BEST MANAGEMENT PRACTICES FOR

FRESHWATER CONSERVATION ON GOLF COURSES

by

Eric Schade

A practicum submitted
in partial fulfillment of the requirements
for the degree of
Master of Landscape Architecture
School of Natural Resources and the Environment
at the University of Michigan
December 2007

Faculty advisors:
Associate Professor Robert E. Grese
Assistant Professor Larissa S. Larsen

Abstract:

Freshwater conservation on golf courses occurs in many areas. Irrigation is the largest water use on a golf course. Proper irrigation design and management is critical to water conservation. It is possible to irrigate golf courses without freshwater. Examples of this technology are desalination and effluent. Wetlands play a vital hydrologic role and must be protected. Cultural practices and turfgrass selection play a role in water conservation. Water quality is in danger from golf course chemicals and erosion. Storm water management is a factor throughout the lifecycle of a golf course. Best management practices allow water conservation in these areas to occur on a broad scale. Case studies show best management practices working today.

Acknowledgements

I would like to thank my parents and grandmother for their patience and support.

Table of Contents

List of Figures

Introduction

The Problem

Fresh water is a finite resource. Excessive water use by humans depletes ground and surface water sources faster than they can be recharged. Excessive water demand is related to population and wasteful consumption. The American West is an example of these two factors. In 1900 the yearly flow of the Los Angeles River represented a fifth of one percent of California's runoff (Reisner 1993). Massive dams and pipelines have been created to transport water thousands of miles to cities such as Los Angeles. Through the manipulation of water, once arid and semi-arid land is now a desert oasis teeming with people. Water shortage is not just a problem in the desert, but throughout the country. In 2007 The Southeastern United States faced water shortages of historic proportions.

Wasteful water consumption is a cultural issue. Bathing, watering lawns and other non-native environments, and a general consumptive attitude all contribute to excessive water demand. The mindset of a never ending fresh-water supply has placed communities, the environment, and individuals in peril.

Modern irrigation is both a cultural preference and subsistence method. It has been instrumental in the past and present in satisfying the food demands of the United States. Former desert land has become the country's food source. Current agricultural productivity levels would be impossible without supplemental water use. Irrigation is also popular for aesthetic reasons. Front yards, parks, campuses, and sports fields have become artificial environments driven by the demand for lush turf.

Pollution further reduces available fresh water. Poor water quality can result from heavy industry, agricultural practices, emissions into the atmosphere, cultural practices, and other population pressures.

Numerous current examples shine light on a developing water shortage. Severe drought in the Southeastern United States has brought the city of Atlanta's drinking water supply into danger. In November 2007 Lake Lanier, the source of Atlanta's drinking water neared its 26 year record low. The U.S. Army Corps of Engineers has had to reduce water released to Florida via the Chatahoochee River. (*Atlanta Journal Constitution.* [Atlanta], 17 November 2007.) Atlanta has enacted watering bans in an attempt to deal with the shortage.

In the western United States the effects of drought and high water use are easily observable with aerial photography. NASA's Earth-observation satellites have detected decreases in soil moisture, shrinking snow pack in the Rockies, withering vegetation, more frequent and severe forest fires, and falling water levels in major reservoirs throughout the West.

Lake Mead was created in the 1930s. It ensures the water supply of Nevada, California, Arizona, and Northern Mexico by restricting the Colorado River through the Hoover Dam. Lake Mead irrigates nearly a half million acres of farmland in southern California's Imperial Valley. Between May of 2000 and May of 2003 the water level of the lake dropped 60 feet. At that time it was at its lowest point since 1965, bringing into play numerous water-use restrictions (Allen, 2003).

Lake Mead © NASA

Golf courses, the subject of this study, are the playground for golf. A moderately equipped golf course with 600 sprinkler heads may have to run each 40 gallon per minute sprinkler head 20 minutes nightly to satisfy July evapotranspiration requirements for golf turf. This translates into 800 gallons of water per sprinkler head nightly, or 480,000 gallons to water the course.

Water coming into contact with a golf course may never be fresh water again. Courses typically require modification of existing vegetation and topography and are then frequently chemically maintained. Water pollution may occur from chemical contact or flood conditions exacerbated by over-watering, and modified ground cover.

The Solution

The time is here for golf courses to examine and adjust their water use towards adapting more sustainable practices. The future of the sport will depend on it. On a broader scale, a culture of water conservation is necessary to realign fresh water demand with fresh water supply. Water use on golf courses must be brought down to a bare minimum. This requires incorporating areas of more locally native vegetation accompanied by a reduction in the amount of irrigated turf. To do this well will require a well designed and efficient irrigation system. A conservation-minded maintenance staff under well trained management will also be necessary. Additionally, a shift in cultural values must take place to change the expected aesthetic for golf courses. The current trend of a lush, green, artificial carpet is out of line with nature, unsustainable, and different from the game's Scottish origins.

Methodology

This paper aims to collect available literature on golf course water conservation and synthesize it into a collection of best management practices (BMPs). Several key areas have been identified in which fresh water can be conserved. The literature summary and BMPs address these areas of concern. The literature summary is organized by topic, while the Best Management Practices are organized temporally.

Three case studies follow the best practices. The Preserve Golf Club in Vancleave, Mississippi was designated an Audubon International Silver Signature Sanctuary in May 2007. The Preserve is one of only 21 golf facilities in the world to receive this designation. Certification in the voluntary Audubon Sanctuary Program requires rigorous water conservation planning among other environmental measures. The case study illustrates the certification process with correspondence between consultants and Audubon International. Practices and procedures used by the golf course architect and other consultants to maximize water conservation are highlighted.

The Heritage at Westmoor Golf Course in Westminster, Colorado gives a look at how a typical well managed golf course might handle the use of effluent water. Effluent requires a close monitoring to ensure the public's safety. Monitoring of nutrient levels is critical to ensuring the turfgrass health.

The need for water conservation education is mentioned frequently in this practicum. The third case study portrays an exemplary program for water conservation used in Albuquerque, New Mexico. In this program the hydrologic cycle is taught as *why* water needs to be conserved, in addition to *how* to conserve water.

Freshwater Conservation: A Summary from the Literature Relating to Golf Courses

Process

I surveyed relevant literature to inform and shape the Best Management Practices for water conservation. Through consultation with advisors and reviewing topical literature, I chose areas most relevant and vital to freshwater conservation. The nine subject areas chosen became points of embarkation in search engines, card catalogs, and obscure bibliographies. Slowly, I developed a knowledge base of freshwater conservation as it pertains to golf courses. Many topics, such as storm water runoff and wetlands, overlap. Other topics such as desalination largely stand alone.

Sources of the literature generally fell into three categories. Turfgrass and golf industry sources were abundant. The most heavily cited industry source was the United States Golf Association. Sources against golf, or without a vested interest in the game, though not as abundant, were also sought and utilized. A source of this nature might point out disease outbreak from treated sewage, or the problems of nitrogen pollution. Both industry and anti-industry sources were well vetted and balanced each other by pointing out opposite sides of the same issues. The third category of sources was academic in nature. These sources were the most heavily cited. While not necessarily indicative of a bias, it should be noted that many of the academic sources cited were funded by the golf industry.

The literature was used to give an overview and insight into the topics. The nine areas of freshwater conservation on golf courses I chose for review are:

1. irrigation site design and management
2. irrigation systems for water conservation
3. effluent wastewater use on turf
4. desalination
5. wetlands
6. cultural practices

7. turfgrass water use
8. stormwater management
9. water quality

If these areas are managed effectively for conservation there is real potential for positive change.

Irrigation site design and management includes the irrigation design and day-to-day irrigation decisions. An effective design puts the minimum coverage of water where it is needed. Irrigation management includes scheduling watering times with evapotranspiration data in order to provide the precise amount of water needed for healthy turf.

Irrigation systems for water conservation are becoming common and readily available. Components in such a system include a weather station, soil moisture sensors, and wind sensors. Appropriate valving can turn off parts of the system in the event of a leak. Low application rate sprinklers prevent runoff and percolation below the root zone. Irrigation systems with these water-saving efficiency measures are integral to conservation.

Effluent is partially treated sewage available, often very cheaply, for irrigation. Effluent treated to the secondary or tertiary stage is suitable for use on golf courses. Tertiary treated effluent is preferred for its lower dissolved solids count. While effluent presents obvious freshwater conservation benefits, it must be monitored to avoid problems from high salinity in the soil.

Desalination is currently very expensive, but does show promise for islands and ocean locales without a sufficient freshwater supply. Due to the abundance of salt water on earth, desalination technologies deserve further research and development for freshwater conservation. I chose desalination and effluent because they eliminate the need for freshwater.

Wetlands are valuable freshwater sources as well as effective at cleaning pollutants. Wetland plant and animal life has become threatened with disappearing wetlands. Wetlands must be protected with buffers and proper grading and drainage techniques. Additionally, wetlands can be created that filter pollutants, helping to maintain a freshwater supply. The federal government's control of the dredging and filling of national waters gives it permitting authority over wetland development.

Cultural practices encompass maintenance and propagation techniques as well as the cultural norms of the golfing public as they relate to water conservation. A rule of thumb for conservation with maintenance is to mow high and frequently. Norms can and should be adjusted to favor courses with a more natural character that do not rely on over-watering.

Increased velocity and volume of **storm water runoff** creates pollution through sedimentation and the transport of chemicals. Runoff is slowed and reduced through a combination of infiltration and detention. Landscaping practices can contain minor storm events, while engineered solutions can reduce storm water runoff from large storm events for the golf course watershed.

Water quality affects drinking water for people and animals. Turf and plant health are correlated to water quality. Water may become contaminated through runoff or leaching into the groundwater table. Possible causes of poor water quality are effluent and maintenance chemicals.

Irrigation is the starting point for the literature summary. Golf courses have come to rely on supplemental watering. Irrigation is by far the single greatest water use on most golf courses.

Irrigation Site Design and Management

Irrigation provides supplemental water not provided through precipitation. The practice has been used since the Roman Empire and helped to bring about our modern agricultural system. Irrigation is used in golf to grow turf grass. Golf originated in Scotland where near constant precipitation and mild temperatures were ideal for fescues and other native grass species.

