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16 Best Management Practices for Turfgrass Water Resources: Holistic-Systems Approach

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The Real Issue

According to the Environmental Literacy Council (ELC 2005), environmental knowledge and practice necessary to positively address environmental problems," requires a fundamental understanding of the systems of the natural world, the relationships and interactions between living and the nonliving environments and the ability to deal sensibly with problems that involve scientific evidence, uncertainty, and economic, aesthetic, and ethical considerations". Or, to put this in the context of positively addressing turfgrass water use and quality concerns, perceived environmental problems must not be addressed in isolation, but in terms of all the interrelationships and stakeholders associated with these landscapes.

Green spaces can have detrimental effects on the environment, just as an agricultural enterprise or a factory or urban hardscapes may, but green spaces also contribute to society and the local community via environmental, recreational, aesthetic, and economic benefits (Beard 2006; Beard and Green 1994; Butler and Marnonek 2002; CAST 2002; Carrow 2006:). Perennial grasses are significant contributors to overall environmental stewardship, which encompasses conserving, maintaining, and improving our natural resources to insure sustainability of air, soil, water quality/quantity, climate, natural ecosystems, energy, and endangered species.

Based on a holistic mindset as defined by the ELC (2005), the real question or concern becomes, “What is the best approach for achieving water quantity and quality stewardship” within the nation, states, watershed/basin, community, specific sites, and regulatory realms that impact green landscapes? Or, in more concise terms, “What approach will maximize turfgrass benefits while minimizing potential environmental problems?” The answer to these questions has profound implications for all direct and indirect stakeholders influenced by green spaces.

For protection of surface and subsurface water quality from pesticides, nutrients, and sediments, an excellent model has evolved over the past 35 years in the form of “best management practices” (BMPs) fostered by the U.S. Environmental Protection Agency (EPA) Clean Water Act (Rawson 1995; EPA 2005a). For landscape water-use efficiency/conservation and protection of water resources from irrigation water constituents, however, a widely adopted, or consensus, approach has not evolved that is integrated into the regulatory realms and site-specific landscape levels. A critical first step in addressing societal concerns relative to these issues is to develop a successful, accepted approach. Certain characteristics have made the BMPs approach for protection of water quality from pesticides, nutrients, and sediments the premier means of dealing with this complex environmental problem. Understanding these characteristics is crucial to understanding how this science-based approach can be adopted as a model for other environmental issues, including water-use efficiency/conservation and water quality concerns related to irrigation water constituents.

Best Management Practices (BMPs)

History

The first federal initiative stating the term "best management practices" came from the 1977 amendment to the Clean Water Act (CWA), which established BMPs as soil conservation practices to protect water quality (Gold 1999). The BMPs focused on a holistic, systems approach that addressed concerns for pesticides, nutrients, and sediments as related to water quality protection and has culminated in comprehensive regulations and supporting BMPs within agriculture (EPA 2003) and urban landscapes (EPA 2005a).

In addition to BMPs for protection of water quality, other systems approaches to alleviate environmental problems have proven to be effective, such as:

- **Integrated Pest Management (IPM)** approach was developed in the late 1960s and early 1970s in response to how to best develop science-based pest control strategies that could include judicious use of pesticides, but within a system of pest control via other means—cultural, pest-resistant plants, pest predators. In 1972, the U.S. Department of Agriculture funded the first major IPM research effort.
- **Sustainable Agriculture** was formalized in 1985 with the Food Security Act. It was another milestone in the whole-systems approach to addressing multiple environmental problems (Gold 1999). This was enhanced, in 1988, by funding of the Low-Input Sustainable Agriculture (LISA) program. The LISA concept was expanded in 1990, to become the Sustainable Agriculture Research and Education Program (SARE).
- **Precision Agriculture**, although not a whole-systems approach, does highlight critical components, including: that inputs should be applied only on the site where they are needed, at the rate required, and only when needed; and that site-specific information is the basis for site-specific management. It recognizes the great spatial variability that must dealt with when managing a site—and illustrates why cultural practices must be based on educated, site-specific decisions.

Characteristics

Although IPM (pesticides), Sustainable Agriculture (soil quality, water issues, air quality, etc.), and Precision Agriculture (efficient use of inputs) concentrate on somewhat different environmental aspects than the BMPs focus on water quality protection, all these approaches have certain inherent, common characteristics that are essential to achieve successful environmental stewardship(ELC 2005). These characteristics are as follows:

