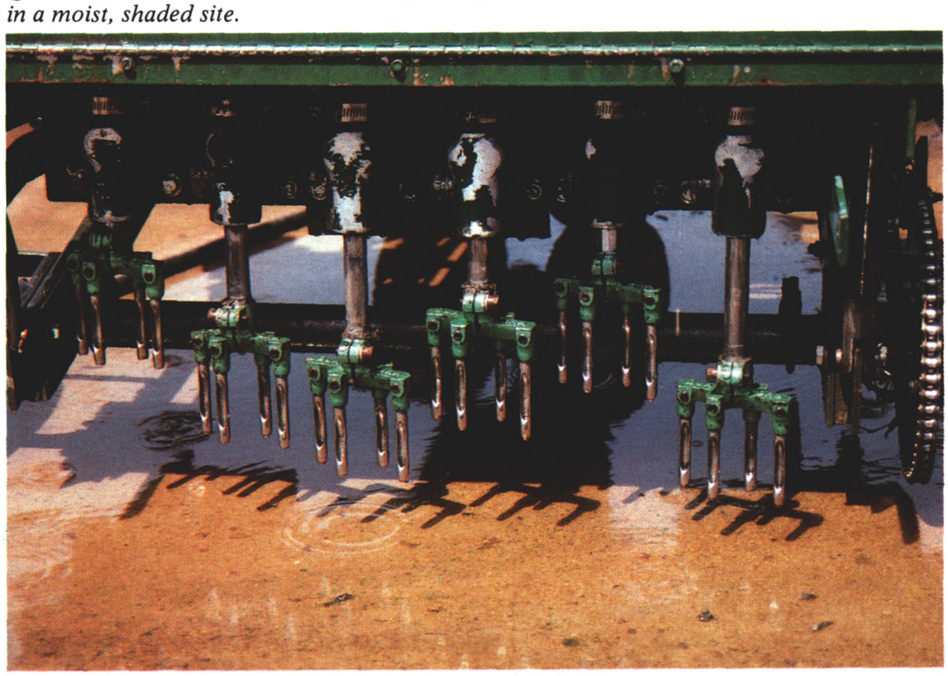
### Summary

The key to success with aeration is to determine the problem and then choose the most appropriate equipment and method of aeration. There is no need to purchase a $100,000 subhydro-vertimole deep-drill shatterslicer to break up a surface crust of algae on the greens. Combinations of techniques are more likely to produce better results than a single unit. For example, an early spring deep-tine aeration, supplemented by quadra-tine or Hydroject aeration during the summer, topped off with a standard hollow-tine aeration during the fall could produce great results with limited disruption to the playing surface.

There is no shortage of reasons to postpone aeration, and before you know it, it has not been performed at all. The potential benefits of aeration are usually well worth the trouble.

Finally, keep the golfers well informed about when and, more important, why aeration is being performed. Make the extra effort to communicate with golfers and you might be surprised how much support there is for your programs.

*Quadra-tine aeration is an excellent way to improve drainage and "dry out" the turf in a moist, shaded site.*



# DRAINAGE IMPROVEMENT — Remedy Without Reconstruction in New Zealand

**by Keith W. McAULIFFE**
Director, New Zealand Turf Culture Institute

*Correcting drainage problems on greens has become more important with increased playing pressures. Installing a trench and backfilling with materials that provide good water conductivity is one corrective technique used to improve drainage.*

DO YOU HAVE a drainage problem with your greens? If your course is deemed to be satisfactorily drained, you don't need to read further; but if you have soft, spongy, or waterlogged greens or other wet spots around the course, then this article could be of some assistance. If your course is like most, you probably have at least one green you consider to be poorly drained.

**Reconstruct or Recondition?**

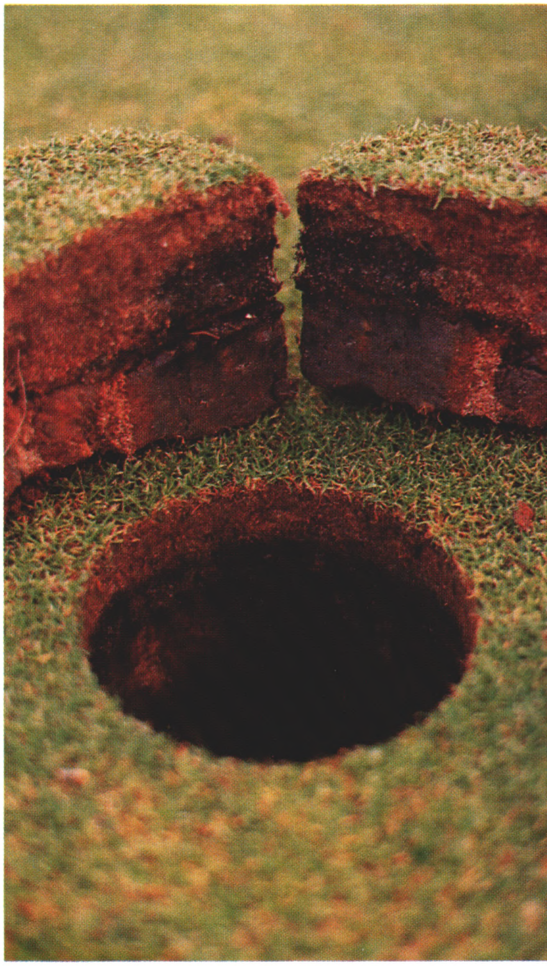
Reconstruction, using correct procedures and materials, is the method of preference when dealing with substandard soil performance on greens. It may not represent the most cost-effective option, however.

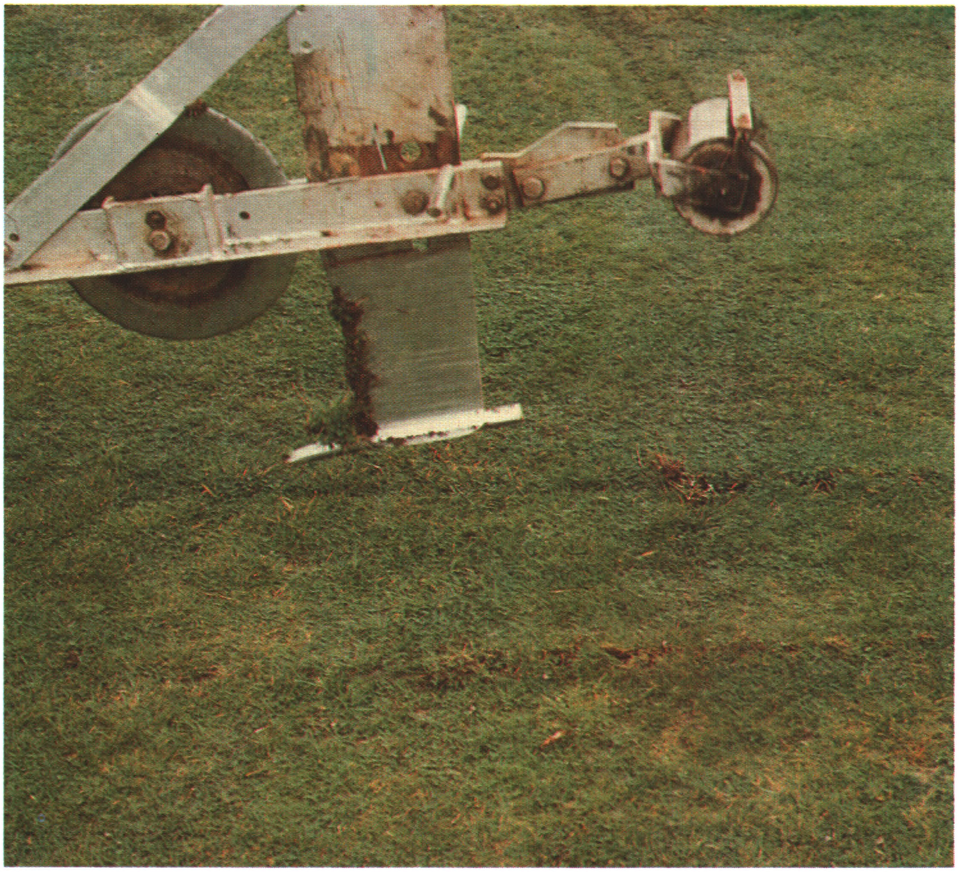
To reconstruct or recondition is an issue faced by many of New Zealand's golf course superintendents. Greens at most of our 390 golf clubs were constructed using local soil, generally silt loam material, at relatively low cost. Initially, these soil-based greens performed satisfactorily, but increasing playing pressures and high player expectations have brought about a growing requirement for consistently good year-round performance.

It is a fact that the majority of our clubs could not afford the costs of proper reconstruction, and most have been forced to try to recondition their troublesome greens to overcome drainage limitations. The spectacular response to low-cost physical treatments such as vibra-moling and mini-moling at many clubs is testimony to the fact that the reconditioning approach can work very well indeed.

The decision to reconstruct or recondition must involve a number of factors. Although it may ultimately boil down to economics, the first decision must be whether reconditioning could offer the desired level of improvement.

To answer this question, a scientific analysis of the following variables is needed:





*(Top left and left) The oscillating mini-mole plow fractures the soil when a torpedo-shaped device is pulled through the soil. Fissures created by the oscillating mini-moling provide seepage planes for excess water to drain through.*

*(Above) Poor soil conditions result in soft, spongy, waterlogged greens or other wet spots around the golf course. In New Zealand, greens are often constructed using local soil, generally a silt loam material, which often exhibits black layer.*

Figure 1.

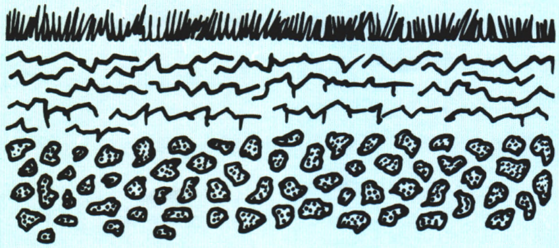


Figure 2.

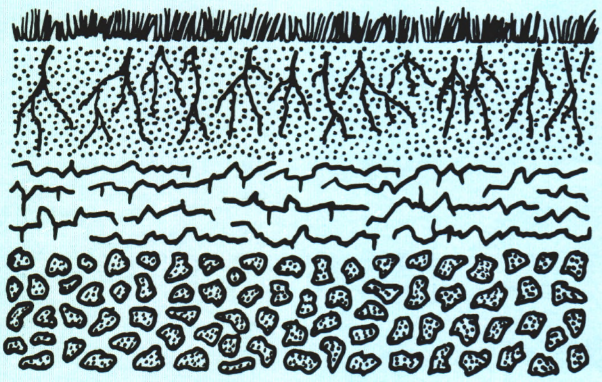
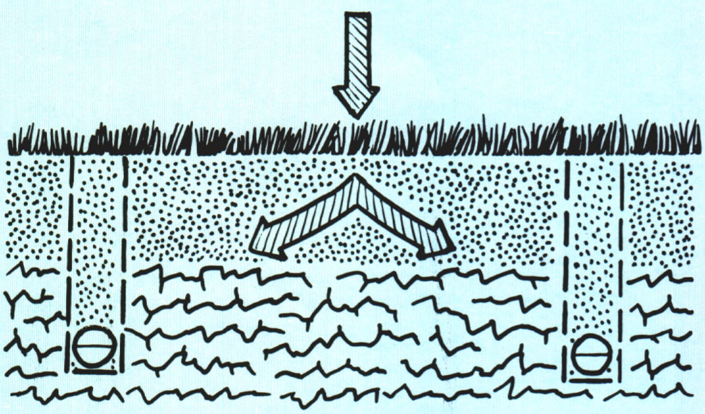


Figure 3.