As the popularity of golf has boomed, golf turf in any range of new locales must rely solely on irrigation for survival. The past century of water extravagance is no longer tenable. As a new ethic of water conservation becomes standard, golf courses must drastically improve efficiency and lower the scope of irrigation.

Water conservation through site design is achieved with a well managed irrigation system. Having a well managed system does not guarantee less, or correct water use, but provides the tools to make these possible. Olson establishes five steps for creating a well-managed irrigation system: establishing design criteria, creating an irrigation master plan, implementing the design, providing guidelines for maintenance, and creating a water management program(Olson 1985).

Similarly, a management and design philosophy focused on ensuring water conservation is *Xeriscape*™, a combination of seven basic landscaping principles (denverwater.org 2004). The principles are *planning and design, soil improvements, efficient irrigation, zoning of plants, turf alternatives, and appropriate maintenance*. Planning and design involves generating an accurate base map and completing a planting plan. Use of soil amendments, such as reducing the amount of clay, results in healthier turf with less water usage. Efficient irrigation is made possible through intelligent component selection and maintenance and scheduling to meet the turf's water needs. The zoning of plants through sectioning with valves allows the irrigation schedule to be customized to the need of each zone's plants. Turf alternatives, such as the native landscaping seen in desert golf courses, can reduce the golf courses irrigation needs by 100 acres or more. In addition turf varieties may be selected with lower water requirements. Water efficiency can decrease dramatically if appropriate maintenance steps such as cleaning valves and keeping components in working order are not taken.

In comparing Olson's five suggestions for irrigation site design and management with the *Xeriscape*™ principles for water conservation, it is apparent that the two work well together. With planning, irrigation management and design decisions can and are being made within a philosophy of water conservation.

Establishing Design Criteria.

An adequate quantity and quality of water must be available for a project. There is an inverse relationship between the availability of water and the demand for water. As demand for water increases less is available. For design considerations, demand and availability will partially determine such decisions as whether effluent or other alternatives to freshwater are necessary, what water storage needs exist, and the scope of irrigation possible.

The maintenance schedule and operations are important in the establishment of design criteria. Mowing schedules must be coordinated to irrigation schedules. Periodic maintenance items such as fertilization and newly sodded areas necessitate individual customization of the irrigation program through controllers and appropriate valve sectioning. As each golf landscape is unique, the designer should request a maintenance plan from the owner.

At an early stage in the design process, all pertinent codes and regulations must be fully understood and their implications for design considered. Typical codes include backflow prevention, the required treatment of wastewater, and the metering of freshwater. In the United States most of these regulations exist at the municipal level. Examples of state level controls include restrictions on the total amount of irrigated turf in Arizona to roughly 90 acres for a golf course (ADWR 1999). As the importance of water conservation becomes increasingly apparent, federal controls are beginning to be legislated. Also to be considered are voluntary regulations. The Audubon Sanctuary Program, as part of its certification process, has particular requirements with regard to water use.

Soils must be analyzed on the site. Clay will have different infiltration characteristics than sand. Areas of cut will have different percolation rates than fill areas. Turf species and climatic variables will affect the irrigation design. With this knowledge, water requirements, sectioning, and nozzle type can be adjusted accordingly.

The water efficiency of an irrigation system is determined in large part by the type of system selected (Robert Evans and Sneed 1996). The system controls deserve careful evaluation. Controls allow system scheduling, saving water by delivering only the appropriate amount. Controllers range in complexity from a manual time clock to a computer with its own hardware and software. As the complexity of a project increases, the irrigation system will demand greater efficiency and a corresponding steeper learning curve for the operator. Olson lists the following considerations for selecting system controls: *energy efficiency, capitalization costs, operating costs, longevity, operator skill level required, simplicity of maintenance or required maintenance, replacement part availability, ability to phase in large projects, power surge protection, fault-signal relay, wiring simplicity, local contractor familiarity, local manufacturer representation, large areas effectively irrigated, central-control capabilities, video readout, quick reaction to climatic changes, 'down-time' effects, and owner desires.* If a computer control system is deemed appropriate, considerations include the above and a weighing of program simplicity *vs.* flexibility.

Various valve types provide control for an irrigation system. A 'curb stop' on the upstream side of the water meter functions as an on/off valve. Below that the water meter acts as a valve in that it measures flow, important in any water management program. Valve choice depends on the water pressure at the site. Terrain will have a major influence on water pressure. If a pump is required to increase water pressure, a pump valve is required that can be closed when the pump is not operation. If a pump is not necessary it is likely a pressure-reducing valve will be needed to maintain constant pressure. Backflow prevention valves are the essential demarcation point between upstream potable and downstream non-potable water. Gate valves are placed strategically to allow maintenance to isolate areas. A pressure relief valve discharges water if the water pressure exceeds the design pressure. Quick coupling valves allow hose connection for manual plant watering. Remote-control valves turn on and off at the direction of the controller. Selection of control valves directly affects the water conservation program. Potential clogging is the greatest concern in choosing valves.

Clogged valves do not close, resulting in greatly inefficient water use. Irrigation systems are discussed in greater depth in the section *Irrigation Systems for Water Conservation.*

Water conservation should be given an important emphasis in the design criteria stage. With a thorough understanding of the site variables present and components necessary the irrigation designer can begin to make choices that maximize water conservation. Examples of design criteria for water conservation used in the Phoenix Active Management Area include minimizing turf and keeping it level, harvesting water, appropriate zoning based on the water demand of an area, and the use of vegetative and other wind barriers to reduce evaporation (ADWR 1999).

Irrigation Master Planning

The irrigation master plan (IMP) requires complete knowledge of the site and its components. The plan will serve as a tool with which to manage the irrigation system during the design phase. Inclusion of the following information on the IMP will help to ensure the design process flows as smoothly as possible: The location, size, and elevation of the water meter must be noted. The 'serve area' is shown by graphically depicting the area served by each meter (a golf course may comprise of only one serve area). The available pressure along with the design pressure is shown. A master numbering system aids in communication with clients and other consultants during the design process. Power meters and requirements are shown at their locations. The size and location of main lines are listed along with their hydraulic calculations. Each serve area is assigned a maximum flow based on peak water requirements (Olson 1985).

Implementation

Contract documents given to the contractor must convey the exact design and construction information of the irrigation system. Field observation by the irrigation designer ensures the thoroughness of the contractor's work. Critical design considerations include sprinkler head spacing, pipe sizing, and elevation differential. Efficient sprinkler head spacing is generally .6 times the diameter of the spray area, with large rotor systems efficient at .5 times the diameter. Pipe size and elevation must be considered to give no greater than a 20 percent pressure differential to sprinklers with uniform application valved to the same system. The available pressure (shown in the IMP) will help establish the sprinkler heads which can operate efficiently in a particular area.

As alluded to above, system separation through proper valving is critical to the ability of the irrigation system to conserve water. Considerations include sun exposure, soil types, plant palette, allowable flow in a serve area, elevation differential, drainage patterns, and system uniformity.

Because the pressure under each sprinkler head differs with the distance from the valve and elevation changes, as the size of the system increases hydraulic considerations become increasingly important. The hydraulic system should be evaluated in light of the water-use requirements of the plants. Velocity and elevation are other primary considerations when evaluating system hydraulics. A typical accepted velocity for water in an irrigation system is 5 feet per second. On golf courses this number often approaches 7-9 feet per second.

The time requirements of an irrigation system should be considered when establishing hydraulic needs. The intense watering of plants for long periods of time during the germination phase should not be overlooked.

Maintenance guidelines

Olson gives examples of how an irrigation maintenance program might be formulated for maintenance staff. Included are general goals for the irrigation maintenance program.

1. The main objective of irrigation is to replace the water used in evapotranspiration as infrequently as possible.
2. Learn the fundamentals of the irrigation system and 'fine-tune' recommendations with experience.
3. Utilize a regular procedure of inspection and control.
4. Ensure an understanding of the soil-plant-water relationship and of the primary needs of turf management.
5. Establish a management-by-season approach.
6. Replace components within the context of the original design as they wear out.
7. Measure, communicate, and record water and energy use, climate data, and changes in the program as they occur.

With these goals as the conceptual basis of an irrigation maintenance program the system's water conservation and efficiency will be well looked after. Prerequisites to meeting these goals include a superintendent with knowledge of plant science and a modern, computerized irrigation system linked to a weather station.

After the initial system design, a number of considerations must be used by the water manager and maintenance personnel in the fine tuning of the irrigation system. Evapotranspiration rates (ET) change on a regular basis. Increases in radiant energy, temperature, and humidity all cause ET to rise. The soil-moisture absorption rate should be monitered. Dry air and wind cause evaporation to increase. Wind influences the watering of turf. An understanding of climate and plant needs and soil management will help ensure the correct amount of water is used.

The water manager should be educated as to the basic design of the irrigation system as well as the function and purpose of component parts. This will ensure future repairs and maintenance are carried out in the spirit of the original design. The maintenance will provide information on the sprinkler heads, pipes, valves, controls, and application rates.

Olson presents a hypothetical example of 'management-by-season' water flow changes in which July has 100% water flow. This is provided as an example as site specific water flow will vary by location and time.

Recommended Water Flow Changes

Month	%
January	0
February	0
March	13
April	47
May	80
June	93
July	100
August	93
September	70
October	15
November	18
December	0

General maintenance requirements include a monthly inspection of controls and valves, removing dust from the controls and cleaning any electrical contacts. Sprinklers should be checked weekly during seasons of heavy use for damage from mowers, vandalism, etc. Soil should be checked regularly to establish and maintain proper sprinkler operating frequency and duration.

Water Management Programs

A water management program entailing the keeping of accurate records is essential to the efficacy and measuring of any water conservation program undertaken. Measurement is the initial step in water management. Choose water meters or flow meters and measure against goals to evaluate performance. Landscape water use should be measured separately from other water use (ADWR 1999). In the setting of goals, information on average rainfall, ET, and climate will be needed to establish recommended monthly watering requirements. Calculate water expectations for each meter's 'serve area' to get the expected quantities of water needed for each metered area.