- *Science-based.* All are science-based and have inherent, foundational principals involving application of inputs only on the site where needed, when necessary, and only at the quantity required. The very definition of BMPs illustrates why this approach is effective: a) "best" is used to imply the best combination of strategies that can be adopted on a site or for a particular situation with current technology and resources, b) "management" denotes that environmental problems must be managed, and that management decisions by trained personnel can maximize success, and c) "practices" implies that multiple strategies are necessary to make a positive difference. Thus, whether called a BMP, IPM, or SARE, all emphasize wise and efficient use of resources using a science-based and flexible philosophy. These approaches can be documented, and accountability can be monitored.
- *Holistic or whole-systems based.* These approaches recognize that no "silver-bullet," or single practice, can achieve successful stewardship with regard to a specific environmental problem because we work within whole dynamic ecosystems. In contrast, rigid regulations (or command and control approach) are based on limited strategies and a "one-size fits all" concept, ignoring the principal that successful environmental stewardship must consider interactions among ecosystem components (ELC 2005). The ecosystem includes soil, plant/landscape, atmosphere/climate, turfgrass manager's expertise, irrigation system, irrigation water, precipitation/stormwater, surface/subsurface waters, hydrology, the positive/negative impacts that any practices have on all stakeholders, and any other related aspects.
- *Holistic in considering all stakeholders and implications relative to potential environmental and economic effects.* The holistic and multiple-stakeholder dimensions as components of the CWA are noted by: "Evolution of CWA programs over the last decade has also included something of a

shift from a program-by-program, source-by-source, pollutant-by-pollutant approach to more holistic watershed-based strategies. Under the watershed approach equal emphasis is placed on protecting good quality waters and restoring impaired ones. A full array of issues are addressed, not just those subject to CWA regulatory authority. Involvement of stakeholder groups in the development and implementation of strategies for achieving and maintaining state water quality and other environmental goals is another hallmark of this approach" (EPA 2006). The latter aspect notes that practices focused on a single environmental goal may result in unintended, adverse environmental consequences (Beard 2006).

- *Educated site-specific choices and management.* Because there is no single factor that will achieve maximum environmental benefits on a site, adjustments within the whole ecosystem are the basis of the BMPs model; and educated decision-making is important. BMPs encourage professionalism and education of the turfgrass manager, including continuing education. Each site is different, and adjustments, therefore, must be site-specific and account for system changes over time. Also, regional differences in climate and soil will modify site-specific BMPs.
- *Fosters entrepreneurial development and implementation of new technology and concepts.* BMPs encourage on-going integration of new technology, plants, concepts, and products to achieve the "best" practices. Guideline templates can be developed and updated over time.

BMPs for protection of water quality are at multiple levels, starting at the federal level with the CWA, but also at state, regional, watershed, urban, and site-specific levels (DEP 2002; EIFG 2006; EPA 2005a). For perennial grass landscapes, the site-specific levels may be home lawns, general grounds, seed or sod production farms, parks, golf courses, or other areas using grasses. At the site-specific level, the BMPs model is exhibited in the diversity of state IPM and BMPs programs for different landscapes (UFL 2006; UGA 2006). It is important that the site-specific BMPs or IPM approaches maintain their multiple-strategy, science-based nature, rather than reverting to a mentality of banning (rigid regulations, command and control) pesticides or nutrients. Instances at the state or local levels involving political pressures for a command and control approach have occurred and will likely continue to occur. But, the vast majority of the EPA and state regulatory agencies have recognized that long-term, successful ecosystem management for protection of water quality must be based on incorporation of all stakeholders in a positive, interactive, and participatory (true partnership) manner.

Interestingly, the EPA has recently attempted to avoid the BMPs notation in favor of a rather neutered term "management practices or measures" (EPA 2005a) because, "The word 'best' has been dropped…because the adjective is too subjective. The 'best' practices in one area or situation might be entirely inappropriate in another area or situation." The initial and long-term meaning of BMPs, however, has traditionally been to denote the best combination of practices to resolve water quality issues on an area or specific situation. It was never meant to identify a single "best" practice. Therefore, we strongly prefer the continued use of BMPs rather than "management practices," which could imply good or bad practices relative to the particular issue.

BMPs Applied to Other Water Issues

Three interrelated water issues arise in urban perennial landscapes, and all can be addressed by a BMPs approach with the characteristics as defined in the previous section:

- BMPs for Protection of Water Quality.
- BMPs for Irrigation Water Quality Management
- BMPs for Landscape Water-Use Efficiency/Conservation.

As noted, the "BMPs for Protection of Water Quality" concept arose out of water quality concerns, and the traditional focus of BMPs has been on protection of surface and ground water quality from applied nutrients, pesticides, and sediments. Considerable progress has been made toward landscape BMPs in this area at the national level (EPA 2003, 2005a) and within the turfgrass industry (Cohen et al. 1999; DEP 2002: Dobson 2005; EIFG 2006). Because BMPs in this arena are more developed than the other areas, the current paper will focus on the remaining two areas.

A significant development in recent years has been the BMPs terminology and concept being adopted and expanded into the water conservation area (Carrow, Duncan, and Waltz 2005; Carrow, Duncan, and Wienecke 2005a,b; Cathy 2003; CUWCC 2005; EIFG 2006; GreenCo and Wright Water

Engineers 2004; IA 2005). The increasing inclusion of the BMPs concept/terminology into ordinances, regulations, and management manuals to deal with all water issues is a significant step toward defining a unified, science-based approach. The BMPs terminology/concept will likely be used for an expanded array of environmental concerns beyond water issues, such as for soil quality/health and wildlife protection within the turfgrass industry, as well as within the regulatory arena.