*Selection and use of proper cultivation equipment can help overcome drainage problems caused by compacted layers near the surface (Figure 1) or several inches deep in the profile (Figure 2), particularly when underlaid with a free-draining base. When the compacted zone is too deep to penetrate (Figure 3), another option is to install closely spaced collectors (drains) in the base which link with the permeable top layer.*

- The sources of water loading (where is the excessive water coming from?).
- The present and potential flow paths for water movement through (and from) the green.

### Identifying Sources of Excess Soil Water

An examination of the surrounding landscape, coupled with an intensive study of the soil profile, will point to the sources of waterlogging. The following matters need to be investigated:

- Is there any runoff or seepage of water from surrounding high zones?
- Is there an underlying spring or aquifer bringing water to the surface?
- Is the improper function or use of the irrigation system compounding the water loading?
- Are features such as trees accentuating the waterlogging by preventing sunlight penetration and blocking good air circulation?
- Is it conceivable that the wrong type (and depth) of sand or soil mix has been used to construct the green?
- Are there layers within the green profile which restrict water flow?

### The Pathways for Water Flow

Having diagnosed the likely sources of excess water loading to our trouble spot, attention should be given to determining how surplus water is going to be removed from the soil (other than by evapotranspiration). This requires a close evaluation of the soil profile and an assessment of the permeability of the different soil horizons in both the vertical and horizontal directions.

Although there are techniques available to quantify soil permeability, we often rely on *subjective* means of assessment. For example, reference may be made to the soil texture, structure, hardness, color, root distribution, or number of visible pores to indicate soil permeability. If roots have difficulty moving through a soil layer, so too will water.

Using any or all of the above indicators, we can gauge which zones, if any, will freely conduct water through and away from the root zone. With this information at our fingertips, we are now in a position to assess drainage improvement options. Recall that drainage improvement involves a two-pronged attack: (1) minimizing excess water loading and (2) improving internal drainage.

### Improving Drainage by Minimizing Water Loading

Strategies should be developed for dealing with diagnosed sources of excess soil water. For example:

- Seepage from high spots can be intercepted before it gets to the green. A cutoff drain running perpendicular to the flow (slope) and with the correct depth and backfill specification will overcome this problem.
- A spring or high ground water table will need to be intercepted and lowered. In most cases this requires the installation of a deep pipe drainage system.
- Irrigation practices need to be managed to achieve maximum water use efficiency. This point was dealt with admirably by James Snow in the January/February 1991 issue of the

GREEN SECTION RECORD. Points highlighted in this article included:

Controlling application rate to avoid ponding and runoff.

Ensuring uniform application through correct system design and maintenance.

Cultivating regularly to maintain good infiltration.

Adopting correct irrigation methods (e.g., hand watering) which consider site-specific features.

### Drainage Improvement by Aiding Internal Drainage

From the soil permeability assessment, determine if there are any free draining layers in the soil profile. If the answer is yes, then aim to exploit them. Some examples:

### Impermeable Surface with Free Draining Subsoil

Where the surface has become compacted or sealed through traffic, algae, or other problem (Figure 1), provide vertical water passageways down to the free-draining base. Options include slicing, coring, drilling, Verti-Draining, Hydro-Jecting, and oscillating mini-mole plowing (e.g., Jacobsen sub-air).

The choice of equipment would depend on the depth to the free-draining zone and would be site specific. In fact, using the wrong tool could worsen the condition.

In the longer term, we could also look to build up a more porous surface medium by topdressing with sand.

### Relatively Free Draining Top Layer Over an Impermeable Base

This could occur when a sand layer has been created on a poorly drained base by topdressing with sand or a high-sand-content material (Figure 2).

If the poorly drained layer cannot be penetrated with conventional cultivation tools to reach a free-draining layer below, significant improvement in water clearance is not likely to be achieved. In fact, opening up a soil to aid water penetration can sometimes worsen the drainage problem if an outlet is not provided at the same time.

A better option in this instance could be to install close-spaced collectors (drains) in the base of the green that link up with the permeable top layer (Figure 3). Ideally, a collector pipe drain system for a green would have:

- A narrow trench width to minimize surface disturbance. Trench widths as narrow as 50mm (2″) are used.
- Pipes positioned well below any planned physical treatment. If the Verti-Drain or deep oscillating mini-mole plow will be used, there should be at least 350mm (14″) to the top of the pipe.
- Correctly selected permeable backfill specifications which provide good water conductivity yet do not affect surface play, either by subsidence or added droughtiness. A very coarse sand or fine pea metal is often preferred as backfill. Experience also has highlighted the need to firm the backfill thoroughly before replacing the turf slice.
- Drain lines installed perpendicular to the surface gradient to give maximum interception of flow.

### The Entire Profile has an Undesirably Low Permeability

One bypass technique commonly used in New Zealand (although less frequently in the USA) is "moling." This technique involves creating an unlined channel at a determined depth by pulling a torpedo-shaped device through the soil. Fissures created by moling (which will occur if the moling is carried out under relatively dry soil conditions) provide seepage planes for excess water

*Figure 4: The temporary fissures and holes created by moling make pathways for surplus water to drain through to the underlying drain. Figure 5: Closely spaced, sand/gravel-backfilled slits divert surface water directly to the underlying drain.*

**Figure 4.**

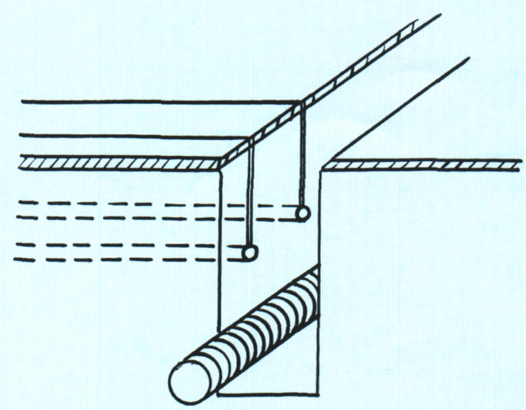
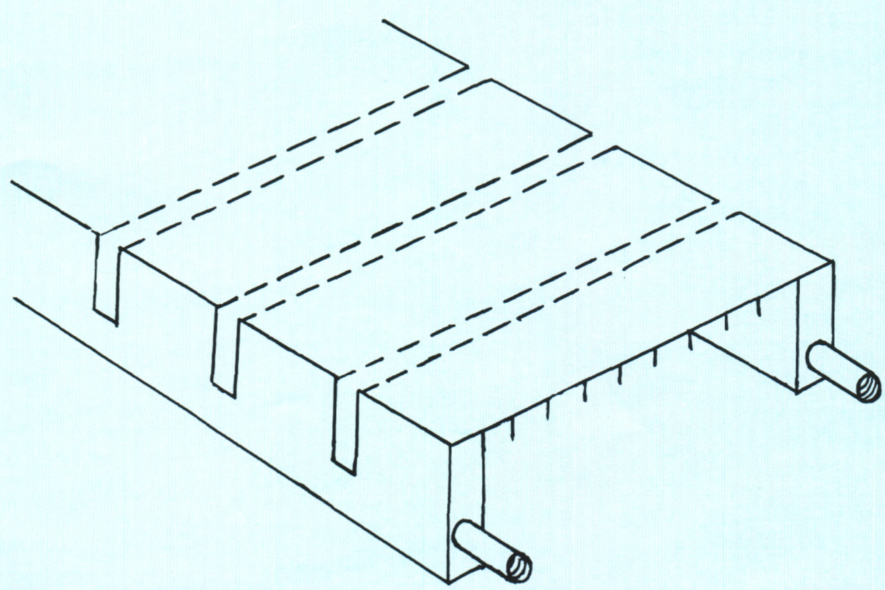


**Figure 5.**



to drain through to the underlying channel and then to an underlying pipe drain (Figure 4).

Note that there is a clear distinction between moling, where the goal is to form a stable channel, and oscillating mini-moling, where we aim to condition (fracture) the soil. Moling is not applicable to all soil types, such as stony soils, soils which crack excessively, or where excessive surface disruption occurs. Furthermore, moling is not a permanent remedy, and repeat treatments are needed. It can be an effective, low-cost method of improving drainage in fine-textured soils, though.

A second bypass option involves installing closely spaced, sand/gravel backfilled slits (often termed "sand slits") to direct surface water directly from the shallow cultivation treatment zone through to an underlying pipe drain. Sand slit spacing is typically 1-2m (3-6′).

As with the moling option, a base pipe drain system is installed perpendicular to the sand slits. The slits need to be sufficiently deep to intercept the permeable fill over the pipe drain.