With the information for expected water use, yearly and monthly water use can be projected in a water budget. Allowances should be made for use above and beyond these projections and plans should be established for periods of water shortage. Landscape water management software can help in the monitoring or water use and to see whether or not the budget is being met. Water use exceeding the budget will need to be pinpointed to adverse conditions, faulty budgeting, or problems with the irrigation system.

Conclusion

Good management does not ensure water conservation, but makes it possible. Management within the *Xeriscape*™ philosophy will go a long ways towards meeting conservation needs. The first management step to implement is a well designed irrigation system. This will include appropriate sectioning of the irrigation system and irrigation components that reduce water use. Implementation of the irrigation system should not be done before completing an Irrigation Master Plan. Implemention should be done to specifications and overseen by the irrigation designer. The foundation of an irrigation maintenance program is providing a basic education of the principles of water conservation to personnel. Maintenance personnel must also understand the irrigation system design and ensure that all repairs and routine maintenance are carried out within the spirit of the original irrigation design.

Irrigation Systems for Water Conservation

The perfection of water conservation methods and equipment for golf course irrigation is an ongoing process reflecting the increasing cost and decreased availability of water, and growing environmental concerns over the use of water. This section reviews technology, old and new, that conserve irrigation water. Where possible, specific brand references have been omitted in favor of citing a more general treatment.

Jewell Meyer lists basic areas in which irrigation technology can be adapted to suit water conservation needs: *efficiencies of coverage, efficiencies of distribution, site considerations, design considerations, and budget considerations* (Meyer and Camenga 1985). These areas are considered below.

Efficiency of Coverage

Along with the controller, sprinklers are the most important irrigation component for water conservation. Sprinklers determine the uniformity of coverage and deserve careful consideration on the part of the irrigation designer. Issues to consider with sprinkler selection include control of overthrow, application rates, and control of frequency. Overthrow onto sidewalks or trees and shrubs is often a result of using too few sprinklers rather than the unavailability of part circle sprinkler heads. Although fewer sprinklers translate into lower material costs, the result is inefficiency resulting in wasted water and ultimately higher costs.

Sprinklers with high rates of application tend to create runoff and percolation beyond the root zone, both wastes of water. The rate of application is defined as sprinkler output / sprinkler spacing. Meyer, (1985), gives a more complete mathematical description. Currently available sprinkler heads have a higher rate of application than the percolation rate of most soils. Spray heads – fixed, single-orifice sprinkler heads, have an exceptionally high rate of application. Application rates become higher as a greater sprinkler radius is used. Meyer estimates that an increase of one foot in radius increases the application rate 25 percent and only increases spacing by 10 percent.

Rotating sprinklers significantly reduce the rate of application. Only a portion of the irrigated area is covered at any one time allowing for percolation and reducing runoff. Because the water is concentrated in a stream, a greater radius of coverage can be achieved with less water. The materials cost of rotating sprinklers is greater than spray heads, but operational costs in respect to water savings justify the expense. A method for weighing operational costs is to calculate the runoff water potential for high application v. low application sprinklers. Put a dollar value on the difference with the water bill.

The deep watering of turfgrass below the root zone is lost water. To provide the amount of water necessary to counteract evapotranspiration, while avoiding watering below the root zone, cycling of the irrigation system is necessary. Multi-cycling consists of watering not to exceed the point of runoff. Then, after an appropriate period of percolation, another short application is administered. Similar to the caloric cycling of food, the important point is that water can be used more efficiently when applied for shorter durations at multiple periods. Soil moisture sensors work well with multicycling, triggering the end of one cycle, but have in the past proved impractical on golf courses. Reasons for this include difficulty in locating the place where soil moisture should be measured and the time limitations of irrigation scheduling (Barrett and Vinchesi 2003). The absence of soil moisture sensors further necessitates the monitoring and subsequent programming of the irrigation system for effective multi-cycling. A multitude of controllers are now available which allow multi-cycling.

As alluded to with overthrow, watering precision is sometimes sacrificed in favor of lower materials cost. Precise watering requires that the proper sectioning of the irrigation system be provided. This pertains to valves and controllers and is covered in the section *Irrigation Site Design and Management*.

Efficiency of Distribution

Wasted water from runoff and percolation below the root zone was discussed in the previous section. These factors are also affected by the efficiency of distribution. If one section of an irrigation system is receiving more water than needed, it will by necessity be overwatered. Below is an example of how this can often occur.

To prevent overthrow, half circle sprinklers are used on borders and quarter circle sprinkler heads in corners. If these are on the same system as the full circle heads, areas irrigated with quarter circle sprinkler heads will receive four times the water. One method to alleviate this is to section the system with separate valves for every sprinkler head. A preferable method is to use sprinklers with matched precipitation rates. For example, while a full circle head might flow at four gallons per minute, half circle sprinklers flow at two g.p.m. while quarter circle sprinklers flow at one g.p.m. Using matched sprinklers with similar radii allows the sprinkler to be run on the same valve while correcting the distribution problem.

Wind is an important variable in water distribution. Sprinklers generally cover a circular area. Because water distribution decreases with an increase in radius, sprinkler overlapping is necessary. Commonly recommended spacing for triangular systems is 60 percent of the diameter and 55 percent of the diameter for equilateral spacing. In a five to ten mph wind, distribution becomes uneven and 50 percent (or 100 percent overlap) spacing is recommended for triangular designs, with 45 percent overlap for equilateral designs. Prevailing winds should be considered. Spacing should be reduced perpendicular to the wind. A wind controller can shut off the system if wind becomes untenable for irrigation (greater than 10 mph). The diagram below illustrates sprinkler head spacing taking into account the prevailing wind.

Site Considerations

On-site considerations affect the irrigation systems efficiency. For example, low head drainage on slopes is an important issue. When an irrigation cycle terminates, water remaining in the pipes will drain through the lowest sprinkler head creating a soggy area. This creates unhealthy turf conditions, wastes water, and can become an aesthetic nuisance. One way to alleviate this problem is to install check valves at each sprinkler which will keep the water in the pipes, preserving it for later use.

Design Considerations

The multi-cycling of irrigation can be difficult to achieve on golf courses. Golfers pay substantial fees to play golf and will not tolerate playing through running sprinklers. The available times for sprinkler operation are typically 7 p.m. to 7a.m. This creates the problem of water not being available to turf during the hottest part of the day when evapotranspiration is highest. Because efficient water use requires multi-cycling, manual watering can help alleviate scheduling obstacles. This is done through the installation of quick-coupling valves, which allow direct connection of a hose to the water supply.

Located at critical locations around the course, especially greens, quick-couplers allow attention to be given to particular areas at critical times during the day. Material costs of quick-coupling valves are low with a corresponding higher manual labor cost. To ensure effectiveness, watering should be performed by someone with knowledge of the turf's water requirements and experience in locating areas of turf stress.

A mixture of manual and automated irrigation practices will be necessary to ensure water conservation. The degree of automation will vary depending on the site scale and is generally quite high for golf courses. Irrigation equipment features assisting in water conservation, many of which have already been mentioned, are listed below:

- *Moisture sensors:* Sensors in the shallow and deep root zones of the golf course can identify the point where runoff is about to occur and identify when watering below the root zone is occurring, shutting off the system. As mentioned, this may prove impractical in golf courses with varied terrain.
- *Excess flow-sensing device:* When water flow is excessively high this device can shut the system off. A good device should be able to pinpoint the area where flow is high allowing maintenance to make rapid repairs to any breaks or leaks.
- *Low-precipitation sprinklers:* Low-precipitation sprinklers reduce runoff, improve uniformity, lower application rates, and allow greater coverage area for a given amount of water.
- *Matched-precipitation rate sprinklers:* Mentioned above, these sprinklers conserve water in corners and along borders by ensuring uniform distribution.
- *Check valves:* Check valves prevent drainage through the low head in a pipeline, preserving the water for future use.

- *Master valve:* Upstream from all automatic valves, the master valve allows the shut-off of the system. It is used instead of an excess flow-sensing device.
- *Wind-sensing devices:* Irrigation ceases to be useful when wind velocity exceeds 10 mph. A wind sensor will either pause or end the irrigation cycle (depending on the model) when this velocity is reached, resuming when the wind has subsided.
- *Rain sensors:* A rain sensor avoids the embarrassment of irrigating in the rain. It works well with a soil moisture sensor to ensure the turf's water requirements are met.

Effluent Wastewater Use on Turf

Introduction

The use of reclaimed water, effluent, is not a new practice. It was used in Ancient Greece and was first used on golf courses in San Francisco in 1932 (McCarty 2001). Wastewater has been a popular choice for irrigation needs in the United States, particularly in the arid regions, for the past 30 years.

Nearby metropolitan areas contain a significant source of effluent. At Barton Creek Country Club in Austin, Texas, effluent is provided at no charge from the city of Austin. This compares to 90 cents per 1000 gallons for potable water. The potable water source for the city of Austin is the Colorado River which is heavily relied upon by other municipalities for drinking water (Long 1994).

With mounting water shortages and water restrictions, all golf courses should become equipped to handle reclaimed water or risk having their water turned off. State governments and municipalities are beginning to push golf courses towards reclaimed water usage. California law AB 174, which became effective January 1, 1992, prohibits the use of potable water for golf courses if reclaimed water is available at a similar cost. Effluent conserves potable water, but it has other benefits too. Use of effluent may be ideally suited for turf because of turf's ability to absorb nutrients such as nitrogen and phosphorous contained in wastewater.

Wastewater provides economic incentives in that the water is generally cheaper than potable water, and sometimes given away for free. However, this cost advantage may be diminishing. Gill notes that in California golf courses are required to connect to a wastewater line. This line is metered, and the water is sold at nearly the same rate as fresh water (Garrett Gill and Rainville 1994). It appears that California law AB174 acts as a price support artificially holding up the price for wastewater.