BMPs for Irrigation Water Quality Management

Decreased quantities of available potable water combined with increasing domestic demand emphasized the need to irrigate with recycled or other nonpotable alternative water resources of lesser quality relative to potable sources. Use of alternative irrigation water sources, rather than potable water supplied by a municipal water treatment system, is not a new practice to many large turfgrass areas. This is now becoming the normal practice in many areas, however, as competition for potable water increases (because of population increases and demand) and as grasses are developed that can tolerate much poorer water quality (Harivandi, 1991; Carrow and Duncan 1998; Duncan and Carrow 2000; Huck, Carrow, and Duncan 2000; Pettygrove and Asano 1985; Marcum 2005; Snow 1994; Thomas et al. 1997).

The umbrella terms of nonpotable and alternative irrigation water sources include a diversity of sources—e.g., brackish or saline surface or groundwater, reclaimed, recycled, stormwater, grey water, harvested water, or any other water source that is nonpotable. Specific water quality concerns are often associated with particular irrigation water sources (AWA 2000; Ayers and Westcot 1994; Pettygrove and Asano 1985; Snow 1994). Each source may exhibit chemical, biological, or physical constituents that can challenge landscape plant performance short-term and require specific cultural practices for long-term environmentally safe use. The most prevalent constituents in many alternative water sources, which often are higher in concentration than found within potable sources, are soluble salts and nutrients, but many **biological, physical, or chemical contaminants** are possible depending on the source, such as the following:

- **Biologicals**—human pathogens, plant pathogens, algae, cyanobacteria, iron and sulfur bacteria, nematodes, weed seed.
- **Physical contaminants**—total suspended mineral or organic solids, turbidity, color, temperature, and odor.
- **Chemical constituents**—total soluble salts, specific salt ions, nutrient ions, potential root or foliage toxic/problem ions, metal and trace ions, total dissolved solids, alkalinity, oxygen status, biodegradable organics, nonbiodegradable (refractory or resistant) organics, free chlorine residual, hydrogen sulfide gas.

Irrigation water constituents as potential pollutants logically would seem to come under the "BMPs for Protection of Water Quality" area. In much of the literature, however, the emphasis is on irrigation practices as they may affect runoff or drainage water, and not on irrigation water constituents as a potential contributor to pollutants (Barton and Colmer 2005; EPA 2003,2005a). Irrigation water constituents can be very diverse and quality guidelines have evolved that incorporate environmental, health, and agronomic considerations (AWA 2000; Ayers and Westcot 1994; Carrow and Duncan 1998; Yiasourmi, Evans, and Rogers 2003). Additionally, development of halophytic (salt-tolerant) grasses has allowed the use of poorer quality water than previously used for agronomic or turfgrass situations, and maintenance strategies for managing salinity in the ecosystem and in adjusting management to these new grasses have become a priority (Duncan and Carrow 2000).

Depending on the chemical, physical, and biological characteristics of the irrigation water, the problem that confronts the landscape manager may occur at different points within the spectrum of water movement: from the initial source location, on-site storage, delivery system, turfgrass plant, soil profile, runoff areas, and underlying geo-hydrology. There may be multiple water quality challenges that can occur within the hydrological cycle on a particular site not just from the irrigation water source, but also from other hydrological aspects, such as tidal influences, water table depth and fluctuations, and stormwater flooding or surges. BMPs must be developed that encompass all possible problems and are sustainable for water, soils, and aquatic/wetland systems across the spectrum of water movement. An in-depth treatment of irrigation water quality issues across the whole water delivery spectrum and using a BMPs approach is currently underway for completion by fall 2007 (Duncan, R. R., R. N. Carrow, and M. Huck. Personal communication. "Turfgrass and Landscape Irrigation Water Quality: Assessment and Management.").

General management protocols are reasonably well developed in terms of overall concepts for saline irrigation water uses in agriculture and for turfgrass landscapes (Carrow and Duncan 1998; Hanson, Grattan, and Fulton 1999; Marcum 2005; Oster 1994; Rhoades, Kandiah, and Mashali 1992). But, more detailed BMPs need to be developed and presented in a BMPs format for perennial grass landscapes in urban areas. With more saline irrigation water being used on turfgrass sites, it is essential that potentially, detrimental effects of salinity loading, accumulation, or movement in the environment be mediated by sound, integrated BMPs (Carrow and Duncan 1998; Duncan and Carrow 2000; FAO 2005).

Irrigation on landscape sites with reclaimed waters has received increasing attention as pressure for water conservation and water-use efficiency increases. Problems associated with reclaimed irrigation water have received extensive discussion (Bond 1998; Carrow and Duncan 1998; Duncan, Carrow, and Huck 2000; EPA 2004; Harivandi 1991; Pettygrove and Asano 1985; Scott, Faruqui, and Raschid-Sally 2004; Snow 1994; Stevens et al. 2004; Thomas et al. 1997; WHO 2005). As with saline irrigation water sources, more in-depth BMPs protocols to deal with specific problems need to evolve and be targeted to urban landscape sites utilizing perennial warm- and cool-season grasses.