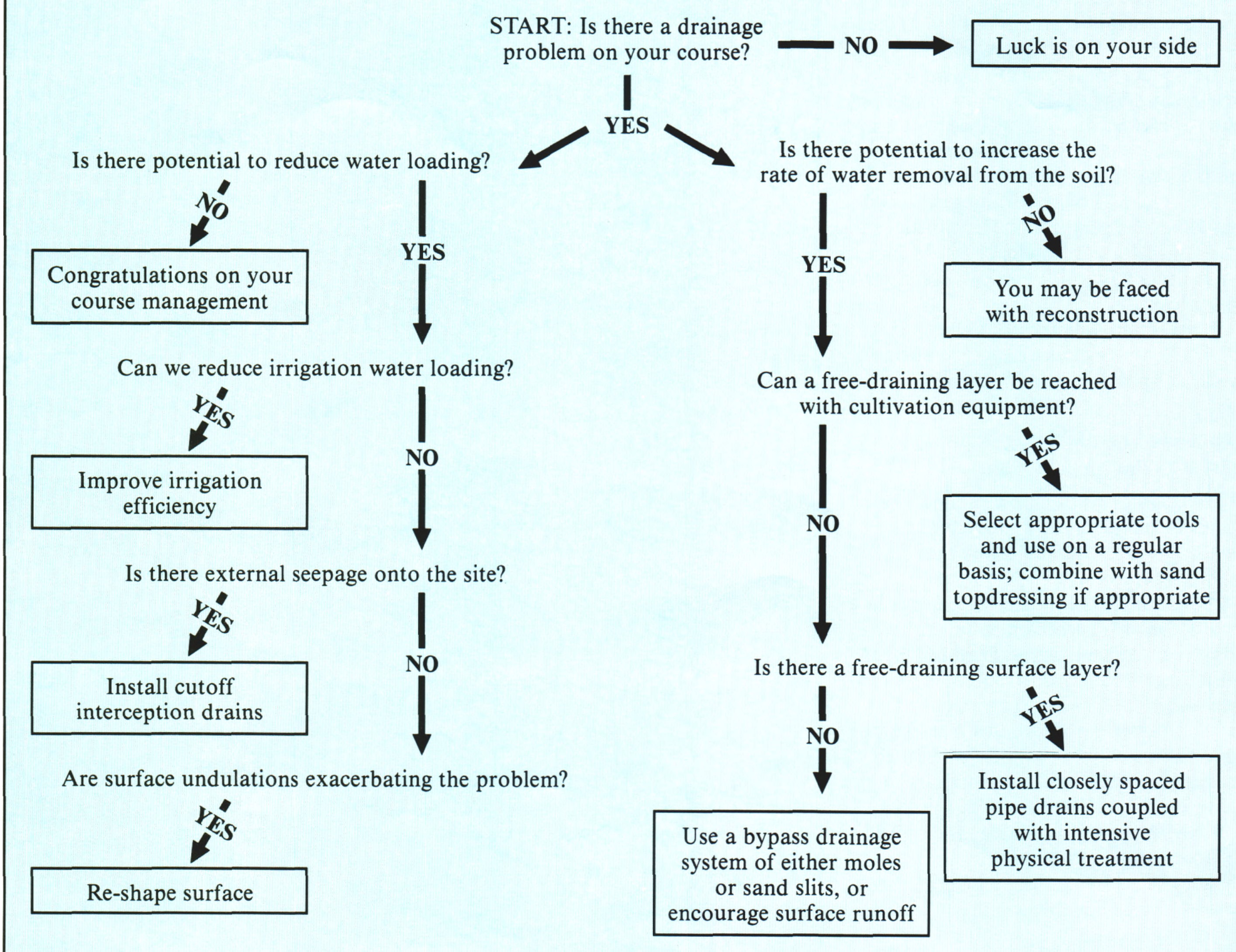
In some instances, it is better to forget about transferring water through the profile and instead aim to encourage surface runoff. This situation often applies to sloping green surrounds, where we may prefer to leave the surface intact and collect runoff at the base of the slope. In this way a portion of rainfall (and irrigation) loading is diverted away from the trouble zone.

Of course, one option that remains is reconstruction. Maybe, when all is said and done, there is no other choice.

**Summary**

- Drainage problems are "site specific"; a single recipe for solving all drainage problems is meaningless. Good advice from a knowledgeable agronomist or drainage expert can save money and time and can prevent frustration.
- An intensive study of each site needs to be undertaken before the best improvement option can be determined. The study should seek to identify the ways of reducing water loading onto the problem site and the ways of speeding up the water removal rate.
- Lateral thinking can be of considerable benefit in deriving the best approach to the problem.
- A logical thought process for drainage problem-solving is presented in Table 1.

**Table 1. The Thought Process for Drainage Improvement**



A USGA-SPONSORED RESEARCH PROJECT

# Biological Control of Diseases on Golf Course Turf

by DR. ERIC B. NELSON
Cornell University

ONE OF THE more exciting alternative strategies being developed for turfgrass disease management is the use of biological controls. Individual or mixtures of microorganisms are deployed to reduce the pathogens' activities or enhance the disease tolerance of plants. This approach to disease control has been used successfully on an experimental and commercial basis for the control of plant pathogens on several crop species, but only recently has it gained interest as an alternative pest management strategy for use on turf.

The microbiology of disease-suppressive composts has not been extensively studied. A USGA-funded study entitled "Microbial Basis of Disease Suppression in Composts Applied to Golf Course Turf" is currently being conducted at Cornell University. The goal of this project is to understand the microbiology of composts in order to predict disease-suppressive properties and assemble microbial antagonists useful as inoculants or biological fungicides for turfgrass disease control.

In addition to disease-causing microorganisms, turfgrass soils harbor a variety of non-pathogenic microorganisms that actually improve plant health. These soil bacteria and fungi are responsible for increasing the availability of plant nutrients, producing substances stimulatory to plant growth, and protecting plants against infection from diseases. The practice of biological control attempts to take advantage of these beneficial microbial attributes in order to minimize damage from plant pathogens. Biological control may be achieved either through the application of introduced microbial antagonists or through the manipulation of native antagonists present in soils, composts, or on plant parts. In either case, the goal is to reduce or eliminate pathogen activity by reducing pathogen inoculum in the soil, protecting plant surfaces from infection, or inducing natural defense mechanisms within the plant.

### The Use of Composts for Biological Disease Control

Although few in-depth studies on the biological control of turfgrass diseases have been conducted, promising results have been obtained using complex mixtures of microorganisms and individual antagonists as tools for managing fungal diseases of golf course turf (Table 1). While individual organisms isolated from many different environments can be suitable for use as biological control agents, compost-based organic fertilizers are perhaps the best sources of complex mixtures of antagonistic microorganisms.

Composting has been defined as the biological decomposition of organic constituents in wastes under controlled conditions. Since composting relies exclusively on microorganisms to decompose the organic matter, the process has biological, as well as physical, limitations. During composting, the environmental parameters (i.e., moisture, temperature, and aeration) must be stringently controlled. This is necessary to maintain adequate rates of decomposition and to avoid the production of decomposition by-products that may be harmful to plant growth. In order to maintain proper temperatures, the composting mass must be large enough to be self-insulating, but not so large that compaction results in reduced air exchange. The composting mass must be moist enough to support microbial activity, but not so moist that air exchange is limited. The particle size

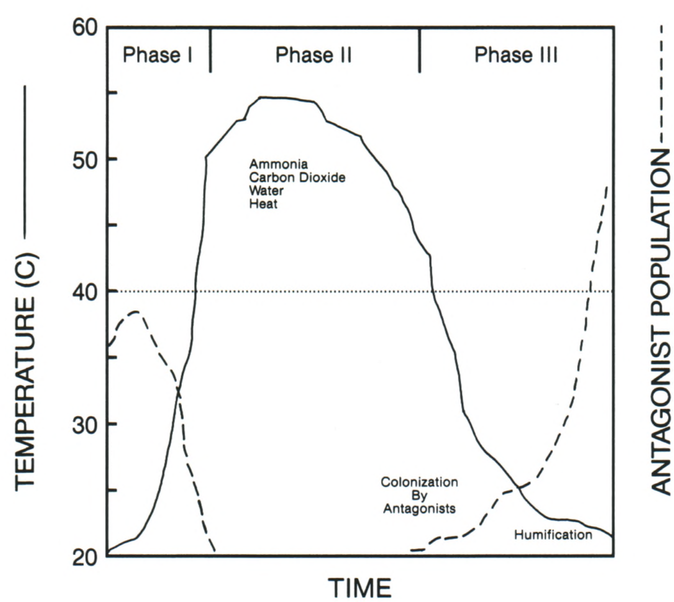



*Figure 1. During Phase I of the composting process, initial heating takes place and readily soluble components are degraded. During Phase II, cellulose and hemicellulose are degraded under high temperature (thermophilic) conditions. This is accompanied by the release of water, carbon dioxide, ammonia and heat. Finally, during Phase III, curing and stabilization are accompanied by a drop in temperatures and increased humification of the material. Recolonization of the compost by mesophilic microorganisms occurs during Phase III. Included in these microbial communities are populations of antagonists.*

**Table 1. Known Examples of Turfgrass Disease Biological Control**

| Disease *(pathogen)* | Antagonists | Location |
|---|---|---|
| Brown Patch *(Rhizoctonia solani)* | *Rhizoctonia* spp. | Ontario, Canada |
| | *Laetisaria* spp. | N. Carolina |
| | Complex mixtures | New York, Maryland |
| Dollar Spot *(Sclerotinia homeocarpa)* | *Enterobacter cloacae* | New York |
| | *Fusarium heterosporum* | Ontario, Canada |
| | *Gliocladium virens* | South Carolina |
| | Complex mixtures | New York |
| Pythium Blight *(Pythium aphanidermatum)* | *Pseudomonas* spp. | Illinois, Ohio |
| | *Trichoderma* spp. | Ohio |
| | *Trichoderma hamatum* | Colorado |
| | *Enterobacter cloacae* | New York |
| | Various bacteria | New York, Pennsylvania |
| | Complex mixtures | Pennsylvania |
| Pythium Root Rot *(Pythium graminicola)* | *Enterobacter cloacae* | New York |
| | Complex mixtures | New York |
| Red Thread *(Laetisaria fuciformis)* | Complex mixtures | New York |
| Southern Blight *(Sclerotium rolfsii)* | *Trichoderma harzianum* | N. Carolina |
| Take-All Patch *(Gaeumannomyces graminis var. avenae)* | *Pseudomonas* spp. | Colorado |
| | *Gaeumannomyces* spp. | Australia |
| | *Phialophora radicicola* | Australia |
| | Complex mixtures | Australia |
| Typhula Blight *(Typhula spp.)* | *Typhula phacorrhiza* | Ontario, Canada |
| | *Trichoderma* spp. | Massachusetts |
| | Complex mixtures | New York |

**Table 2. Turfgrass Diseases for which Composts have been Suppressive**

| Disease *(pathogen)* | Mode of Application | Turfgrasses |
|---|---|---|
| Brown Patch *(Rhizoctonia solani)* | Topdressings | Creeping Bentgrass/ Annual Bluegrass |
| Dollar Spot *(Sclerotinia homoeocarpa)* | Topdressings | Creeping Bentgrass/ Annual Bluegrass |
| Necrotic Ringspot *(Leptosphaeria korrae)* | Topdressings | Kentucky Bluegrass |
| Pythium Blight *(Pythium aphanidermatum)* | Topdressings[1] | Perennial Ryegrass |
| Pythium Root Rot *(Pythium graminicola)* | Topdressings and heavy fall applications | Creeping Bentgrass/ Annual Bluegrass |
| Red Thread *(Laetisaria fuciformis)* | Topdressings | Perennial Ryegrass |
| Summer Patch *(Magneporthe poae)* | Topdressings | Kentucky Bluegrass |
| Typhula Blight *(Typhula spp.)* | Heavy fall applications[2] | Creeping Bentgrass/ Annual Bluegrass |

[1]Applied at the rate of approximately 10 pounds per 1,000 square feet

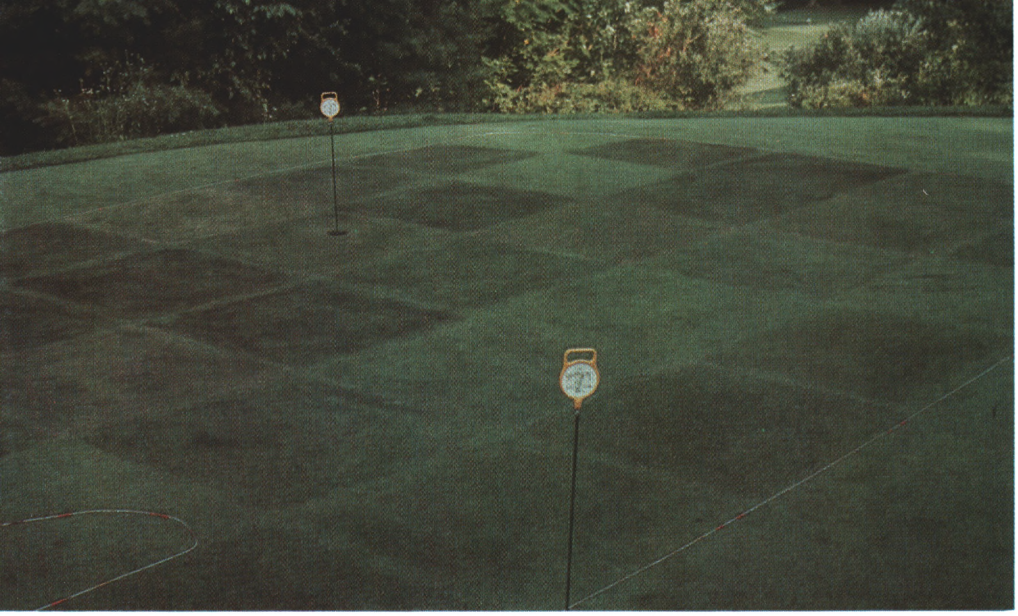
[2]Applied at the rate of approximately 200 pounds per 1,000 square feet

of the material must be small enough to provide proper insulation, but not so small that it limits air exchange.