With the economic benefits of using wastewater diminishing slightly with time, the environmental benefits will receive closer scrutiny. Using simple cost benefit analysis, any water savings from wastewater can be offset for any number of reasons. If effluent runs off into streams, or percolates into groundwater, causing contamination of water supplies, fresh water is not conserved. If a person were to contract illness or infection from contact with wastewater our initial values would be questioned. If wastewater negatively impacts turf quality it is likely the wastewater irrigation will be scrapped completely.

Concerns with Effluent Wastewater

Concerns with using reclaimed water stem from two sources: safety to humans; and the short and long term viability of the turf and plant community. Concerns include health risks; suspended solids; biodegradable organics; pathogens; nutrients such as nitrogen, phosphorous, and potassium; heavy metals such as cadmium, zinc, and nickel; dissolved inorganics, specifically salt; and residual chlorine. These concerns will be discussed in the review.

Levels of Water Treatment

Golf courses wishing to use effluent must overcome the public's negative perceptions (founded or unfounded) of playing on turf irrigated by wastewater. There are three levels of water treatment: primary, secondary, and tertiary. Primary treatment involves screening to remove solids. Its characteristics include less than or equal to 50 percent of origin solids, no large debris, a bad odor, and less than 23 coliform bacteria per 100ml. Water at this stage is not to be used for turf irrigation.

Secondary treatment has greater than 90 percent of solids removed by trickling the effluent through large cylindrical vats containing bacterial colonies. It has coliform bacteria of < 23/100ml and maintains a slight odor. Water at the secondary stage of treatment may be used to irrigate turf provided there is no human contact.

Advanced or tertiary treatment involves using a charcoal bed for chemical coagulation and flocculation, sedimentation, filtration, or absorption of compounds. Greater than 99 percent of solids are removed and there is no, or low odor. The coliform bacteria count is <2.2/100ml. Effluent at the tertiary stage is highly recommended for golf greens and tees as the additional stress these areas are under make them less able to cope with the higher salinity of secondary treated effluent (McCarty 2001).

Total Suspended Solids

Total suspended solids (TSS) level requirements are set between five and ten milligrams per liter in most states. Peacock notes that suspended solids can cause sealing of the soil. High TSS-containing water may eventually clog surface pores, inhibiting water infiltration into the soil. Golf tees and greens using effluent should be constructed with high sand content to assist infiltration (McCarty 2001). Solids accumulated at the surface level will decompose in warmer weather resulting in oxygen depletion in the soil (Peacock 1994). Increased aeration of soil may be necessary.

Salts

The ability to leach out total dissolved solids (TDS) is necessary to prevent the accumulation of toxic concentrates. Tests should be taken to show the sodium absorption ratio or the exchangeable sodium percentage. These indexes show the effects of sodium in reducing the soils permeability. In addition to increasing salt stress, sodium rich irrigation waters can replace soil exchangeable and magnesium with sodium, further reducing permeability. Dissolving gypsum in the effluent stream can partially offset the effects of sodium in irrigation water. However, high concentrations of sodium cannot be overcome. Dilution with freshwater is the best solution.

Nutrient Content

Nearly all essential nutrients for plant growth can be found in wastewater. However, proper monitoring is essential to ensure the correct amounts. The primary dilemma with excessive nutrient content in effluent is algal blooms in storage ponds. See table 15-5, McCarty, for the typical nutrient ranges in effluent used for irrigation. The following steps can help one calculate the amount of nutrients being added using effluent water:

1. Find the concentration of the element in question from the water quality test report.
2. Multiply the value by 2.72 to determine the pounds of nutrient per acre-foot of applied water (approx. 325,000 gallons).
3. Convert the amount of nutrients applied per acre foot to 1000 square feet of turf by dividing the value in step 2 by 43.5. Adjust fertilization as necessary.

Heavy Metals

Heavy metal effluent concentrations are usually not a problem with effluent from urban sources, but effluent from industrial sites poses major concerns. Industrial and mining effluent sources are generally not recommended for turf. The main risk from heavy metals is groundwater contamination. Periodic monitoring should alleviate this concern. A soil depth of five feet to groundwater and an irrigation limit of four inches per week are recommended. Chlorine and boron ions found in effluent are toxic to plants. Generally this is not a problem for turf, as mowing removes any accumulation, but trees and shrubs may be especially sensitive in heavy soils where chloride can accumulate.

Storage Ponds

A typical provision in effluent contracts is that the golf course must accept a certain amount of waste water each day. Because the water is not always needed, the need for effluent storage arises. If not properly designed and maintained, storage ponds can be a source of algae, weeds, odors, and health problems.

The optimal storage solution is an enclosed tank, as it eliminates sunlight exposure. Storage ponds are acceptable on the condition they do not impair the pond's function as a storm water management system. Ponds should be at least six feet deep, have good aeration and have a 3 to 1 bankside slope to prevent weed problems. A deeper pond is preferred as it reduces sunlight penetration, keeps water cooler, and helps manage algae.

Circulation and aeration are needed to prevent algae and odor. One solution is to have the intake and outtake valves at opposite ends of the pond. Fountains and water falls also help.

Irrigation System Design

Corrosion of metallic parts and plugging of nozzles are two possible problems in irrigation components when using wastewater. Corrosion can limit the life of the system. To prevent plugging large irrigation nozzle sizes are recommended. Valves designed to handle wastewater can minimize plugging from algal growth.

Proper attention in the research literature has not been given to the possibilities of contamination from runoff and percolation into the groundwater supply (Peacock 1994). Measures taken to prevent contamination from runoff include placement of sprinkler heads so that 75 feet separates the outside radius of the sprinkler throw from any potable wells and public areas. Part circle heads should be used adjacent to wetlands and estuaries. Above ground spigots, hose bibs, and quick-couple connections are not allowed when using effluent water. There must be a distance of at least six feet between the soil surface and the groundwater supply.

The prevention of cross contamination with freshwater supplies is a major consideration. A cross connection between a potable water system and any nonpotable water source must be avoided. Effluent lines and valves are separate systems, usually identified by purple. Where freshwater lines cross effluent lines one foot vertical separation is necessary. Adjacent lines should be placed a minimum of ten feet apart. Backflow protection should follow local code. Leaking is not acceptable.

Conclusion

Each item in the list of complications from using effluent water contains a remedy. However, the totality of issues indicates a real potential for adverse turf effects.

The ultimate success of effluent for freshwater conservation on golf courses will depend on the golfer's indirect acceptance (Gill and Rainville 1994). The past has shown that golfers do not mind playing on wastewater irrigated courses. However, a foremost concern among golfers in the United States is the turf's aesthetic quality. If wastewater were to negatively impact turf conditions a great deal of political pressure would be placed on the superintendent to discontinue the use of effluent for irrigation. As wastewater science advances and if golfers modify their cultural values toward turf conditions, it is likely that wastewater irrigation will increase its stature as a primary method for conserving fresh water on golf courses.

Desalination

Introduction

The effects of saline irrigation are covered briefly in the effluent and turf sections. Turfgrass generally cannot tolerate highly saline water because it reduces the soils permeability. Species of bermuda grass, fescue, and pasapalum are highly salt tolerant, and in some circumstances irrigated directly with ocean water on coastal golf courses in warmer climates. The allure of ocean water is unavoidable to persons interested in freshwater conservation for golf. Only one percent of the Earth's water is usable freshwater, whereas 97 percent of available water is salt water (Rossillon 1985). In the Caribbean, Middle East, and other arid regions golf courses often face the quandary of having almost no freshwater available, but a nearly inexhaustible supply of seawater. Desalination also allows the utilization of the numerous brackish aquifers in the American west and makes effluent and other recycled waters more palatable for turfgrass, while preserving freshwater usage.

In 1988, almost 60 percent of the worldwide capacity for desalination was in the Middle East with Saudi Arabia using 30 percent of this supply (U.S. Congress 1988). That Saudi Arabia is a leader in this market points to the high costs of desalination. Because of costs desalination is only feasible when economies of scale can be taken advantage of, with large scale plants serving governments, municipalities, or resort areas.

Various methods of desalination, their advantages and disadvantages, and their potential applications for golf courses are looked at here. Some basic techniques used to remove salt and dissolved solids from water are distillation and reverse osmosis (RO).

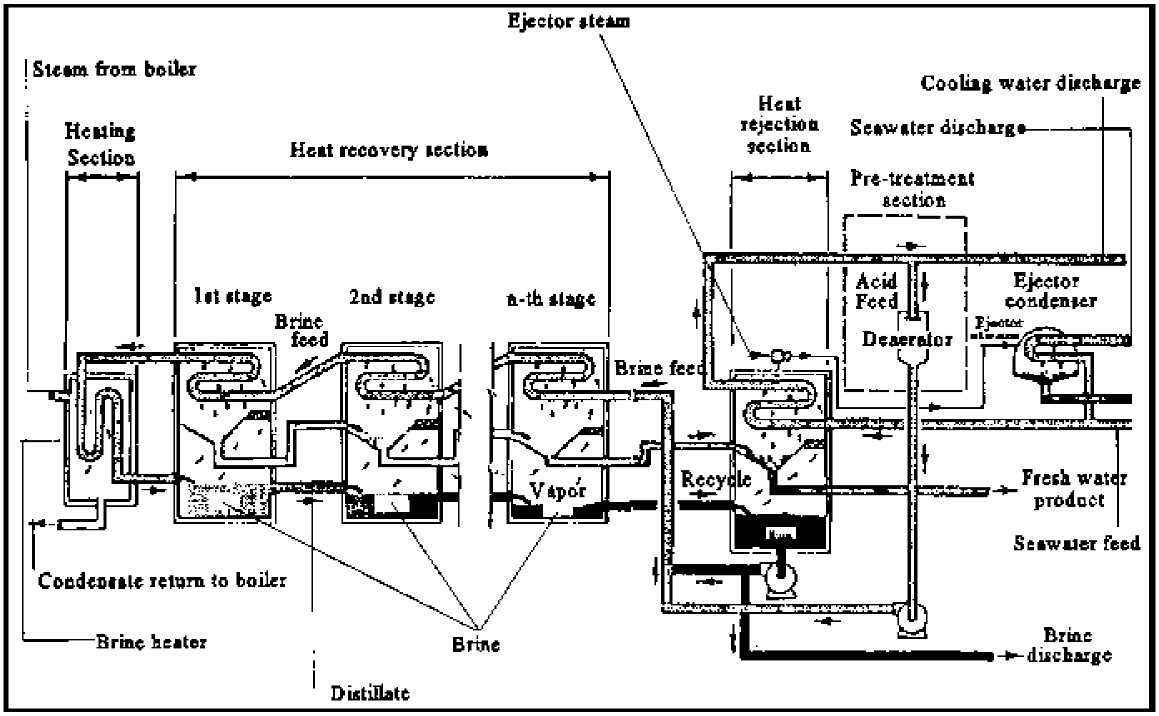
Initially seawater distillation plants dominated the desalination market. Due to lower energy costs the reverse osmosis process is now able to deliver slightly lower costs than distillation and is now the market leader, with electrodialysis taking an increased market share (U.S. Congress 1988). Desalination processes involve three liquid streams: saline feedwater, low-salinity product water, and very saline rejected water (brine) (UNEP 1997). Brine contains 35,000mg/1 dissolved solids and must be disposed of carefully. In some circumstances brine has been mixed with effluent and disposed of on golf courses (UNEP 1997). Feedwater drawn from brackish sources such as the ocean is separated into streams of product water and brine. The product water is then ready for use, while the brine must be disposed of.