BMPs for Water-Use Efficiency/Conservation on Specific Sites

As previously noted, the BMPs approach has recently been applied to water-use efficiency/conservation (Carrow, Duncan and Wienecke 2005a,b; CUWCC 2005; EFIG 2006; GreenCo and Wright Water Engineers 2004; IA 2005; Vickers 2001). In this section, the focus is on BMPs for water-use efficiency and conservation on a site-specific basis, especially for larger turfgrass landscapes, such as parks, seed and sod production farms, golf courses, and large business grounds. In the next section, additional components of BMPs programs for community, regional, or watershed level water-use efficiency/conservation will be addressed.

At this point, the urban landscape industry cannot assume that environmental and water regulatory personnel understand the full scope of BMPs for water conservation, because the BMPs terminology has only recently been applied to turfgrass water conservation in the regulatory realm. For example, it is not unusual for individuals or groups to view “turfgrass water conservation” as involving only one or two strategies—i.e. change the grass species, use only native grasses, decrease the area of irrigated turfgrass, improve irrigation design, Xeriscape™, or use weather-based means (evapotranspiration) for irrigation scheduling. BMPs for turfgrass water conservation, however, must be defined to include the widest set of potential strategies and not be limited to only one or two. Therefore, it is important to develop a consistent understanding of BMPs related to turfgrass water-use efficiency/conservation so that confusion does not arise.

One important BMPs aspect is to maintain the emphasis on inclusion of all stakeholders. Water conservation programs should include consideration of practices on water use-efficiency, the economy, environment (other environmental influences or unintended adverse environmental effects), jobs, and specific long-term site use. The customer, or user/manager/owner of a site, is not the only stakeholder potentially affected by water conservation measures. Others include the supply side (water authorities, suppliers); demand side (site user, site manager, agriculture industry, etc.); and those affected by environmental and economic water conservation measures (society in general, local economy, health related aspects, impact on soil quality, sustainability) (Beard 2006; Beard and Green 1994; Butler and Maronek 2002; Carrow 2006; Gibeault 2002). The importance of avoiding the use of water conservation as the sole determination when considering a BMPs plan is illustrated by the EPA (1998) water conservation plan guidelines for water system planners presented in Table 1 where multiple considerations are noted. Similar considerations afforded to the public utilities realm should be included in a site-specific BMPs plan. Proponents of rigid regulations (command and control) for water conservation often give little attention to those factors that can affect all stakeholders.

Carrow, Duncan, and Waltz (2005) in their BMPs workbook have defined "BMPs for turfgrass water conservation" when applied to a specific site as involving three primary activities: 1) Site Assessment and Planning—information gathering and planning aspects for the entire ecosystem; 2) Identify, Evaluate, and Select Water Conservation Options—options are all within the ten core water conservation strategies; and 3) Assess Benefits and Costs—of water conservation measures on all stakeholders (Table 2). These are presented in the following sections as an initial template to develop more detailed BMPs documents for water-use efficiency/conservation that are holistic and science-based.

Site Assessment and Planning

On complex turfgrass areas, such as golf courses with numerous microclimates, development of an effective water-use efficiency/conservation BMPs program is very complicated, time consuming, and often costly—in contrast to many other urban sites such as home lawns. The initial planning starts with identification of water conservation measures that have already been implemented by a golf course, including estimated costs of implementing these practices and possibly an estimation of the level of improvement in water-use efficiency on the site that arises from these practices, both individually and as a total. This initial step aids in clarifying exactly what is entailed in BMPs water conservation measures for the landscape management team and site owners. Also, when the final document/program is shared with regulatory agencies, this information is very valuable in pointing out that most landscape sites are not starting from zero in this arena, but have been implementing BMPs for many years at considerable cost and effort with little formal documentation. This information should be positioned in the front of the BMPs document developed for a specific site. A few examples of common water conservation strategies already in use on many recreational sites are:

- In many warm-season turfgrass areas, bermudagrass is the most widely used grass and it happens to be one of the most drought resistant species.

- During severe water shortages, selected turfgrass areas may be allowed to go dormant and not receive any irrigation except survival of the grass cover to protect against soil erosion where needed.
- Water sources on a site, such as a golf course, may include stormwater harvesting of rainfall from the surrounding area and collection into irrigation ponds, or the use of reclaimed water as an alternative irrigation water source.
- Soil modification to improve water infiltration/percolation and deeper rooting. And, on U.S. Golf Association golf greens, construction of a perched water table to aid in water conservation.
- Turfgrass cultivation programs and equipment to improve water infiltration/percolation and to enhance rooting.
- Higher mowed areas with limited or no irrigation on a routine basis.
- Irrigation systems zoned to improve water distribution efficiency and aid in efficient scheduling.
- Irrigation scheduling programs based on local plant water requirements determined by a combination of turfgrass manager experience and onsite weather data.
- Educational training specific to water management for turfgrass managers and support staff. Community educational efforts have proved to be effective for the general public (Finch 2006).