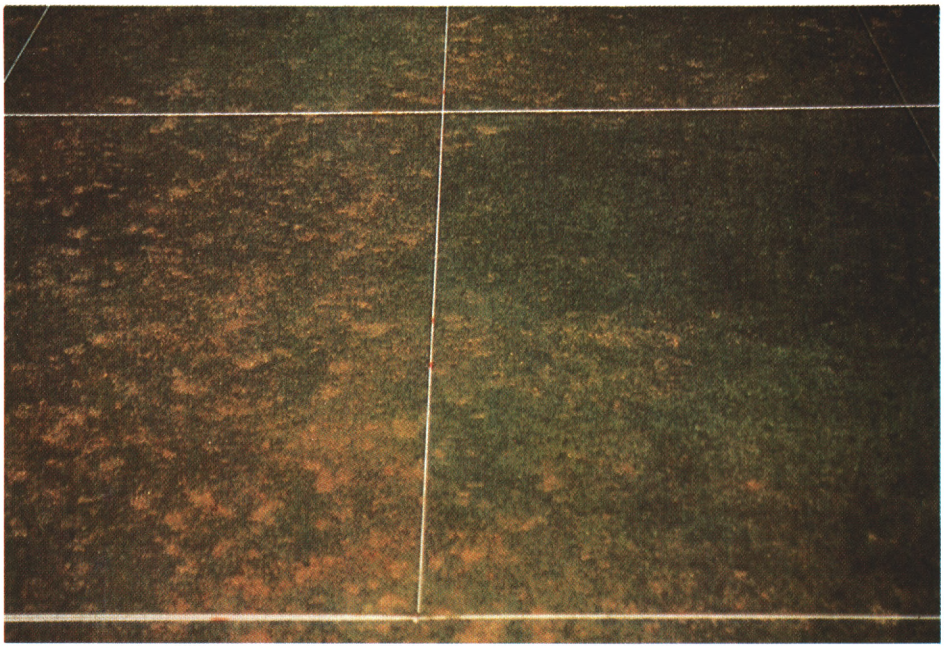
When all of the environmental and physical conditions are optimized, composting should proceed through three distinct phases (Figure 1) involving (1) a rapid rise in temperature, (2) a prolonged high-temperature decomposition phase, and (3) a curing phase where temperatures and decomposition rate decrease. These three phases of decomposition are accompanied by successions of both mesophilic (moderate-temperature) and thermophilic (high-temperature) microflora. Each of these microbial communities makes an important contribution to the nature of the composted material. Failure to maintain environmental conditions favorable for adequate microbial activity could jeopardize the quality of the final product.

In general, the longer the curing period, the more diverse the colonizing mesophilic microflora. These microflora are the most important in suppressing turfgrass diseases. At the present time, unfortunately, there is no reliable way to predict the disease-suppressive properties of composts, since the nature of these colonizing microbial antagonists is left to chance and determined largely by the microflora present at the composting site.

Applications of composted material can suppress turfgrass diseases (Table 2). Monthly applications of topdressing containing as little as 10 pounds of suppressive compost per 1,000 square feet were effective in suppressing diseases such as dollar spot, brown patch, *Pythium* root rot, *Typhula* blight, and red thread. Reductions in severity of *Pythium* blight, summer patch, and necrotic ringspot also have been observed in sites receiving periodic applications of composts. Of particular benefit is the impact of long-term compost applications on root-rotting pathogens in soil. Populations of soil-borne *Pythium* species are generally not suppressed following traditional chemical fungicide applications, but can be reduced on putting greens receiving continuous compost applications in the absence of any chemical fungicide applications. Also, heavy applications of compost (approximately 200 pounds per 1,000 square feet) to putting greens in late fall are effective not only in suppressing winter diseases, such as *Typhula* blight, but also in protecting putting surfaces from winter ice and freezing damage.



(Left) Figure 2. Field research plots immediately after applying topdressings amended with various composts and organic fertilizers.

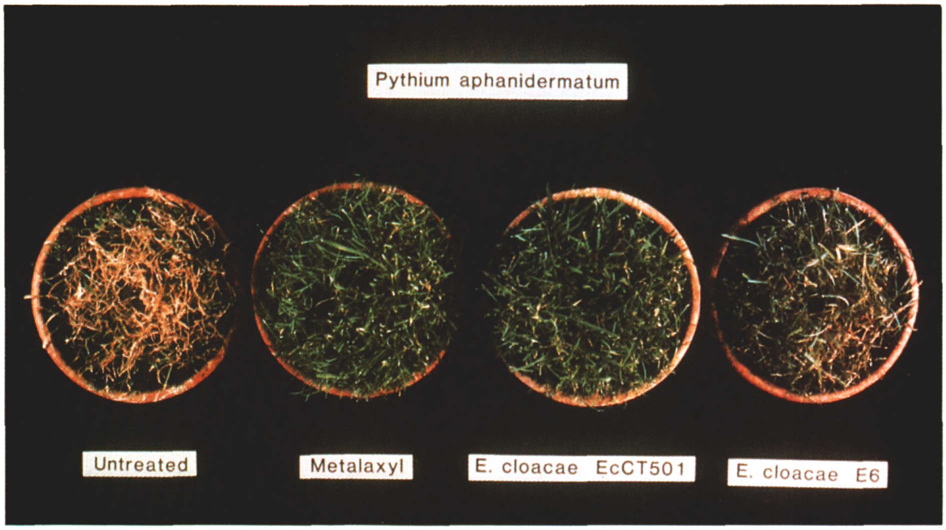


Biological suppression of dollar spot on a creeping bentgrass/annual bluegrass putting green 32 days after application of selected composts and organic fertilizers. (Left photo) The plot on the left was untreated, while the one on the right was treated with approximately 10 pounds per 1,000 square feet of an organic fertilizer. (Right photo) The plot on the bottom was left untreated, while the one on the top was treated with a poultry litter/cow manure compost mixture at the rate of approximately 10 pounds per 1,000 square feet.

Composts prepared from different starting materials, as well as those at different stages of decomposition, vary in the level of disease-suppression and in the spectrum of diseases that are controlled. This is primarily a result of the microbial variability among different composts and differences in the quality of organic matter present in a compost at various stages of decomposition. Although microbial activity is necessary for disease-suppressive properties to be expressed in most composts, the specific nature of disease suppressiveness is, in general, unknown.

In our research, several aspects of the ecology of key compost-inhabiting antagonists are being investigated. For example, the ability of microbial antagonists to establish and survive in turfgrass ecosystems is necessary for biological control to occur. The interactions of antagonists with other soil organisms, and the soil or plant factors affecting optimum biological control activity, will be important in developing strategies with compost-based materials. In addition, these organisms may serve as indicators of how long to compost a material before it can be certified to be disease-suppressive. Research aimed at understanding the fate of antagonistic organisms in soils and on plants following compost applications will aid in understanding why composts fail at certain times and locations. This research also should help predict the compatibility of composts and their resident antagonists with other pesticides and cultural practices commonly used in turf management.

Individual microbial antagonists found in soils, composts, or in association with plants can, in many cases, suppress disease at levels typically achieved with composts or from use of fungicides (Figure 4). Due to the extremely close link between their function and performance, however, one cannot readily predict antagonistic




*Effect of various strains of* Enterobacter cloacae *and the fungicide metalaxyl on the suppression of* Pythium *blight of perennial ryegrass in growth chamber experiments. Disease severity was rated on a scale of 1 to 5, for which 1 equals no foliar blight and 5 equals 100 percent foliar blight. A — Nontreated; B — Drenched with metalaxyl (750 µg a.i./ml); C — Treated with* E. cloacae *strain EcCT-501; and D — Treated with* E. cloacae strain E6. (From Nelson & Craft, 1991).

behavior without an understanding of the microbial traits important in pathogen or disease suppression. It also follows that the performance of antagonists could be effectively enhanced if their function was clearly understood.

The traits necessary for an antagonist to suppress turfgrass disease are unknown; however, a number of traits are currently being investigated. For example, these traits include the ability of antagonists to produce fungicidal compounds or compounds that make nutrients unavailable to pathogens. Other traits include the ability of antagonists to parasitize pathogens, colonize plant parts, and compete with pathogens for resources in soil and on plants.

The use of topdressing materials amended with disease-suppressive composts or organic fertilizers has received some acceptance by turfgrass managers as an attractive disease-control alternative. Many composted materials and organic fertilizers are commercially available from distributors or municipal waste treatment facilities. Preliminary research has shown that use of composts and organic fertilizers for turfgrass disease control is economically and technologically practical and, in some instances, can provide reasonable levels of disease control. In the few cases that have been examined with some of these materials, a reduction in fungicide use has accompanied the adoption of this biological control strategy.

Before disease-suppressive composts become widely accepted and used for disease control, the principal problem of a compost not being consistently suppressive from year to year, batch to batch, or from one site to the next must be solved. Turfgrass managers and compost producers agree that the future success of these materials in commercial turfgrass management depends upon the ability of producers to provide materials with predictable levels of disease control. Gross variation in disease-suppressive qualities of composts cannot be tolerated because end-users need to be assured that every batch of compost used specifically for disease control will work every time.

Unfortunately, we do not yet know how to predict the suppressive activity of certain composts without actually testing them in field situations. A number of tests have been developed to determine compost maturity and degree of stabilization for the purpose of reducing the variability in physical and chemical properties. Very little of the research, however, has been designed to directly assess microbiological aspects of maturity and disease suppressiveness. Currently, predictive tests based on levels of microbial activity and organic matter quality are being explored through this research project as potential tools for predicting composts' disease-suppressive properties.