Distillation

Distillation is the oldest and most commonly used method of desalination. Aristotle and Hippocrates both advocated the use of distillation in the 4th century B.C. (Koelzer 1972). Multistage-flash, multiple-effect distillation, and vapor compression distillation have led to the widespread use of distillation to desalinate seawater (UNEP 1997). In distillation, saline water is heated producing water vapor which can be collected and a brine solution that must be disposed of. The process is similar to water vapor in a warm house condensing on a cold window pane.

The figure below illustrates a simplified multistage-flash unit. Incoming seawater passes through the heating stages and receives additional heating in the heat recovery sections. After the water reaches an optimum heat, flash-boiling, or flashing occurs.

Freshwater is formed by condensation of water vapor which is collected at each stage in parallel with the brine.



(Buros 1982)

In multiple-effect units, steam is condensed on one side of a tube wall while saline water is evaporated on the other side. The heat generated from condensation of steam is used to evaporate the saline water. Saline water is generally applied to tubes in a thin film to facilitate quick evaporation. A new type of low temperature, horizontal tube MED process has been successfully developed and used in the Caribbean. These plants are rugged and economical, using low-cost materials such as aluminum (UNEP 1997). Vapor compression distillation processes differ from MED processes in that mechanical energy, rather than direct heat, is used to heat saline water.

Among other places, about 65 distillation plants are present in Latin America and the Caribbean. In Mexico distillation plants supply freshwater to tourist resorts in Baja California and in the north-central and southeastern parts of the country (UNEP 1997).

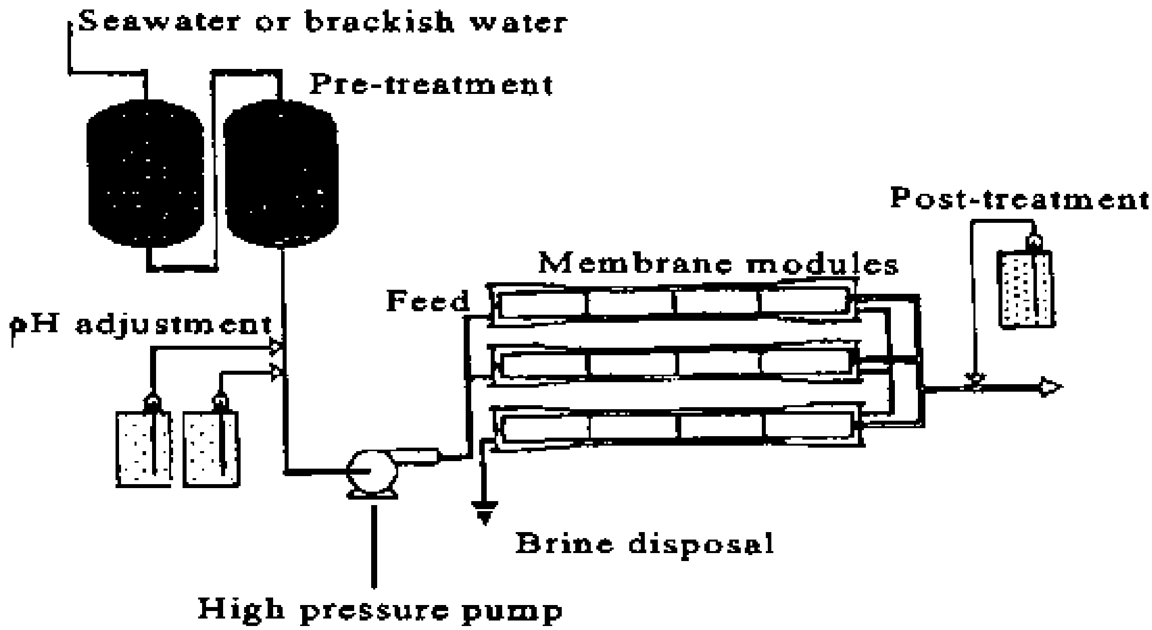
Desalination for Municipal purposes began in Mexico in the late 1960s with the installation of two 14,000 cubic meters per day MSF distillation units in the city of Tijuana. Curacao, in the Netherland Antilles currently operates two distillation plants.

Distillation has a number of advantages, with the primary disadvantage being cost. Advantages include: savings in operational and maintenance costs over other desalination technologies; low temperature distillation plants are energy-efficient; and being able to combine distillation with other processes, such as using heat energy from a power plant. Disadvantages include the environmental costs of brine disposal and the high costs that keep desalination a "method of last resort."

Reverse Osmosis

Reverse osmosis and electrodialysis are the two membrane processes used for desalination. In RO, water is separated from a saline solution by passage through a permeable membrane. The pressure differential created between the feed water and product water facilitates the passage of water through the membrane. The major energy requirement for RO is pressurization of the feedwater. For seawater this can be up to 1000 psi, and approximately half of this for brackish water (UNEP 1997).

Four major processes comprise a reverse osmosis system: pretreatment, pressurization, membrane separation, and post-treatment stabilization. The figure below illustrates a simplified reverse osmosis process:



(Buros 1982)

Pretreatment consists primarily of removing suspended solids and adjusting pH. In the post-treatment stabilization process the product water often requires degasification and additional pH adjustment, typically from a 5 to 7 (UNEP 1997).

RO desalinated water has been used extensively for industrial and agricultural purposes. In Caribbean islands such as Antigua, the Bahamas, and the British Virgin Islands, water desalinated through reverse osmosis has been used for municipal water supplies (UNEP 1997).

Conclusion

Desalination is not practical at the golf course scale because of costs. However, it is a viable technology and will see further development. Golf resorts and municipalities that do not have a freshwater supply, such as arid islands, may find it worthwhile to use desalinated water.

Distillation has been around for centuries. Initially seawater distillation plants dominated the desalination market. Due to lower energy costs the reverse osmosis process is now able to deliver slightly lower costs than distillation and is now the market leader.

Wetlands

Introduction

Wetlands are “lands where saturation with water is the dominant factor determining the nature of soil development and the types of plant and animal communities living in the soil and on its surface” (Cowardin 1979). Wetlands conserve freshwater through storage during floods, recharging groundwater aquifers, and by improving water quality (Libby 2004). Wetlands act as filters by trapping sediment and allowing plants and organisms to biodegrade pollutants. Other pollutants are transformed through the chemistry of anaerobic soils (Thompson 2000).

In addition to water conservation benefits, wetland vegetation helps to prevent flooding and erosion by slowing water and holding the soil in place. Wetlands provide important habitat and can be a valuable scenic attractant for golf courses as well.

With a better understanding of ecological processes, wetlands are now recognized as a valuable natural resource. Legislation at the state and federal level protect and conserve wetlands. The current national trend is that development can affect no net loss of wetland areas. This requires either preservation or compensatory mitigation elsewhere. A 1990 survey by the American Society of Golf Course Architects lists concerns over wetlands loss and degradation as the main reason for difficulties in obtaining course construction permits (Permit problems 1990).

Wetlands Regulations

The most significant federal legislation for wetland regulation is Section 404 of the Federal Water pollution Control Act of 1972. It was renamed the Clean Water Act in 1977, and amended in 1987 (Kosian 1992). The act gave the Corps of Engineers the ability to enact a permit system to regulate the dredging and filling of waters in the United States. There are three primary sections, 404a, b, and c. Section a allows the Corps to issue permits for filling waters after public notification and hearings. Section b requires that the Corps issue permits in accordance with guidelines set by the EPA. The guidelines prohibit the Corps from granting a permit if there is an alternative with a less adverse impact on the wetland, the project degrades the waters of the United States, and if proper steps have not been taken to minimize adverse effects on the wetland. Section c allows the EPA to veto the Corps decision to issue a permit if the EPA finds the project will have an adverse impact on the aquatic ecosystem (Kosian 1992).

Many states now have wetland laws. Among these is the requirement of permits for development that impacts wetlands in addition to those required by the Corps. Meeting state and federal permitting requirements presents a formidable task for the developer.

Wetlands Conservation

Conservation involves identifying existing wetlands and their recharge areas and developing a management plan that maintains and enhances the wetlands ecological function and scenic beauty. Wetland delineation during site selection can help avoid wetlands entirely. If present on site, wetlands should be delineated before the design phase of the golf course construction to avoid project delays and the possibility of regulatory fines (Kosian 1992). This includes meeting with federal and state regulatory agencies early in the process. Wetlands are not always saturated and may be difficult to identify during dry conditions. A professional consultant with experience in wetland delineation may be beneficial or even required by law. An ideal team includes a wetland ecologist, hydrologist, soils specialist, wetlands botanist, and landscape architect (Hammer 1997). Libby (2004) provides a current list of resources for obtaining a professional opinion.