Next, the purposes and scope of the initial site assessment phase should be determined. Site assessment is necessary to provide information to determine the best options (i.e. BMPs) for the specific landscape area. Site assessment and information collection often entail: a**)** determination of the current water-use profile; b**)** conducting an extensive irrigation/water systems audit**;** and c) obtaining additional site infrastructure assessment information including evaluation of alternative irrigation water sources; landscape design modifications; irrigation system design changes; microclimate soil/atmospheric/plant conditions affecting irrigation system design/zoning/scheduling; drainage needs for leaching of salts or any surface/subsurface geo-hydrological considerations that may arise from use of any particular irrigation water source. Gathering information related to infrastructure changes often involves considerable time and costs. Thus, development of a BMPs water conservation plan may require more than a year on some sites, especially when alternative or multiple irrigation water sources must be identified, when the irrigation water is of initial poor or changing quality, when the irrigation distribution system is not efficient, and/or when major landscape design changes must be made. Multiple years are also normal for implementing required infrastructure changes.

Finally, future water needs should be determined, and an initial realistic water-use efficiency/conservation goal should be identified. As implied by the process of gathering site assessment information, plans may require flexible adjustment as new information arises because the entire ecosystem is dynamic and not static. But, initially establishing a realistic water-use efficiency/conservation goal based on projected water needs is a necessary step. In instances where saline irrigation water is used, projected water needs must include an adequate leaching fraction to avoid soil degradation by salinization.

Identify, Evaluate, and Select Water Conservation Options

This is the stage where hard decisions must be made within the **"Ten Core Water Conservation Strategies."** Within each of these strategies, numerous options are available as noted in greater detail by Carrow, Duncan and Waltz (2005), Cathy (2003), the California Urban Water Conservation Council (2005), GreenCo and Wright Water Engineers (2004), and the Irrigation Association (IA) (2005). The choices are site-specific based on the water quantity requirements and conservation goals, expectation of the facility management and local governance, and actual resource requirements and availability. Essentially, all major water conservation options can be classified under one of the following "ten core water conservation strategies,":

1. ***Use of nonpotable water sources for irrigation*—**alternative water sources; water harvesting/reuse. The decisions or choices associated with this strategy can become very costly or difficult, such as water

quantity issues (multiple water sources, reliability over time, permitting, blending, storage, piping water to the location) and water quality issues (water treatment, soil amendments, changes in nutritional programs, leaching ability, salt disposal, effects on subsurface hydrology, drainage) (Duncan, R. R., R. N. Carrow and M. Huck. Personal communication. "Turfgrass and Landscape Irrigation Water Quality: Assessment and Management.". Book scheduled for fall-2007).

2. ***Efficient irrigation system design and monitoring devices for implementing water conservation.*** Items included in this strategy could be low-flow sprinklers in critical areas, adjustable heads, proper spacing of heads and nozzles, strategic placement of soil moisture and salinity sensors, as well as many other considerations. Upgrade or repair of any leakage areas, proper delivery system adjustment, and maintenance protocols would also be included in this category.

3. ***Efficient irrigation system scheduling/operation.*** Both irrigation system design and irrigation scheduling in the future will require much more site-specific information—i.e. a precision agriculture approach. Sensor technology integrated into a Global Positioning System/Geographical Information System approach will assist in development and interpretation of information for improved efficiency in irrigation distribution and scheduling.

4. ***Development and selection of turfgrasses***—with respect to water uptake and utilization requirements in terms of quantity and quality. Because lower quality irrigation water may be used, many of the plants will require not only drought resistance but also multiple genetic-based stress tolerances, such as salinity, traffic, and cold and heat tolerance, across all turfgrass species used for permanent or over-seeded grasses.

5. ***Landscape design for water conservation*****—**design for water harvesting; reducing unnecessary acreage of highly-maintained, closely-mowed, irrigated turfgrass areas; avoiding excessive mounds or slopes; inclusion of nonirrigated turfgrass areas; and allowing for very limited or no irrigation on certain sites during water shortages.

6. ***Altering practices to enhance water-use efficiency***. Some considerations are soil profile amendments, cultivation programs and equipment needs, mowing, fertilization, and chemigation. Maintenance of deep root systems is especially important to allow for deep and less frequent irrigation application and favors improved capture and storage of rainfall to replace or delay irrigation events. Practices to enhance soil infiltration, percolation, and soil moisture retention are key options, as well as judicious use of wetting agents to enhance water infiltration and uniformity of percolation.

7. ***Indoor water conservation measures in buildings, air conditioning units, pools, and other facilities associated with a landscape site.*** Water conservation will not be a reality on some sites if it is confined to only the actual landscape area. Instead, it will be viewed as the responsibility of the turfgrass or landscape manager, and not as a policy or philosophy by the site owners, whether privately or publicly owned. Application of water conservation practices on a facility-wide basis, such as parks, large business grounds, sports complexes, or golf course, should involve all facility owners/managers and site users.