# Back to the Basics for Golf and the Environment

**by GEORGE B. MANUEL**
Agronomist, Mid-Continent Region, USGA Green Section

LOOKING ahead into this decade of environmental concerns, it is a distinct possibility that superintendents throughout the country will experience restrictions in the application or availability of pesticides. To prepare for these future reductions, there is a need to search for alternatives to make grasses healthier and less chemically dependent. The successful superintendent in the 1990s will be one who is able to combine proven agronomic practices of the past with some of today's technology. A "back to basics" approach will help you meet the environmental challenges at your doorstep.

Three of the most important factors in maintaining healthy turf are proper nutrition, reasonable cutting heights, and regular aeration. In order to prepare a fertilization program, the soil from a portion of the greens, tees, and fairways should be tested annually. For best results, it is preferable to continue with the same testing laboratory to achieve a consistent evaluation year after year.

When test results are received, they should be examined closely and compared to the previous year's analysis. Adjustments can then be made to provide optimum growing conditions for the turf. In particular, potassium and phosphorous levels should be closely monitored. Soil potassium can be depleted due to rapid uptake by the turf as well as its tendency to be leached through the soil profile. This results in reduced vigor and turf that is less tolerant of stresses of all types (traffic, cold, heat, pests, etc.).

To counteract this nutrient depletion and improve turf performance, many superintendents have opted to apply potassium at a ratio of 1:1 with nitrogen to their greens. Potassium applications should be split among several different sources. Because of its low salt index and its acidifying effects, potassium sulfate has become the standard for turf. However, research is proving that other potassium sources also have multiple benefits to turfgrass. Potassium chloride is thought to be a good preventative for diseases such as take-all patch. With the incidence of this disease increasing at courses throughout the country, including potassium chloride in your fertilizer program could be a prudent move. Watch out for the burn potential of this material, though.

Potassium nitrate has its advantages as well. A low salt index makes this an excellent potassium source. Additionally, research at Michigan State University indicates that nitrate-based fertilizers can be of particular importance for golf courses which have experienced black layer problems. Their research suggests that nitrates limit the accumulation of sulfides, which contribute to the formation of black layer. Granted, good drainage and proper irrigation are the main keys for inhibiting black layer formation, but potassium nitrate is another weapon you can put in your arsenal when combatting this frequently seen condition. Finally, when seed of some varieties of grass (such as buffalograss) is treated with potassium nitrate prior to planting, a significant increase in germination can be expected.

While increasing use of potassium has met with a positive response in recent years, the opposite has occurred with phosphorous. To many superintendents, the mere mention of the word phosphorous conjures up visions of *Poa annua*. But that should not be the only consideration. With the advent of frequent, light topdressings, an additional inch of sand and organic matter can be added to the soil profile every couple of years. Most sands used for this purpose are practically sterile and contain very little phosphorous. With these thoughts in mind, it is easy to see that in a very short time the upper few inches of the profile could become phosphorous deficient. In these cases, light, foliar applications of phosphorous can sometimes produce a favorable turf response, even though soil tests may indicate adequate phosphorous levels. Generally, three to four applications of monoammonium phosphate (14-61-0) at the rate of .25 pounds of $P_2O_5$ per thousand square feet will benefit the turf both above and below the surface. For a more accurate analysis of available rootzone phosphorous, as well as other nutrients, a separate sample composed of the upper one to two inches of the profile should be submitted.

**Mowing Height**

Another critical factor in getting back to the basics is mowing height. There is no doubt that turf stress increases as the cutting height is lowered. This is particularly true on greens where the cutting height has reached ⅛ inch or less. Putting surfaces often become thin, algae infested, and more prone to failure. While the grass may tolerate low heights for short periods of time, a wise superintendent will keep his resume updated when attempting to maintain these extremes on a daily basis. Instead, a return to mowing heights of 5/32 or 3/16 inch is recommended to sustain healthy turf. Speed can be preserved by more frequent grooming, light topdressing, and other techniques.

*Although contested by many golfers, the benefits of aerification to the turf are undisputable.*

*Tim Uptmore, golf course superintendent at Cottonwood Creek G. C., in Waco, Texas, recognizes that soil profiles should be taken on a routine basis to determine topdressing frequency.*

Grooming can be done as often as every other day when the turf is healthy and the weather cooperative. Light topdressing is sometimes done once a week during the same period. This may seem like too much sand, but instead of using a spreader attached to a truckster, some superintendents utilize a walk-behind rotary-type fertilizer spreader or similar unit. About one hopper-full of sand is applied every week to each green. Now, that's not much sand!

The best way to determine the rate and frequency of topdressing is to utilize a soil profile tool. Though many of these are seen in superintendents' offices, most collect more dust than soil. Remember, the rootzone is constantly changing as the plant contributes organic matter and as topdressing accumulates. By taking a profile on a regular basis, the developing rootzone can be monitored to ensure layering does not occur. Unless this is checked routinely, the topdressing schedule is merely a guess.

### Aerification

The third factor mentioned earlier is aerification. Arguably, there is no other single cultural practice that produces stronger, healthier turf. The alleviation of compaction, improved drainage, and increased gas exchange associated with aerification promotes deeper rooting. As a rule, the deeper and more often the greens are aerified, the more consistently healthy the turf will be. In days past, greenkeepers bought out a hardware store's supply of pitchforks in order to break through compacted layers to promote air and water movement deep into the soil profile. Fortunately, today we have excellent mechanized equipment to accomplish this task. The success of these machines and the rapid growth of this market are tributes to well-founded agronomic principles adopted by turf managers many years ago.

Another "secret" of turf managers in the past was to spread a gallon of water mixed with pyrethrum or liquid detergent over a one-square-yard area of turf. Within a few minutes irritated insects would come to the surface of the green, and correct identification could be made. This procedure still works well today, especially for armyworm, cutworm, and sod webworm detection. Simple techniques such as this allow early detection of insect pests and can be a helpful tool as golf course superintendents develop effective IPM programs. Finally, circumstances which lead to devastating losses of turf can occur when disease organisms are misdiagnosed and subsequently sprayed with the wrong fungicide. As it stands now, a superintendent has the option of spraying one product after another until the effective material is pinpointed. This option may not be available to superintendents in the near future. To ensure proper identification, the following steps should be taken.

- Consider the environmental effects under which the disease has prospered, such as temperature, humidity, light, etc.
- Be aware of the disease history on your particular course. In other words, be familiar with areas of the course that are most susceptible to certain diseases, and scout these areas frequently.
- Become knowledgeable of the injury symptoms, which include patterns (patches, spots, streaks) and visible signs (mycelium, wilt, etc.).
- Acquire a microscope and become familiar with its use. Though microscopes are not helpful with all diseases, they can give you an edge when the going gets tough.
- Make use of commercial detection kits for identifying or ruling out certain diseases.
- Cultivate a good relationship with your local or state extension turf pathologist.

There is no doubt that golf course superintendents and golfers will have to deal with many changes in the 1990s. Absolute perfection on the course is no longer a reasonable or practical goal, but this does not mean that we will have to sacrifice healthy turf and good playing conditions. As chemical tools are lost or restricted, turf managers will have to rely on solid agronomic principles and practices. This "getting back to basics" approach always has been extremely effective and always will be.

# Using Computer Simulations to Predict the Fate and Environmental Impact of Applied Pesticides

## *An Aid to Developing Environmentally Sound Integrated Pest Management Plans for Golf Courses and Other Turf Areas*

**by KEVIN J. FRANKE**
Environmental Scientist, The LA Group, Saratoga Springs, New York

IN THESE TIMES of increased environmental awareness and uncertain economic future, many turf managers must answer questions regarding the safety and economy of their chemical pest control practices. These questions may be raised by golfers, the general public, and even government regulatory agencies. Are pesticides being applied only when and where they are needed? Are the right pesticides being applied? What are the potential side effects of pesticide use? Are there threats to humans, fish, wildlife, or water resources? Are there safer alternatives which will accomplish the job? Oftentimes, answers are hard to come by.

While it is the goal of every turf manager to use chemical controls in the safest and most efficient manner, there is always uncertainty involved in applying pesticides to a highly variable and often uncontrollable environment. Variability in factors such as soils, weather, and past management practices can all influence the occurrence of pests as well as the effectiveness and fate of applied pesticides.

Without extensive and expensive field studies, it is impossible to accurately predict the fate of applied products on a site-specific basis. Or is it? Recently, the use of computer simulation has significantly reduced the work necessary to answer questions which previously could be addressed only by more time- and labor-intensive means. Today, computer simulations can help determine the fate of a particular pesticide or fertilizer applied at a given rate, on a given schedule, and on a site-specific basis. Currently, The LA Group, a landscape architecture, engineering, and environmental consulting firm in Saratoga Springs, New York, uses computer simulations to aid in the preparation of Integrated Pest Management (IPM) plans for proposed and existing golf courses.

### Modeling as a Predictive Tool

Mathematical modeling is an accepted scientific process by which systems can be analyzed in a comprehensive manner based upon documented observations of quantifiable phenomena. Models have been developed to simulate specific processes, often quite complex, and describe these processes beyond what could be accomplished using simple predictions. The effectiveness and reliability of any such predictive tool is dependent on the accuracy of the data used to formulate the model. Development of a model is a process whereby scientifically established values are used in a series of interrelated equations to best fit conditions which have been observed to occur naturally. The relationships of variables and equations are arranged and rearranged in the model development process until they best describe real occurrences over a range of measured conditions.

Models vary in their complexity and in the amount of data that must be supplied by the user (input data). Generally, the more complex the model, the more precise the information it generates (output data). A number of models have been developed to describe the movement of pesticides in soil. These models range from simple, one-equation predictions to the data-intensive computer simulations. The simpler evaluations of leaching or runoff potential deal with the physical properties of a product (i.e., solubility in water, half-life, etc.), regardless of the environment in which they are applied. The more complex models integrate the properties of a product with specific environmental data such as soil type and temperature, rainfall, soil water, evaporation, and the amount and type of crop present. More data-intense models provide more site-specific results.

Models developed to predict the movement of pesticides include the USEPA's "Pesticide Root Zone Model" (PRZM), USDA's "Chemicals, Runoff, and Erosion from Agricultural Management Systems" (CREAMS), Jury et al's "Chemical Transport Screening Model" (CTSM), and Wagenet and Hutson's "Leaching Estimation and Chemistry Model" (LEACHM). All of these models were intended for simulation of field agriculture scenarios.

**Table 1: Characteristics of Four Selected Pesticide Models**

| | PRZM | GLEAMS/ CREAMS | CTSM | LEACHM |
|---|---|---|---|---|
| Predicts vertical movement | X | X | X | X |
| Predicts horizontal movement | X | X | | |
| Simulates pesticides | X | X | X | X |
| Simulates nutrients | | X | | X |
| Site specific | X | X | | X |
| Software available | X | X | Not Needed | X |

Characteristics and capabilities of each of the four models are presented in Table 1.

The choice of which model to use depends on the precision required to determine the potential for and magnitude of negative environmental impacts associated with turfgrass management practices. Regardless of which model is selected, however, users of the data should be aware of their limitations. Models are predictive tools whose accuracies reflect the quality of the data used to develop them and, just as importantly, the data used to operate them. Data generated from modeling should be used to guide management decisions rather than define them.