Wetland indicators include hydrophytic vegetation and hydric soils. Hydrophytic vegetation, such as cattails and sedges, are highly adapted to saturated soils and wet conditions. Hydric soils, indicated by saturated ground, have soil oxygen limited by the presence of water for long periods of the growing season (Libby 2004). The ground may not be saturated year round. Areas that are slow to drain and hold water are good indicators of wetlands.

An option in wetland conservation is to simply leave the wetland alone. However, the active management of a wetland can help to ensure its ecological and aesthetic quality and ensure the wetland is being conserved. A number of steps can be taken to ensure effective management. Plants populations must be monitored with invasive exotic species removed. This will increase the value of the wetland as habitat and facilitate the wetlands cleansing and storage functions. Trails or walkways should be built to direct foot and cart traffic. This will prove essential when the ground is saturated and is effective at reducing soil compaction and protecting vegetation and habitat. Signs, ropes, and fences keeping golfers out will serve the similar function of preserving the integrity of the wetland (Libby 2004).

To maintain a wetland function, groundwater must also be protected at its upland source where it is recharged. This is especially pertinent to golf residential communities where golf often occupies the low ground while housing occupies higher ground.

Restoring and Creating Wetlands

The United States has lost 50 percent of its wetlands (National Research Council 1992). Wetland restoration is the improvement of a degraded wetland to a more natural state. The goal of wetland creation and restoration is to regain some of this lost wetland and maintain it at optimum function. As water conservation moves into the spotlight wetland creation and restoration will play an important role.

State and federal regulations often call for compensatory mitigation when development can not avoid impacting a wetland. Compensatory mitigation is an attempt to replace the functions and values of affected wetlands (Kosian 1992). Mitigation can be achieved by both wetland restoration and creation. The choice of which to pursue depends on site specific factors that consider the site as well as the larger context of the region and watershed. Permitting bodies will often have requirements as to which course of compensatory mitigation to pursue.

Wetland restoration involves the improvement of degraded wetlands and the reestablishment of vanished ones. Both human activities and natural events such as lake level rise may have contributed to loss of wetland function. Restoration requires reestablishing soils, plants and hydrology at the site. The larger the ratio of watershed/wetland the better. The period of saturation, or "hydroperiod," is important in determining the type of community restored. Areas with hydric soils should be selected for restoration. Restoration locations near existing wetlands can facilitate the natural regeneration of vegetation (Libby 2004).

Wetland creation involves the creation of a wetland in an area that was not previously a wetland. Often this is done through the removal of upland soils to create depressions supporting wetland species (Kosian 1992). Careful planning of site hydrology can be used for soil saturation or seasonal flooding in the created wetland. Establishing the proper elevation and the proper hydroperiod is the critical factor for success (Kosian 1992).

Conclusion

Wetlands historically have been eliminated on golf courses, either drained or filled. Remaining wetlands were manicured to the point where waters became sterile and the diversity of species reduced. Regulations, public scrutiny and changing values in the golf community have caused opinions and practices to shift. Today many appreciate wetlands for both their ecological function and scenic beauty.

Water conservation benefits of wetlands are flood storage, groundwater recharge, and improved water quality. For these effects to be fully realized the wetland must be maintained in as close to a natural state as possible. Wetland conservation, restoration, and creation techniques derived from expert guidance can help ensure this. Existing wetlands must be delineated at an early stage in the design process with an eye for hydric soils and hydrophytic vegetation. Once identified an appropriate wetland management plan can be established.

Wetland restoration and creation, often required by the state and federal government, aim to replace lost wetland habitat, and degraded wetlands. The establishment of appropriate soils, hydrology, and vegetation are essential to the success of the wetland. Restoration efforts should focus on areas with hydric soils. Establishing the proper hydrology will be the most difficult factor in wetland creation.

Cultural Practices

Introduction

Irrigation, fertilization, and mowing, as well as a shift in cultural expectations, are the primary cultural practices that can promote water conservation. Blade height, blade sharpness, frequency of cutting, and mowing equipment all affect water use. Fertilization influences water use by changing the plant growth process. Irrigation practices affect both the water use and the drought resistance of turfgrass. Robert Shearman concludes that maintenance crews should mow high and frequently, fertilize to meet nutritional needs and irrigate less frequently based on soil moisture. Cultural expectations with regard to turf quality play a direct role on the amount of water used.

Mowing practices

Increased water use has been correlated with increased mowing height. Studies have shown that 'Penncross' creeping bentgrass increased its water use as the mowing height was raised from a quarter inch from four and three-fourths to five inches. Similar results have been shown for bermudagrass and ryegrass (Shearman 1985). These results are likely associated with an increased canopy resistance and decreased leaf area for shorter turf.

It is possible to manipulate mowing height and frequency to increase the depth of rooting and lower excessive leaf area. Reducing excessive leaf area would reduce evapotranspiration while increased root depth would increase soil-moisture extraction. The end result is less water used. In fact, a higher mowing height allows for deeper rooting of the turf species. Frequent mowing at these extended heights will minimize leaf area, counteracting the water loss associated with taller grasses.

In field studies comparing mowing with blades of varying sharpness, mowing with dull blades decreased long-term water use by decreasing leaf area and turf health through mutilation (Balogh and Watson 1992). This finding runs counter to the long held belief that a sharper blade would conserve water. However, out of regards for the health of the turf community and human safety it is not suggested that mowing be carried out with dull and/or poorly adjusted equipment.

Fertilization

Fertilization influences turfgrass growth and water use. Research, although incomplete, has shown a negligible correlation between potassium and phosphate use and water conservation (Shearman 1985). Nitrogen fertilization has a definite influence on turf water use.

Nitrogen increases the health and vigor of the turf community. Intuitively this results in increased water use. Water use continues to increase with increases in the nitrogen application rate until the rate reaches 2 pounds of nitrogen / 1000 square feet, or 10g N/m^2. At this point a critical threshold of nitrogen is reached and the turf community becomes prone to wilting and drought injury (Shearman 1985).

An Arizona study on warm and cool season turfgrasses examined the effects of varying applications of nitrogen on both water use and turf aesthetics. 'Low-management' turf received 5g N/m^2 every other month, while 'high-management' turf received 5g N/m^2 monthly. Aesthetically the 'low-management' turf was characterized as being similar to that on many campuses and parks. The 'high management' turf was characterized as being slightly better than parks, but not as nice as many corporate lawns. The water use for ‘low-management’ turf was 13.5 inches per year less than for ‘high-management’ turf. Within acceptable levels, nitrogen fertilization bi-monthly as opposed to monthly conserved water with negligible aesthetic differences when compared to ‘high-management’ turf (Kneebone 1982).

It has been shown with Kentucky bluegrass that drought recovery is more substantial when nitrogen is applied in the fall, as opposed to the spring. Additionally, bentgrass has been shown to produce more root weight with nitrogen fertilization in the fall as opposed to the spring (Shearman 1985). Recall from above that greater root weight conserves water through increased soil-moisture extraction. The appropriate seasonal application of nitrogen aids in drought recovery and promotes root weight, while avoiding the excessive use that causes an increase in water use.

Irrigation

Irrigation has a definite impact on water-use. Shearman (1985) and Balogh and Watson (1992) both point to the potential for conserving water through improved efficiency, both in management and system setup. Irrigation is covered in depth in the sections: *Irrigation site design and management, Irrigation systems for water conservation,* and *Effluent irrigation.*

Among the irrigation practices most mentioned for conserving water is the use of soil-moisture sensors as a basis for irrigation scheduling. However, it has been noted that these devices have been ineffective at handling a site as varied as a golf course (Barrett 2003). More research is needed in this area to take advantage of this water conservation resource.

Socio - Cultural expectations

In the United States a golf course is expected to be a lush green carpet, resulting in prohibitively high water use in some regions of the country. This is not necessarily in line with golf tradition. In Scotland golf is played on the existing landscape as opposed to adapting the landscape to meet golf's expectations. Although rainfall is quite high, irrigation is a new phenomenon there brought on by the westernization of the sport. In order to reduce the water use on golf courses a shifting of cultural values is in order. The golfer, in paying his or her green or membership fees, determines the value to be placed on immaculate turf. Through a shift in the golfer's expectations significant changes can be affected in the amount of water used by golf courses in the world.

Research has shown that the way to shift cultural expectations is through education (Nassauer 1995). An educated public is more likely to accept and embrace environmental principles such as water conservation. With education comes a shift in what is deemed aesthetically pleasing. An immaculate oasis in a desert may no longer hold its charm. Through education of the golfing public the aesthetic standards inherent in the game's roots can become more readily accepted.

One solution, laid out in the section on *Irrigation management*, is to embrace the *Xeriscape*™ guidelines. *Xeriscape*™ principles include reducing the total amount of irrigated turf and using as much native vegetation as possible (denverwater.org 2004). With its emphasis on water conservation this program can lay the groundwork for a more responsible use of water in the golf community.

Conclusion

Within the parameters of acceptable height, mowing high and frequently will improve water conservation. Mowing high allows the turf to develop a deeper root zone, improving soil-moisture *extraction*. Frequent mowing minimizes the greater leaf area associated with taller grass.

Nitrogen use has an impact on plant water use. As nitrogen use increases, to a point, the plant becomes more robust and uses more water. Research has shown that nitrogen fertilization can be minimized without significantly affecting turf quality. The fall application of nitrogen aids in drought recovery and results in greater root weight.

Irrigation systems, design, and management are covered in other sections of the literature review.

Cultural expectations currently demand a lush green turf. This is not consistent with the game's roots. Changing cultural expectations is accomplished through education on the benefits of water conservation. One program that effectively educates and conserves water is *Xeriscape*™.

Mowing, fertilization, and irrigation practices, as well as cultural expectations all affect the ability of a golf course to conserve water. A management program and appropriate education organized around the above cited literature are necessary cultural modifications for golf course design and management.

Turfgrass water use

Introduction

At this point in time, irrigated turf is the accepted norm for turfgrass on golf courses. When dealing with water conservation, the question revolves around understanding the plant/water relationship and selecting species and cultivars that exhibit a low water-use rate relative to others. Water-use rate is the amount of water required for turfgrass growth and the amount transpired from the grass and evaporated from soil surfaces. Lowering the water-use rate of turf reduces the amount of any supplemental irrigation necessary.