8. ***Education.*** Complex issues require educated, science-based decision-making. Planning for initial and continuing education on water conservation/management is essential for landscape managers, support crew, and facility officials with direct communication to state, regional, and local water regulatory officials. BMPs for turfgrass water conservation are complex, and when poor irrigation water quality is involved, the level of infrastructure and maintenance costs and management complexity greatly increases. Fertilization, cultivation, leaching of salts, salt disposal/hydrological issues, complex irrigation systems and scheduling of irrigation are just some of the complex issues involved.

9. ***Development of formal conservation and contingency plans***. A formal BMPs document should be developed and agreed on by all facility officials so the landscape manager has support for any reasonable, science-based measures undertaken. Also, a written plan may be required by regulatory agencies. This should be an on-going, flexible, and realistic plan subject to revision over time. Additionally, the components should be integrated into daily operation of the club or facility activities, implemented as routine practice, and subsequently documented for progress in achievement of the

targeted goals. Previously, we noted that a rigid regulation approach to water-use efficiency/conservation (or any other environmental issue) is much less desirable for all stakeholders compared to a BMPs approach. A more positive regulatory approach is to foster BMPs for water conservation. For example, a governmental unit may require that managers of larger landscape areas develop and implement BMPs. Additionally, during a water shortage crisis, more rigid regulations are often necessary for all water users, but should be avoided as the long-term or primary means to deal with environmental issues. In the matter of water quantity, a state, region, watershed, or community may incrementally go into a series of increasingly restrictive water-use regulations during a prolonged water shortage. Normally, there are triggers for each step, such as a reservoir level, and all water users are affected by the restrictions.

10. ***Monitor and revise plans.*** Proactive monitoring is essential and may involve sensor technology on-site or sample acquisition and testing off-site. Regularly scheduled monitoring of specific conservation effectiveness, and of the overall BMPs plan, is essential for achieving goals and making effective adjustments. Flexibility in short- and long-term plan implementation is critical because climatic changes are major, uncontrolled variables.

Assess Benefits and Costs of Water Conservation Measures for All Stakeholders

Assessments of costs and benefits associated with developing and implementing a long-term BMPs water conservation plan are necessary not only for facility planning, but also for demonstrating to regulatory agencies and possible critics of perennial, urban landscapes that substantial efforts and costs in water conservation have been documented by the facility. Readers are encouraged to review the papers by Beard and Green (1994), Gibeault (2002), Carrow (2006), and Beard (2006) for information on economic, recreational, environmental, and other social benefits of turfgrasses to direct and indirect stakeholders. BMPs documents should define or at least list the benefits of the particular landscape facility, especially to indirect stakeholders who may not be aware of the benefits the turfgrass/landscape industry contributes to the local, regional, or state society.

BMPs for Water-Use Efficiency/Conservation on a Watershed or Community Basis

In addition to the components of a site-specific BMPs program, other practices can be used on a watershed or community basis to foster water-use efficiency/conservation. Some of these may be regulatory in nature whereas others are voluntary. An excellent example of a successful community-wide BMPs program for San Antonio, Texas, by Finch (2006) is presented in this publication. Vickers (2001) and EPA (1998) present good overviews of water conservation measures that may be used. Pricing for water conservation, consistent public outreach education efforts, and reasonable regulations to limit water waste are especially conservation-effective for sites without a professional turfgrass manager.

One aspect of turfgrass sites often not considered relative to water-use efficiency/conservation is turfgrasses can be allowed to go semi- or completely dormant. In fact, in most locations in the United States, both cool- and warm-season grasses naturally go dormant in the cold season months. Perennial grasses also can be allowed to go dormant in water shortage periods as part of a water conservation plan (Wade et al. 2003). Finch (2006) notes that in 2007 within San Antonio, lawn grasses for new home sites must be capable of surviving 60 days of drought. Important aspects of drought resistant dormant turfgrass include: a) irrigation is not needed; b) pesticide and nutrient applications are not used during water-induced dormancy, yet the cover remains to prevent soil degradation by erosion, to limit sediment movement, and to foster rain infiltration when it occurs; and c) dormant grass is not dead grass, so the groundcover can be regenerated when the water shortage is less severe.