*(Editor's Note: Pesticide and nutrient fate studies being conducted on turf at several universities suggest that most current computer models tend to overestimate the amount of these potential pollutants that reach groundwater.)*

### Computer Simulations Using LEACHM

The Leaching Estimation And Chemistry Model, or LEACHM, was developed by Drs. J. L. Hutson and R. J. Wagenet of Cornell University to predict the movement of water, salts, fertilizers, and pesticides through specific soil profiles. Originally developed for use in agricultural situations, the model was modified to more accurately simulate proposed pesticide program options for golf courses from Lake Placid, New York, to Lanai, Hawaii. Results of simulations have aided in the selection of products which will pose the least potential for negative impacts on groundwater, surface waters, and non-target insect, fish, and wildlife species, while still effectively controlling anticipated target pests.

Realistic results are ensured by inputting information specific to the area being simulated. Parameters such as local rainfall, snowfall, temperatures (air and soil), and pan evaporation are taken from published meteorological data. Irrigation events can be tailored to simulate any schedule, and schedules can be modified based on weather conditions. For model soils, the percentages of sand, silt, clay, and organic matter, as well as bulk density for any number of segments within the soil profile can be specified. The thickness of the soil profile can be modified to simulate the depth-to-groundwater or a seasonally high water table. Soil data are obtained from USDA Soil Conservation Service Reports, USGA specifications, or, if desired, on-site sampling. For any product simulated, a specific water solubility, soil half-life, organic carbon partition coefficient, and vapor density are input from published literature values and manufacturers' information. Simulations up to three years in duration have been run to date.

### Simulation Results

Execution of the model will provide the information necessary to assess the environmental mobility and safety of the simulated chemical control program. Output data include the amount of product and water which leach through the simulated soil profile, the amount of product which still remains in the profile, and the amount of undissolved surface residues. Mass balances, which account for all of the applied pesticide, also will show how much product has been volatilized, taken up by the turf (if it is a systemic product), and chemically or biologically degraded, and how much has been transformed to specified breakdown products. Output can be obtained for any time interval within the specified simulation period.

Based on these mass balances, it is possible to predict, and thus avoid, adverse environmental impacts of a hypothetical or currently implemented chemical pest control program. For example, simulations have indicated that certain products, even when applied at assumed safe, label-recommended rates, have the potential for reaching groundwater or surface water, or posing unnecessary risks to non-target organisms which may use or occur in a treated turf area. Comparing the values produced in the mass balances of the LEACHM simulations with established water quality standards and published toxicity values for a number of representative potential non-target organisms, ultimately yields the hazard potential. This risk assessment procedure, when applied to a number of pesticides, will result in a relative safety factor being assigned to each product, upon which recommendations for use will be made.

### Examples of Simulation Scenarios

For example, if a particular snow mold product applied in late fall or early winter were shown to produce surface residues well past spring snow melt, and if this product were applied to an area where Canada geese might forage, the potential impact to the geese could be quantified. Similarly, if a curative white grub insecticide application were made in late August and an unexpected intense thunderstorm occurred the next day, the potential for leaching to groundwater and runoff to nearby surface water could be predicted.

Figures 1-4, "Sample LEACHM Output," is a portion of an output file generated from the execution of the LEACHM model. In this particular execution, the application of four preemergence crabgrass products was simulated. The results are shown for one of these products, Dacthal. (Note: Trade names appear in the output files for convenience only. All data are inputted and simulations performed for active ingredients. Appearance of trade names does not imply endorsement of any particular product.) Day 210 of the simulation, which began on April 1, is presented here. Both the day number and the date appear in the upper left-hand corner of Figure 1.

The uppermost table, Figure 1, is the Mass Balance Table, which gives an account of the whereabouts of all of an applied product, including the mechanisms of removal from the soil profile. For risk assessment, "undissolved on soil surface" and "losses in drainage" are particularly important parameters. In this instance, Dacthal has not leached through the simulated soil (a green built to USGA specifications). However, elevated surface residue does exist for the product.

The distribution of Dacthal within the soil profile, described in Figures 2 and 3, also is used in the risk analysis process. Potential problems which may arise as a result of persistence can be ascertained by following trends in soil concentrations over time. Results in this section can be used to make adjustments to multi-year plans or seasonal rotation strategies.

Information from Figure 4, Plant Growth, Transpiration, and Product Absorption, does not play an important role in pesticide risk analysis, but is quite useful when analyzing simulated fertilizer programs. Used in conjunction with the other tables, it is possible to determine the efficiency of a fertilizer program. With multiple executions of the model, each simulating a slightly different fertilizer program, it is possible to derive a program that maximizes turf nitrogen uptake while minimizing losses to drainage or other routes.

All simulations will produce a similar output format. The total length of a simulation and report intervals are specified in the input table. Thus, it is possible to evaluate scenarios ranging from the behavior of a single product over a single day to a full chemical management plan for a multiple-year period, and anything in between.

The LEACHM model has been used to make recommendations regarding the timing, amounts, and particular products being applied to specific areas. For every potential pest, there is a window of opportunity in which effective treatments can occur. LEACHM simulations can provide an interval within this window when treatments will be effective and, potentially, produce the least or no negative environmental impact. In conjunction with timing, amounts of products applied, especially for those which are applied more than once (e.g., a preventative *Pythium* program), also can be adjusted to produce the desired effect and safety. Eliminating from consideration any product that provides an unnecessary risk due to its overall toxicity or mobility also will result in a more environmentally sound integrated pest management program.

### Integrated Pest Management Programs and LEACHM

LEACHM, by itself, however, will not produce an integrated pest management (IPM) plan. What LEACHM will provide is a determination of what, where, and when products can be expected to work efficiently and safely. This is only one aspect of a comprehensive IPM plan, which also contains regulatory, genetic, cultural, biological, and physical tactics integrated with chemical tactics. The misconception that integrated pest management is synonymous with eliminating pesticide use is slowly being replaced. In reality, reductions in reliance on pesticides are often desirable economic and environmental benefits of a properly implemented IPM plan and not a true goal. By properly implementing other practices, the need for chemical treatments is naturally decreased.

IPM, by definition, is the implementation of a combination of compatible tactics in a manner that maintains pests below injurious levels, while at the same time eliminating threats to humans, animals, and other non-target organisms.

**Sample LEACHM Output**

**Figure 1**

Time Elapsed 210.000 Days
Date 10/27/89

| | Cumulative Totals and Mass Balance Dacthal (mg/m²) |
|---|---|
| Initial total | .0 |
| Currently in profile | 124.8 |
| Undissolved on soil surface | 3123.6 |
| Simulated change | 3248.4 |
| Additions: i) in rain or irrigation | .0 |
| ii) as amendment | 4200.0 |
| Losses: i) in drainage | .0 |
| ii) by evaporation/volatilization/conversion | 632.9 |
| iii) by transformation | 318.9 |
| iv) by degradation | .0 |
| v) by plant uptake | −.2 |

**Figure 2**

| | Water | | | Dacthal | | |
|---|---|---|---|---|---|---|
| Depth (mm) | Theta | Potnl (kPa) | Flux (mm) | Total ug/kg | Solution mg/l | Gas ug/l |
| 25. | .089 | −199.5 | 106.7 | .203E+04 | .324E−02 | .295E−03 |
| 76. | .066 | −202.0 | 97.8 | .168E+02 | .112E−03 | .102E−04 |
| 127. | .066 | −196.2 | 86.4 | .394E+00 | .272E−05 | .247E−06 |
| 178. | .069 | −156.5 | 74.1 | .732E−02 | .522E−07 | .474E−08 |
| 229. | .074 | −120.3 | 69.1 | .111E−03 | .822E−09 | .746E−10 |
| 279. | .077 | − 96.5 | 65.5 | .142E−05 | .109E−10 | .991E−12 |
| 330. | .079 | − 84.8 | 67.4 | .636E−08 | .509E−13 | .462E−14 |
| 381. | .066 | − 79.6 | 69.2 | .000E+00 | .000E+00 | .000E+00 |
| 423. | .066 | − 78.9 | 70.9 | .000E+00 | .000E+00 | .000E+00 |

Drainage flux: 72.5mm

**Figure 3**

The following distribution is calculated ignoring undissolved chemical on the soil surface and that lost from the profile by leaching, plant uptake, and volatilization.

| | | |
|---|---|---|
| Depth and concentration of 1st %ile | 0mm | .12E+03 |
| Depth and concentration of 5th %ile | 2mm | .12E+03 |
| Depth and concentration of 16th %ile | 8mm | .12E+03 |
| Depth and concentration of 50th %ile | 25mm | .12E+03 |
| Depth and concentration of 84th %ile | 43mm | .12E+03 |
| Depth and concentration of 95th %ile | 48mm | .12E+03 |
| Depth and concentration of 99th %ile | 50mm | .12E+03 |

**Figure 4**

Plant Growth, Transpiration, and Pesticide Absorption (if calculated)

Time: 210.000 Days Crop Cover: .900 Root Potential: −.2190E+03 kPa

| Depth (mm) | RDF | Temp °C | Transpiration (mm) Incr. | Cum. | Uptake by Plants (mg/m²) Dacthal Incr. | Cum. |
|---|---|---|---|---|---|---|
| 25. | .200 | 3.8 | 12.2 | 114.0 | .000E+00 | .000E+00 |
| 76. | .300 | 5.4 | 14.0 | 127.6 | .000E+00 | .000E+00 |
| 127. | .350 | 6.9 | 14.8 | 127.4 | .000E+00 | .000E+00 |
| 178. | .100 | 8.2 | 7.5 | 63.8 | .000E+00 | .000E+00 |
| 229. | .050 | 9.3 | 5.8 | 63.7 | .000E+00 | .000E+00 |
| 279. | .000 | 10.2 | .0 | .0 | .000E+00 | .000E+00 |
| 330. | .000 | 10.9 | .0 | .0 | .000E+00 | .000E+00 |
| 381. | .000 | 11.3 | .0 | .0 | .000E+00 | .000E+00 |
| 432. | .000 | 11.5 | .0 | .0 | .000E+00 | .000E+00 |
| Total: 500.0 | | | 54.3 | 496.4 | .000E+00 | .000E+00 |