There are significant differences in the water-use rate of the primary turf species in the United States. Among warm season grasses, species adapted to temperatures of 80-95 degrees Fahrenheit, zoysiagrass, bermudagrass, buffalograss, and centipedegrass have low water-use rates. St. Augustinegrass, seashore pasapalum, bahiagrass, and kikuyugrass have relatively high water-use rates. There is limited information available on cool season grasses. Cool season turfgrasses tend to have higher water-use rates than warm season grasses.

Plant characteristics may contribute to a low water-use rate. These factors are a slow vertical leaf extension rate and canopy resistance, which includes a high shoot density, narrow leaf, and a somewhat horizontal leaf orientation.

Plant/water relationship

Grass species typically require a water content that is 75-85 percent of the plant's weight. A reduction in water content by as much as ten percent could be lethal. The major portion of plant water is transpired into the atmosphere, while a lesser portion is reserved for plant growth. Transpiration should not be considered a waste of water as it is critical to temperature regulation in surviving heat stress.

There is a triangular soil, plant, atmospheric relationship. The soil provides the source of plant water and the atmosphere is the sink of plant water, influenced by air temperature, wind, and relative humidity. Distribution of water through any of these three parts may occur in either the liquid or gaseous phase. In the soil water may be either liquid or vapor. In the plant water is a liquid continuum. A phase change in the substomatal cavity from liquid to vapor results in the transpiration of water in the leaf to the atmosphere.

Evaporation is critical to the flow of water from the soil to the atmosphere. This occurs both directly from the soil surface into the atmosphere, and from the soil, into the plant, and into the atmosphere. Transpiration applies only to evaporation from plant surfaces. Evapotranspiration, ET, considers both evaporation from the soil and transpiration from plant surfaces. Water-use rate, WUR, refers to the amount of water required for turfgrass growth and the amount of evapotranspiration. Water-use rate is expressed per unit of time. Equations for the determination and measurement of these rates are found in Beard, 1985. Most studies looking at plant water use have focused on ET. ET and WUR are considered interchangeable with the caveat that WUR will be slightly higher because it is also measuring the water plants use for growth.

Interspecies evapotranspiration profiles

Most studies comparing evapotranspiration rates among species have focused on warm season grasses. Bermudagrass and zoysiagrass, two popular golf turfs have been studied extensively. A broad range in canopy structure, shoot density, leaf area, and vertical leaf extension exists among the bermudagrass cultivars. This results in varying evapotranspiration rates. The evapotranspiration rate, measured in mm/day, was 8.7 for Santa Ana bermuda in Arizona, 5.9 for Tifway Bermuda in Texas, and 4.0 for common Bermuda in North Carolina. (Beard 1985) It should be noted that areas with the lowest reported ET were in the northerly ranges of bermudagrass and face less evaporative demand.

The ET rates among cultivars of zoysia varied as well, and not necessarily as a function of evaporative demand. The studies that Beard (1985) cited ranged from an ET rate of 7.2mm/day for Meyer cultivars in Texas to 4.8mm/day for Emerald cultivars. Beard notes that the potential for developing cultivars with still lower ET rates is promising.

Other warmseason turfgrasses include seashore pasapalum and buffalograss. Pasapalum has been documented to have an ET rate of 7. Despite this medium-high rating, seashore pasapalum is well documented to have other water conservation benefits. Its high salt tolerance makes it an ideal candidate for effluent irrigation, brackish, or possibly seawater irrigation. (Beard 2002) Buffalograss is native to semiarid regions of the United States. Although not commonly used for golf fairways, it is commonly found in roughs. Buffalograss had an ET rate of 5.3, or 7.3 without nitrogen fertilization.

Limited research exists on cool season grasses. Fescues have been shown to have relatively high ET rates, ranging from 12.6 for tall fescue to 7.2 for Kentucky 31 in Texas. However, in some places where fescue is used for golf turf the high amounts of rainfall negate the need for additional irrigation water. Penncross creeping bentgrass is used throughout the country on golf greens and on fairways in the upper Midwest. Penncross displayed a range of ET rates from 9.7 in Texas to 5.0 in Arizona. Kentucky bluegrass had an ET rating of 5. Beard emphasizes that available information on cool season grasses is deficient.

Kentucky bluegrass, zoysiagrass, and bermudagrass have potential as low water-use turfgrass species. It is interesting that buffalograss, native and adapted to semi-arid climates, has a higher ET rating. Drought resistance must not be confused with low water use. In a drought environment buffalograss will be successful. However, in an irrigated environment other turf species will use less water. Kentucky bluegrass has a low drought tolerance.

Conclusion

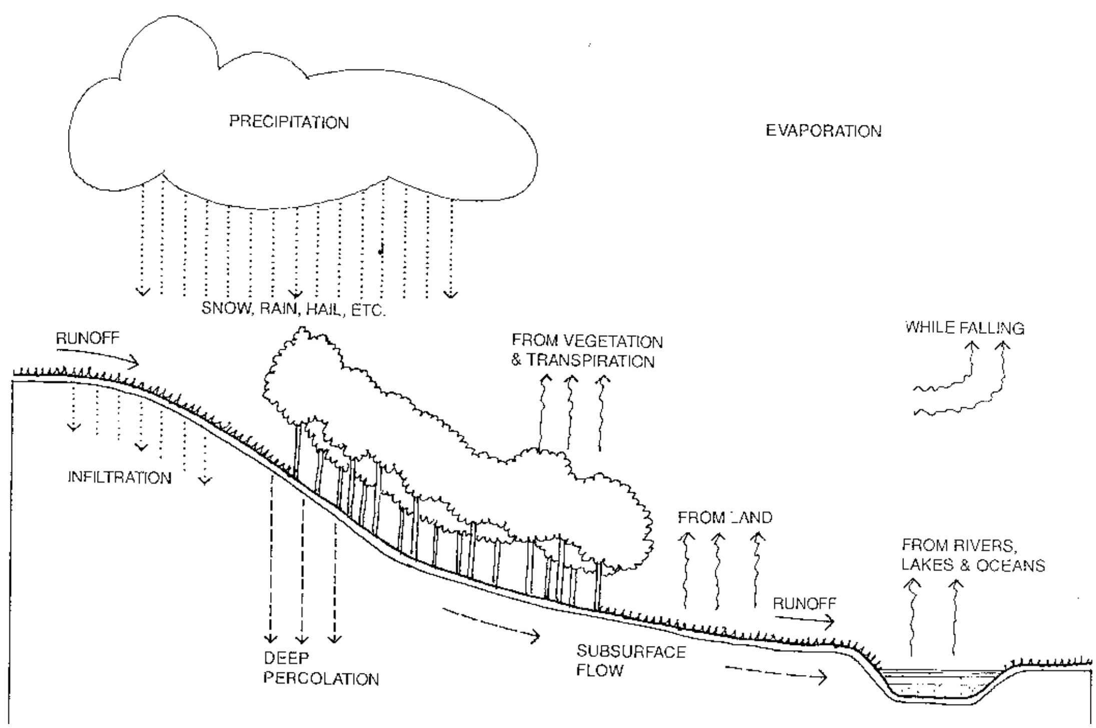
The soil is the source of plant water, while the atmosphere is the sink. Water passes from the soil to the plant in the liquid phase and from the plant to the atmosphere in the gaseous phase. Evapotranspiration includes evaporation from the soil surface and transpiration from plant surfaces. Plants exhibiting lower evapotranspiration rates wil use less water.

Evapotranspiration varies between species. Among warm season grass zoysiagrass, bermudagrass, and buffalograss had lower evapotranspiration rates. Among cool season grasses Kentucky bluegrass had a relatively low ET. Water use is not the same thing as drought resistance. Drought resistance is also an important factor to consider in turf selection for water conservation.

Storm Water Management for Freshwater Conservation

Introduction

Storm water will either infiltrate a site or move across the ground as runoff. Storm water runoff is a result of gravity and flows into streams, rivers, ponds, lakes, and oceans. For runoff to occur the surface must be saturated, meaning the precipitation rate exceeds the infiltration rate. The hydrologic cycle is illustrated in the diagram below.



(Strom 1998)

A key goal in managing storm water is to reduce runoff velocity and volume while improving water quality (Dines 2001). Increased velocity and volume of runoff causes such environmental problems as: flooding, decreased groundwater supply, soil erosion and sedimentation, as well as other pollutants. The velocity and volume of runoff is best controlled through promoting infiltration with vegetative swales and other infiltration devices.

Water quality is a major area of concern for storm water on golf courses. Pollutants existing on many golf courses are sediment, nutrients, and pesticides. Sediment can be detrimental to aquatic life by interfering with photosynthesis, respiration, growth, reproduction, and oxygen exchange. Additionally, sediment can transport other attached pollutants. Nutrients such as nitrogen and phosphorous are prominent in golf course fertilizers. These can lead to excessive growth of algal vegetation as well as being toxic to fish. A study by the city of Austin, Texas found that among different land uses, effluent–irrigated golf courses had the highest concentrations of phosphorous and nitrogen in storm water runoff (Watershed Protection and Development Review Department 2005). Pesticides, found often in water at toxic levels, pass through the food chain where they can have a toxic effect on humans, among other organisms (Stormwater B.M.P. 2003).

Infiltration has been shown to have a dramatic effect on improving water quality. Bruce Ferguson (1998) notes that it takes only a few inches of soil to trap, accumulate, and treat common pollutants. As an example Ferguson notes that Long Island's aquifer has not been polluted chemically or microbiologically by storm water infiltration basins.

Golf courses do not have to deteriorate water quality and accelerate runoff at a boon to the environment. Proper grading and drainage should keep runoff on site and, as discussed in the wetlands chapter, existing and designed storage facilities can improve water quality (Libby 2004). Methods discussed below that manage storm water on golf courses to provide the greatest environmental benefit and least costs are: site planning, landscaping practices such as vegetation and swales, retention and detention ponds, wetlands, and cultural practices.