Integration of BMPs

Stacking together of several complex management issues is a challenge that will become more commonplace, especially on sites with a combination of poor irrigation water quality, water restrictions/conservation, and more salt-tolerant turfgrass and landscape species. Protection of water resources from pesticides, nutrients, and sediments, as outlined by the EPA (2003, 2005a) and the

Department of Environmental Protection (2002), is the first complex challenge. Second, increased emphasis on stormwater management in urban settings has resulted in more active attention to this issue, with many sites requiring a stormwater management plan (CASQA 2003). A third issue is cultural and irrigation practices for optimum water-use efficiency/conservation and turfgrass performance, which requires a systems or holistic BMPs approach with proactive monitoring and frequent adjustments in practices that influence water-use efficiency (Carrow, Duncan, and Waltz 2005; Carrow, Duncan, and Wienecke 2005a,b; Cathy 2003; CUWCC 2005; GreenCo and Wright Water Engineers 2004; IA 2005). A fourth complex management challenge arises from the quality of irrigation water. BMPs for salt-affected sites where the irrigation source is a major contributor of salt load are essential to avoid negative accumulation impacts on the entire ecosystem—soil, water, and plants (Carrow and Duncan 1998; FAO 2005; Oster 1994). Reclaimed water irrigation sources may or may not be high in total soluble salts, but generally contain higher levels of nutrients than domestic water sources (Bond 1998; Huck, Carrow, and Duncan 2000; Scott, Faruqui, and Raschid-Sally 2004; Stevens et al. 2004; Thomas et al. 1997). Proactive monitoring of soil, water, and plants should become more frequent in dynamic saline or reclaimed water situations to adequately manage salt levels and nutrient status. Poor irrigation water quality may necessitate a change in grass species or cultivar, which presents additional long-term maintenance adjustment challenges for the turfgrass manager, especially in terms of managing salt loading in soils and in budgeting for this dynamic continuum.

Therefore, when water conservation pressures increase to the point where lower quality irrigation waters are used, turfgrass management becomes more complex. As individual BMPs for water conservation, ecosystem salinity management, turfgrass nutritional programs, and new salt grass additions all interface—each complex in its own right—they face markedly increased challenges. Turfgrass managers of the future must become whole-systems (holistic) managers, with the ability to understand and apply multiple BMPs for site-specific water use, water quality, new grasses, fertilization, and other site-specific management aspects.

As more turfgrass sites use poorer water quality, turfgrass managers and facility owners must address the above challenges of salinization prevention, multiple water quality problems involving the hydrological cycle on a site, and the stacking of multiple, complex BMPs. The Council for Agricultural Science and Technology (CAST) (2002) has summarized many of these environmental challenges within urban areas. Currently, the most comprehensive treatment of integrated environmental issues in the perennial, urban landscape has been by Audubon International (Dodson 2005).

In recent years, the EPA (2005b) has been promoting the **Environmental Management Systems (EMS) approach** to deal with multiple environmental concerns on a site, not just in agriculture, but across all entities that may have an environmental impact. The EPA (2005b) defines an EMS as "a set of processes and practices that enable an organization to decrease its environmental impacts and increase its operating efficiency. An EMS is a continual cycle of planning, implementing, reviewing, and improving the processes and actions that an organization undertakes to meet its business and environmental goals." This is a program where plans developed to deal with environmental concerns are integrated into normal, daily operation of the organization at all management levels. Plans must be in accord with current environmental regulations, but the EMS is voluntary in nature.

Within the relatively near future, the authors anticipate that the integration of management protocols to address multiple environmental concerns, including the water quality and quantity issues addressed in this CAST special publication, will require an **EMS approach** on many sites. A component of the planning phase is to assess all potential environmental concerns on a site and then develop and implement plans to minimize environmental impacts. Positive aspects of this approach for the turfgrass industry include:

- EMS is for all entities, public or private, that may have potential environmental impacts. Thus, it is not targeted toward a single industry.
- The EMS approach brings under one umbrella all environmental issues on a site. When a single issue is targeted by a group (e.g. water conservation) toward the turfgrass industry or a single facility, it is not uncommon for the only determination of success to be the reduction of water use

without any consideration to economic/job or unintended environmental consequences. Within an EMS, all environmental issues are combined together. Thus, potential adverse effects must be addressed. For example, the method to decrease water use may be to remove turfgrass acreage, but in an EMS approach the issues of soil degradation (wind and erosion loss, decreased organic addition to soils), human health effects from dust, and adverse effects of decreased grass surface on water infiltration, stormwater movement, and sediment movement must be addressed within the same EMS. Additionally, a basic premise of EMS is to consider "operation efficiency" or business impacts.

- EMS can be developed by stacking together the BMPs for each environmental issue of concern for the site. By using the BMPs model for each environmental concern on a site, the development of an EMS is simply an extension and integration of BMPs and not a whole new system or paradigm change.

Conclusion

The BMPs approach developed over the past 35 years by the EPA for protection of surface and subsurface waters from pesticides, nutrients, and sediment has a long track record for being successfully implemented because of several critical characteristics. It is science-based; incorporates all strategies in the ecosystem (holistic); embodies all stakeholders and their social, economic, and environmental concerns; values education and communication outreach; allows integration of new technologies and concepts; has been applied at the regulatory, watershed, community, site-specific levels, as well as educational realms; and maintains flexibility to adjust to new situations. Thus, this BMPs model is the template for dealing with other complex environmental issues.