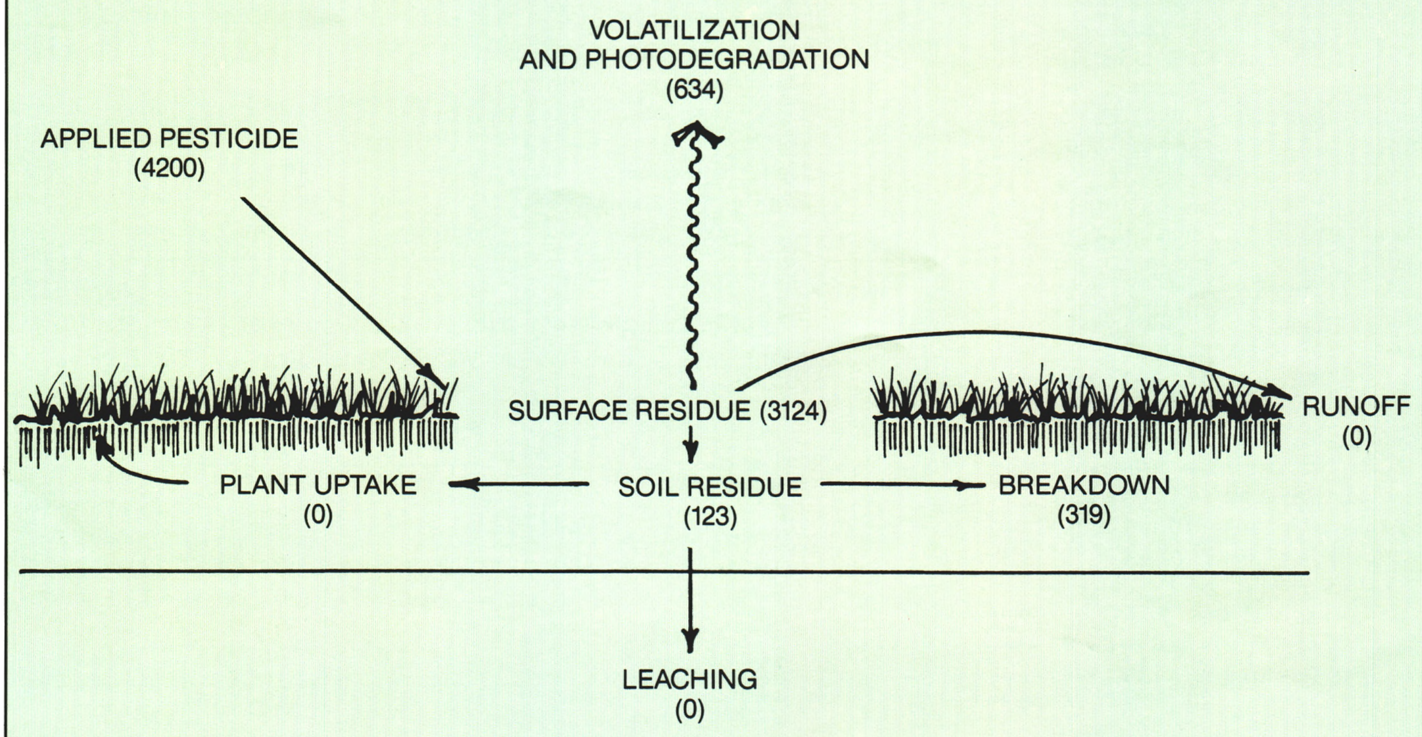
Like the previously discussed LEACHM simulations, IPM programs should be site specific. Practices which prove successful in a particular location may not produce the same effects in other areas due to variations in soils, topography, climate, pest pressure, and past management practices. Therefore, it is essential that an IPM plan contain all practices which can be performed successfully within the limitations imposed by the site and the resources available to those implementing the program.

An increased ability to control the factors which influence turf pest occurrence will decrease the probability of pests exceeding established thresholds and the need for subsequent remedial actions. For this reason, formulating an IPM plan during the design phase for a site will allow preventive measures to be implemented that will reduce the need for future curative actions. This does not mean that comprehensive IPM plans cannot be formulated for, and successfully implemented on, existing turf areas. Rather, less opportunity exists to provide a negative environment for the turf pests at a relatively reasonable cost on established turf. Examples of some IPM tactics which are easier and less expensive to implement prior to turf establishment include proper species and cultivar selection, establishment of high-, medium-, and low-intensity management areas, topographic alteration (grading), planning and installing surface and subsurface drainage and irrigation systems, and introduction of biological control agents. These, and other tactics, all can be considered in the context of existing environmental constraints, such as on-site wetlands, surface waters, and other potentially sensitive areas, and implemented in a way to minimize the potential for negative impacts.

Regardless of the content and extent of a proposed IPM plant, the program must remain flexible to realize its full potential. Since the program is being applied to a variable environment, which, in turn, influences pest occurrence, new situations will arise constantly for the turf manager. Preventative measures and curative actions will be undertaken in response to this variable environment. From a regulatory standpoint, it is important that an IPM plan not limit itself to the tools the turf manager may or may not use to prevent or correct a problem. In designing the IPM plan, it is imperative that a preparer consider all available options for a particular site. This includes consideration of recent advances in techniques, equipment, and products.

Prescreening potential pesticide products and defining what, where, when, and how much of a particular

**Figure 5. Schematic of a Prediction of the Environmental Fate of an Applied Pesticide as Simulated by the LEACHM Model (Data Taken from Figure 1)**



product can be safely applied can greatly aid the IPM plan formulation process. Information obtained from computer simulations of chemical treatments such as LEACHM can provide estimates which otherwise could not be obtained unless expensive on-site studies were completed. More and more, this type of information is being requested by regulatory or other groups which influence how areas may be managed in the future. In order to insure that a turf manager continues to have all necessary tools to combat a potential or existing problem, it is essential that pertinent questions receive the proper attention and be satisfactorily addressed.

**Modeling Today and Tomorrow**

Considerable time and effort are currently being devoted to developing more sophisticated and comprehensive modeling systems with yet unrealized precision. The development of modeling systems is an evolutionary process which is always giving rise to superior products. This is not to say that the models we have today are inefficient or inaccurate. In reality, today's models are "state of the art" and are representative of the best technologies currently available.

As stated in Table 1, the software for each of the three more complex models is readily available. The CREAMS/GLEAMS model is available at no cost from USDA Research Labs in Tifton, Georgia. Similarly, the PRZM model is available from the USEPA. LEACHM, however, must be purchased from its authors at Cornell University (contact person: Dr. John Hutson, (607) 755-7631).

All three models can be used by anyone with an IBM-compatible PC, available site-specific input data, the time necessary to formulate accurate input files, and a general working knowledge of computer operation. The models are generally user-friendly and are accompanied by detailed explanatory literature. In order to assure accurate results, however, significant time must be invested by the user during the familiarization process. It is this initial time investment that limits the usefulness to today's turf managers for stimulating their own site-specific program. However, once the initial time investment is made, and after the user becomes accustomed to using a particular model, modification of input data allows for the simulation of an infinite number of management practices as long as the user has confidence in the data he is using.

# ON COURSE WITH NATURE
# Working Within the Quagmire of Wetland Regulation!

**by NANCY P. SADLON**
Environmental Specialist, USGA Green Section

HISTORICALLY, wetlands have been considered wastelands, but now they are recognized for providing environmental and economic benefits, including wildlife and fish habitat, shoreline and erosion control, flood protection, improved water quality, storm water management, aquifer recharge, and valuable recreation areas. Wetlands are protected by law, and golf courses are required more frequently than ever to file wetland permit applications. Though the wetland regulatory process is complicated, a few basics can introduce you to the process.

**How to Recognize Wetlands on the Golf Course**

When analyzing the golf course to determine if a wetland environment exists, there are three basic things to look for:

1. **Water** at or near the surface.
2. **Saturated soils** that often (but not always) display gray-green colors.
3. **Plants** that are typically water tolerant.

These three simple indicators represent the basics for the layman to identify areas of wetland concern on the golf course. It is important to recognize that when analyzing these parameters, it is often necessary to look below the surface (at an average depth of 0-18″) to determine the presence or absence of water or saturated soils. Wetlands *do not* have to exhibit all three parameters to meet the regulatory regulations (as is the case with many drained farm lands), nor are all three indicators always present throughout the year. These basics to wetland identification are not sufficient guidelines for do-it-yourself wetland delineation. They are presented to help the golf course superintendent recognize the potential for wetland existence on the golf course and the need to consult a local expert.

Complete delineation of wetlands to meet regulatory requirements has become a detailed, scientific process that requires the expertise of an experienced wetland consultant.

**Why Are Wetlands Such a Big Issue on Golf Courses?**

Many golf courses deal with wetland regulations. By their very nature, many

*Whitefish Lake Golf Club, Whitefish, Montana.*

golf courses are located in areas where water is available to provide a source for irrigation, play a part as a water feature in course design, or provide scenic beauty. This source of water, by definition, is responsible for the wetland environment.

> The term "wetlands" means those areas that are inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." (1979 Clean Water Act, Sec. 404 — 33 CFR328.3(b); 1984)

This definition is found in Section 404 of the Clean Water Act, which has been the federal government's primary tool for protecting and regulating wetlands. Federal legislation has given the Army Corps of Engineers (ACOE) authority to establish a permit system which regulates dredging and filling in waters of the United States, which includes wetlands.

### Who Regulates Wetlands?

Regional differences in wetland development regulations are a result of complex federal and state laws. With the exception of Michigan, all states fall under the jurisdiction of the EPA, the federal wetland permit process, and the ACOE. The wetland permitting process becomes more complex when the state wetland offices become involved in reviewing wetland impacts on water quality. This state review process is built into the ACOE permit process and is responsible for allowing states to incorporate their specific regional requirements.

Many states have enacted or are currently developing inland and coastal wetlands laws and policies. Often, state wetland permit programs are more stringent than the ACOE permit program by involving wetland value classification and buffer requirements. If your golf course is located in a state listed on the accompanying chart, contact your state agency if you believe you will impact wetlands as a result of proposed golf course renovations or operations. If your state is *not* listed, contact the ACOE Washington office at (202) 372-0571 and ask for your state's regional office number.

### What About the Proposed 1992 Changes to Wetland Legislation?

Wetlands protection has been at the forefront of the political news, with the Bush Administration's support of a "No Net Loss" wetland policy. Proposed changes for wetland deineation procedures (Congressional vote currently pending) incorporate revisions that have kept wetland protection in the news. Two of the controversial proposed revisions include:

| Current Wetland Regulation | Proposed Wetland Regulation Change |
|---|---|
| 15-day saturation definition | 21-day saturation definition |
| All wetlands considered same value | Wetland classification system identifying wetlands of different values (high and low values) |

A change from a 15- to a 21-day saturation duration would likely result in millions of acres (up to 30 million, according to some estimates) no longer meeting the wetlands definition, leaving these areas unprotected. This could be a big asset to golf courses with areas no longer considered wetlands, relieving them of many wetland regulation restrictions, permit processing costs, and time delays. The negative effect of the change would be felt by those golf courses that qualify as having wetlands, based on a 21-day saturation definition. They would be involved in a potentially more difficult wetland delineation process and a longer permit processing time delay. Production of new delineation manuals, training programs and guidelines will undoubtedly delay implementation of the new wetland definition laws.

Golf courses classified with high-value wetlands will bear the burden of stringent permit requirements (probably more restrictive than current Federal regulations) if the proposed changes in wetland classification are passed. Many states, such as New Jersey, Pennsylvania, and Michigan, currently evaluate wetlands for value classifications and impose regulations accordingly. The more highly valued wetland is often protected by larger buffer areas and has other restrictions associated with it. Sometimes this can represent a hardship on the maintenance program used in buffer areas on the golf course. The positive side of the new regulations, as far as golf courses are concerned, is that low-value wetland areas, such as ditches or man-made detention ponds, would receive more lenient treatment, and the time delays and costs associated with the permit process would likely be reduced.

**State Wetland Regulations**

| | | |
|---|---|---|
| Alabama | Department of Environmental Management | (205) 271-7389 |
| Alaska | Department of Environmental Conservation<br>Department of Environmental Quality | (907) 465-5260 |
| California | California Coastal Commission<br>Wetlands Task Force | (408) 479-3511 |
| Connecticut | Department of Environmental Protection<br>Division of Inland Water Resource Management | (203) 566-7280 |
| Delaware | Department of Natural Resources & Environmental Control | (302) 739-4691 |
| Florida | Department of Environmental Regulation<br>Division of Water Management | (904) 488-0130 |
| Georgia | Department of Natural Resources<br>Coastal Resources Division — Marsh & Beach Section | (912) 264-7218 |
| Hawaii | Coastal Zone Management Program | (808) 587-2875 |
| Louisiana | Department of Natural Resources<br>Coastal Management Division | (504) 342-7591 |
| Maine | Department of Environmental Protection<br>Division of Natural Resources | (207) 289-2111 |
| Maryland | Department of Natural Resources<br>Water Resources Administration<br>Non-Tidal Wetlands Division | (301) 974-3841 |
| Massachusetts | Department of Environmental Protection<br>Division of Resource Protection | (617) 292-5695 |
| Michigan | Department of Natural Resources<br>Land & Water Protection Division | (517) 335-2694 |
| Minnesota | Department of Natural Resources<br>Protected Waters & Wetlands Permit Program | (612) 296-4800 |
| Mississippi | Department of Wildlife Fisheries & Parks<br>Coastal Management Section | (601) 385-5860 |
| New Hampshire | Department of Environmental Services<br>Wetlands Bureau | (603) 271-2147 |
| New Jersey | Department of Environmental Protection & Energy<br>Land Use Regulation Element | (609) 633-6755 |
| New York | Department of Environmental Conservation<br>Division of Fish & Wildlife | (518) 457-9713 |
| North Carolina | Department of Environment, Health & Natural Resources<br>Division of Coastal Management | (919) 733-2293 |
| Oregon | Division of State Lands | (503) 378-3805 |
| Pennsylvania | Department of Environmental Resources<br>Division of Rivers & Wetlands Conservation | (717) 541-7803 |
| Rhode Island | Department of Environmental Management<br>Division of Groundwater & Freshwater Wetlands | (401) 277-6820 |
| South Carolina | Coastal Council | (803) 744-5838 |
| Vermont | Department of Environmental Conservation<br>Water Quality Division | (802) 244-6951 |
| Virginia | Marine Resources Commission<br>Habitat Management Division | (804) 247-2200 |
| Washington | Department of Ecology<br>Shorelands & Coastal Zone Management Program | (206) 459-6790 |
| Wisconsin | Department of Natural Resources<br>Bureau of Water Regulation & Zoning | (608) 266-7360 |

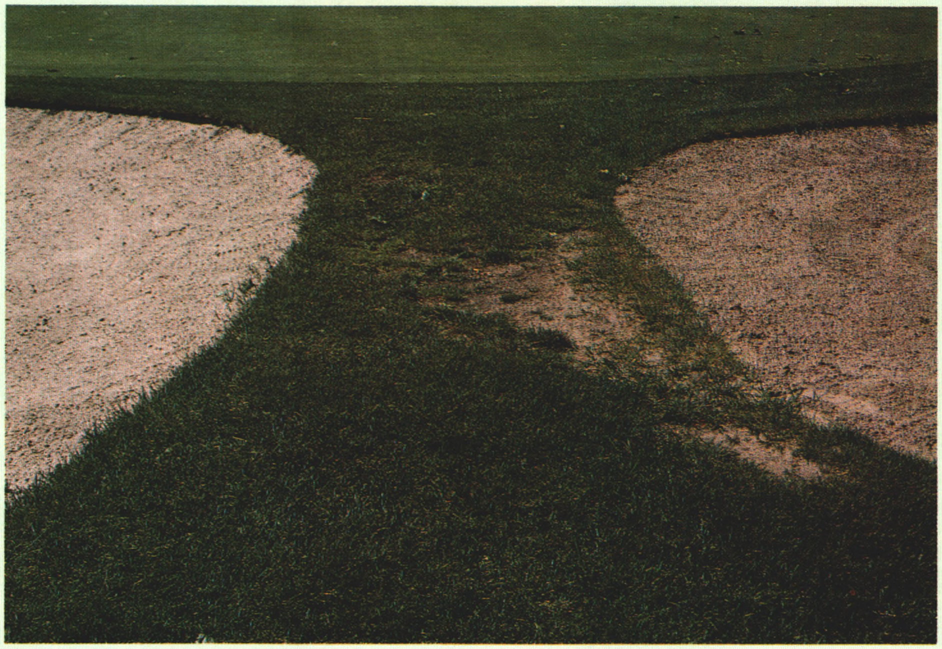
# ALL THINGS CONSIDERED

## Search Your Sole — Remove Your Spikes!

by **LARRY W. GILHULY**
Director, Western Region, USGA Green Section

TURN ON your television and you will see the action. A tall, slender individual rises high into the air while throwing his arm forward with great malice. The hand contacts a round ball that proceeds across a net at 100-plus mph and hits the ground. Great spike! Now change channels. The golf professional methodically lines up a five-footer to win the tournament. After what seems like an eternity, he strikes the putt only to watch it hop right and lip out. Bad spike or, more correctly, spike mark!

Golf spikes have been cussed and discussed for years. Their negative effects were well documented by the USGA Green Section in the November 1958 and September 1959 issues of the *USGA Journal and Turf Management*. These early studies (33 years ago!) showed that the conventional golf spike not only caused severe damage to the turf, but the curved shoulder of the spike also resulted in noticeable soil compaction and inhibited turfgrass recovery for weeks, when compared to other shoes.



*Foot traffic damage on walkway to the green.*

In 1983, the Golf Shoe Study II results were reported in the September/October issue of the GREEN SECTION RECORD. Once again, work with the spiked golf shoe showed exactly the same results: weaker turf, more compaction, reduced recovery, and poor putting quality.

Let's skip forward to today — 1992. What have we learned from not one, not two, but three excellent studies concerning the negative effects of golf shoe spikes? Apparently very little! We continue to use the same types of shoes, or even worse, that do millions of dollars of damage to fine turf by requiring more labor, aerification, topdressing, mowing, cup changing, and other cultural programs.

These items should be enough to encourage shoe manufacturers to devise some type of acceptable shoe that golfers will use that will cause less damage to the turf. Thus far it has not occurred. However, given the ongoing concern about the effects of golf courses on the environment, perhaps golf shoe spikes should be more of an issue. Are we not encouraging the use of more fertilizer, herbicides, insecticides, and fungicides by continuing the use of shoes that weaken the grass? You bet we are!

Still skeptical? In our area, a small nine-hole public golf course was built with large, somewhat flat bentgrass greens. The greens are now two years old, display *Poa annua* encroachment, exhibit weak turf in the traffic areas, and require more fertilizer and pesticides than the practice putting green. Guess what! The practice putting green received *double* the traffic, has little *Poa annua* and does *not* allow spiked golf shoes! Mother Nature has a way of telling us — if only we will listen.

Can you make a difference? You can by learning about the truly negative effects of golf shoe spikes. Try different shoes that have a good grip with a very high surface contact area. Educate golfers about the bad side effects of spikes and the relationship to environmental concerns. Imagine, someday spike mark controversies will be a thing of the past, bentgrass will compete better against *Poa annua* invasion, chemical usage will be reduced, and putting greens will be healthier and smoother. All it takes is a little "sole searching."

# 1992 GREEN SECTION REGIONAL CONFERENCES

| | | | |
|---|---|---|---|
| **Great Lakes Region** | April 16 | Medinah Country Club | Chicago, Illinois |
| **Western Region** | March 25 | Hyatt Alicante | Anaheim, California |
| | March 26 | Northern California | Site TBA, California |
| | March 30 | Royal Oaks Country Club | Vancouver, Washington |
| | April 7 | Union Hills Country Club | Sun City, Arizona |
| | April 14 | Oakridge Country Club | Farmington, Utah |
| | April 27 | Waialae Country Club | Honolulu, Hawaii |
| **Northeastern Region** | March 17 | Marriott Hotel | Albany, New York |
| | March 19 | Marriott's Wind Watch Hotel | Long Island, New York |
| | March 24 | Colonial Hilton & Resort | Wakefield, Massachusetts |
| **Mid-Atlantic Region** | April 21 | Beechmont Country Club | Cleveland, Ohio |
| | April 23 | Guyan Golf and Country Club | Huntington, West Virginia |
| **Southeastern Region** | March 31 | Atlanta Athletic Club | Duluth, Georgia |
| **Florida Region** | March 10 | Royce Hotel | West Palm Beach, Florida |
| | March 12 | Orlando Marriott Hotel | Orlando, Florida |
| **Mid-Continent Region** | February 25 | Champions Golf Club | Houston, Texas |
| | March 18 | Oak Tree Country Club | Edmond, Oklahoma |
| | April 2 | Texas A&M University Research and Extension Center | Dallas, Texas |
| | April 8 | Lakewood Country Club | Lakewood, Colorado |

# TURF TWISTERS

## COMPARABLE TOPDRESSINGS

**Question:** I have heard it said that once a club switches to a straight sand topdressing program, it cannot revert to an 80-20 or comparable type of mix. Is this true? (New York)

**Answer:** The answer is no. It is not recommended, but it can be done. The change must be a gradual one, though, that minimizes layering within the soil profile. A good aerification program should help avoid layering problems, and it may be advisable to return the cores brought to the surface along with some of the new topdressing material. It may also be advisable to change first to a 90-10 material for two or three years before making the final switch to the 80-20.

## ENSURE A GOOD

**Question:** We have a hilly golf course. When attempting to repair a broken pipe it is almost impossible to completely drain the system in order to ensure a good glue joint. The water seems to trickle forever. Any tips? (New Mexico)

**Answer:** Believe it or not, a loaf of bread should solve your problem. After the water has slowed to a trickle, prepare the two pieces of pipe to be joined together. Wad together enough pieces of bread to form a ball slightly bigger than the pipe's diameter. Shove the bread ball into the pipe. This should give you at least 10 to 15 seconds of dry pipe on which to make the repair. By the time the pipe is ready for use, the bread will have dissolved to the point that it can be completely discharged from the sprinkler.

## BLEND

**Question:** We are considering the construction of a continuous cart path. Several golfers are concerned that a paved path will ruin the appearance of the golf course and have suggested we build one no wider than six feet. Any suggestions? (Wisconsin)

**Answer:** An experienced golf course architect can often design a functional cart path that blends into the existing landscape. A six-foot-wide path is an absolute minimum, but golfers often have difficulty keeping carts on the path when passing others and on tight curves. The result is rutted, compacted turf on either side of the path. An eight-foot-wide path is more desirable because it can accommodate two carts, side by side, and makes the entire golf course accessible by heavy maintenance equipment.