The authors encourage adoption of the BMPs model with the previous characteristics for other water-related issues involving the turfgrass situations, such as water-use efficiency/conservation and irrigation water constituents. Primary benefits would be:

- A basic, realistic approach to achieving water-use efficiency/conservation and management of irrigation water constituents will allow the turfgrass and landscape industries to go forward in a positive and unified manner to develop sound BMPs for these environmental issues.
- The BMPs model has all the characteristics necessary to resolve these complex environmental issues. Adoption of a BMP approach by various facets of the turfgrass industry for water issues would be an excellent environmental model and demonstrate a high degree of environmental stewardship.
- When confronted with pressures for rigid regulations that do not include the essential characteristics of the BMPs approach, those that have adopted and implemented BMPs programs would be able to show due diligence in these areas and to demonstrate their approach as being the best science and practical model to resolve complex environmental issues.
- Development of BMPs for each specific water-related problem would allow combining the BMPs into an EMS document and management style in the future.
- The BMPs model as a common approach will aid in focusing research, education, and extension needs to serve the turfgrass industry and society. For example, in addition to the traditional turfgrass science four-year university programs, perhaps a future program would be the addition of an environmental turfgrass/landscape science option where the focus would be on whole ecosystems management and the ability of students to integrate knowledge into implementable BMPs and EMS management protocols.

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Table 1. Criteria that can be used by water systems planners in selecting conservation measures for implementation on a community-wide or watershed basis (USEPA, 1998). Illustrates multiple considerations are required and not just a water conservation target.

Program costs	Environmental and social justice
Cost-effectiveness	Water rights and permits
Ease of implementation	Legal issues and constraints
Budgetary considerations	Regulatory approvals
Staff resources and capability	Public acceptance
Environmental impacts	Timeliness of savings
Ratepayer impacts	Consistency with other programs

Table 2. Outline of the planning process and components of a golf course BMPs for water-use efficiency/conservation.

A. Initial Planning and Site Assessment.

1. Identify water conservation measures that have already been implemented by a golf course including costs of implementation—this initial step aids in clarifying for the golf course management team and club members exactly what is entailed in BMPs water conservation measures. Also, when the final document/program is shared with regulatory agencies, this information is very valuable in pointing out that golf courses are not starting from "zero" in this arena but have been implementing BMPs for many years.

2. Determine the purposes and scope of the site assessment. Site assessment is necessary to determine the best options for the specific golf course.

3. Site assessment and information collection.

- Determine current water-use profile.
- Irrigation/water system distribution audit.
- Additional site infrastructure assessment information---evaluation of alternative irrigation water sources; golf course design modifications; irrigation system design changes; microclimate soil/atmospheric/plant conditions affecting irrigation system design/zoning/scheduling; drainage needs for leaching of salts or any hydrological considerations that may arise from use of any particular irrigation water source.

4. Determine future water needs and identify an initial water conservation goal.

B. Identify, evaluate, and select "water conservation strategies" and options.

1. Selection of turfgrasses and other landscape plants.
2. Use of nonpotable water sources for irrigation---alternative water sources; water harvesting/reuse; water treatment if necessary.
3. Efficient irrigation system design and devices for water conservation.
4. Efficient irrigation system scheduling/operation. Both irrigation system design and irrigation scheduling in the future will requires much more site-specific information. Sensor technology integrated into a GPS/GIS approach will assist in development and interpretation of information for improved irrigation system distribution efficiency and scheduling.
5. Golf course design for water conservation.
6. Altering management practices to enhance water-use efficiency---soil amendments; cultivation; mowing; fertilization; etc.
7. Indoor water conservation measures in facility buildings. Conservation strategies for landscape areas other than the golf course and immediate facilities.
8. Education. Plan for initial and continuing education on water conservation/management by golf course superintendent, support crew, club officials, etc. BMPs for turfgrass water conservation is complex and when poor irrigation water quality is involved the costs and level of management complexity greatly increases ---i.e., fertilization, leaching of salts, salt disposal/hydrological issues, complex irrigation systems and scheduling of irrigation, these are some of the complex issues.
9. Development of conservation and contingency plans. A formal BMPs document should be developed and agreed on by all club officials and members so that the golf course superintendent has support for any reasonable science-based measures to be taken. Also, a written plan may be required by regulatory agencies.
10. Proactively monitor and revise plans.

C. Assess benefits and costs of water conservation measures on all stakeholders.

Assessment of costs and benefits associated with developing and implementation of a long-term BMPs water conservation plan is necessary not only for facility planning, but also to demonstrate to regulatory agencies and possible critics of golf courses that substantial effort and cost has previously been involved in water conservation by the facility.

1. Benefits.
   - Direct and indirect to the owner/manager and site customers.
   - Direct and indirect to other stakeholders, including water savings but also other benefits—economic, environmental, recreational, etc.

2. Costs.
   - Facilities costs for past and planned implementation of water conservation strategies---irrigation system changes; water storage; pumping; new maintenance equipment; water/soil treatments; course design alterations; water harvesting, storage.
   - Labor needs/costs.

- Costs associated with changes in maintenance practices; different irrigation water sources (water treatment, soil treatment, storage, posting)
- Costs that may impact the community if water conservation strategies are implemented (especially mandated ones), such as revenue loss, job loss.