Site Planning

Planning for storm water management should be carried out at the watershed and site scales. There are three management systems: major flood protection, minor flood protection, and water quality protection. Major flood protection is carried out at the watershed level and is designed for 25, 50, and 100 year floods. Pictured is a detention dam built at Neosho Municipal Golf Course in Neosho, Missouri as part of the Hickory Creek Watershed Project. The dam will protect lower portions of the watershed from major flood events. The dam was built as a stipulation for construction permitting on a new nine holes at Neosho and covers a drainage area of 256 acres and holds 119 acre feet of water.

Planning at the watershed level is cost effective, mitigating the need for expensive structural solutions on every site. However, watershed-based storm water management does not relieve the need for effective site planning. Minor flood protection and water quality protection strategies are carried out at the golf course scale. Minor flood protection in the form of gutters and swales protects against 2, 5, and 10 year storms and conserves freshwater by controlling erosion and sedimentation. Water quality protection strategies focus on one inch rainfall events with techniques such as detention, filtration, and infiltration (Dines 2001).

In the planning process, municipal, state, and federal codes must be reviewed and understood. Increasingly progressive storm water management legislation prohibits off site runoff and sets water quality parameters. An exhaustive review highlighting examples of storm water legislation can be found in the April 1995 EPA publication: *National Conference on Urban Runoff Management: Enhancing Urban Watershed Management at the Local, County, and State Levels.* This document is available at www. epa.gov/ordntrnt/ord/WebPubs/runoff.pdf (Viewed 10/25/05).

Reducing the amount of impervious cover (i.e. parking lots and structures) to a bare minimum should be planned for. A degradation of water quality in streams takes place when the impervious cover of the drainage area exceeds 20% (Strom 1998). The placement of fertilized areas of the golf course immediately adjacent to impervious surfaces degrades water quality. A good way to combat imperviousness in parking lots is to use a realistic demand scenario rather than the typical highest-demand scenario. Vegetated swales in parking lots capture and clean runoff on site and prevent the sheet flow that picks up pollutants and increases runoff velocity.

A thorough site plan will balance the estimated precipitation and other water use of the golf course with the hydrologic capacities of the site without sending problems such as increased runoff velocity and volume and degraded water quality off site. Methods for cleaning and conserving water kept on site should be addressed.

Also important for minor flood protection is protecting native vegetation cover and undisturbed soil layers. Converting native forest or prairie cover to another use is going to greatly increase runoff and reduce infiltration. Site planning can strive to identify such areas through careful site analysis and site selection and concentrate areas of grading and land cover change to those parts of a site that have already been drastically disturbed.

Landscaping Practices

Planting, vegetative and grading methods are important storm water management techniques for minor flood protection and water quality protection. Techniques include vegetated swales, filter strips, basin landscaping, and urban forestry. Properly designed, these methods will slow runoff, encourage infiltration, and clean water.

Vegetated swales are an alternative to curbs and gutters and function well on golf courses. In addition to directing drainage they create surface friction that slows runoff (Strom 1998). The swales permit infiltration that impervious channels would not, promote wildlife and vegetative diversity, and may provide an aesthetic amenity. Techniques such as riprap and bioengineering in addition to vegetation increase the channel's resistance to erosion (Ferguson 1998).

Vegetated swales for improving water quality are known as *biofilters*. Biofilters limit runoff velocity to 0.5 feet/second. At this velocity up to 83 percent of pollutants adhering to vegetation may be captured. It should be noted this level of effectiveness is not achieved for nutrients commonly found in fertilizers. A biofilter must be at least 200 feet long to keep water in the swale for a necessary nine minutes (Ferguson 1998).

Taking vegetated swales a step further, swales may be created with geomorphic calculations to reflect natural stream models. An aesthetic plus for golf courses, these natural stream models seek to provide an erosion, transportation, and deposition system that restores natural equilibrium to a developed site.

Vegetation selected for swales should be native to the area and have hydrophytic qualities. Native hydrophytic vegetation will tolerate saturation as well as seasonal dryness. State natural resource departments are prepared to recommend local vegetation that is adapted to streambank conditions.

Filter strips, commonly filled with stone or vegetation, intercept sheet flow and slow runoff to encourage infiltration. Placed next to or within impervious surfaces such as a parking lot these strips effectively limit the pollution coming off of these surfaces. Improperly designed filter strips may concentrate runoff, reversing their pollution control effectiveness. Grass filter strips are very effective at stopping pollution from sedimentation and can be used to improve the performance of other infiltration devices (Strom 1998). This is particularly true with deep rooted prairie species.

Grading and subsurface drainage will be introduced by the golf course architect to prevent standing water in low areas and to protect greens, tees, and fairways from maintenance hassles. The design of swales, infiltration, detention, and retention devices can not be completed until after the rough grading design is complete and the subsurface storm drainage system has been laid out. Stormwater management techniques should complement and improve the surface and subsurface drainage plans (McCarty 2001).

Similar to swales, detention and retention basins require properly designed planting schemes. Factors for plant selection include slope stabilization, pollutant removal, aesthetic value, and wildlife. Soil saturation and type will necessitate different planting zones (Strom 1998).

Urban forestry involves the preservation of existing trees and the planting of additional ones. As shown in the diagram of the hydrologic cycle, tree canopies capture a significant amount of precipitation. Additional tree benefits include increasing the site's water storage capacity and preparing the soil profile for infiltration.

Retention and Detention

Often it is necessary or beneficial to store storm water temporarily or for more extended periods. Storage serves flood control purposes and is a valuable source of irrigation water. Additionally storage collects and treats common pollutants. Retention, or wet, basins contain a permanent pool of water. Detention, or dry, basins control peak discharge rates through the temporary storage of runoff. Management and aesthetic goals will determine the necessity and volume of storage required and mitigate the duration of storage called for (dry or wet basin).

Properly designed retention, or wet basins store runoff, create habitat, remove pollutants, and provide aesthetic value. A permanent pool has important advantages for water quality maintenance. A permanent pool lengthens residence time and continues settling and biodegradation after a storm is over (Ferguson 1998). Retention basins should maximize the length between the inlet and outlet. Extending the flow path allows pollutants and sediment to settle. A pond expanding in the direction of flow and an irregular shoreline help to displace existing water, preventing "dead zones." Basin depths should be between four and eight feet. Shallower basins would result in elevated water temperatures. The basin must be above the water table to allow recharge and prevent mixing with groundwater (Strom 1998).

Additional storage volume must be planned for sediment. Planning a sediment storage volume equal to one half inch of the drainage areas runoff will prevent dredging more than every 20 years (Ferguson 1998). Overall, sediment storage plus a depth of greater than four feet must be planned for. However, there are advantages in varying the depth of a pool. A deeper forebay at the entrance of the basin will slow water and quickly remove sand. Another deep zone near the outlet will keep trash and debris in the pool. A zone shallower than 18 inches allows pollutant removing aquatic vegetation to take root (Ferguson 1998).

Detention, or dry basins control peak discharge rates with temporary storage of storm runoff. Basin outflow is controlled until no water remains. Effective detention can prevent flooding and control erosion and sedimentation. Additionally, basins can be designed to remove pollutants, improving water quality.

Surface methods of detention may be in ponds, basins, or paved areas. Subsurface detention may be accomplished with dry wells, porous fill, drainage structures, and cisterns (Strom 1998).

While similar to retention basins, detention basins have some critical design differences. These features include a stabilized inlet and outlet, a minimum of two percent slope towards the outlet, the ability to detain water at multiple depths, a stabilized embankment at the outlet, and an emergency spillway. Outlet size will determine the time a pool is in existence. Vegetated detention facilities slow flow, promote infiltration, and remove water through plant uptake.

Strom lists three design considerations for detention basins: An elongated form maximizing the distance between inlet and outlet is preferred. Positive drainage can be ensured with a minimum of two percent slope towards the outlet. And a low flow channel will accelerate drying time and allow for greater usability of the site.

A problem with detention basins stems from the fact that “first flush” storm water is often highest in pollutants. Pool volume is small at the beginning of a storm event allowing for maximum out flow. As the storm progresses, heavily polluted “first flush” storm water will often be pushed out of the detention basin before satisfactory residence time has allowed for pollutant removal (Ferguson 1998). The importance of a maximized distance between inlet and outlet is illustrated by this shortcoming.

Calculations for the design of detention and retention basins can be found by consulting a hydrology text, or the Strom, Ferguson, and Dines references provided.

Wetlands

Existing wetlands can improve the quality of water and may be beneficial when used in conjunction with retention or detention basins. However, in order not to damage the stability of an existing wetland, discharges into them from stormwater runoff should be held to a minimum.

Wetlands creation and restoration is covered in the ‘Wetlands’ section of the literature review. It is critical to work with state and federal regulatory agencies when dealing with the possibility of any runoff being cleansed and slowed in a wetland. A wetland ecologist and appropriately trained landscape architect can help select hydrophytic vegetation for pollutant removal functions.

Cultural Practices

The current culture of golf courses allows the possibility for stormwater to come into contact with pollutants, both stored and applied, such as pesticides, and fertilizers. Landscaping techniques, mentioned above, as well as irrigation and mowing practices also affect the efficacy of a stormwater management program.

Although becoming less so in most areas, golf courses have been managed by chemical fertilizers and pesticides since their origin in the 1950s. From a systems perspective storm water poses the danger of adversely affecting other systems and the golf course proper by carrying these chemicals to other areas. For example, storm water nitrogen may be carried from the golf course, where its dangers are monitored, to an area where it disturbs local vegetative diversity and becomes toxic to animal life. As such, storm water management practices are critical in the everyday management and operation of a golf course.

Because material stockpiles such as sand can pollute when mixed with runoff they must be kept clear of drainage pathways, roadways, and slopes steeper than ten percent. Temporary stockpiles should be covered in plastic weighted down with sand bags or hay bails. Permanent stockpiles should be contained in concrete or similar impervious storage.

Golf course chemicals are generally stored on site. Chemicals are to be stored in a covered, appropriately designed storage facility that storm water is directed away from. The walls and floor of the storage facility shall be impervious and hold the largest container plus ten percent. If fire protection is necessary the facility must also hold any necessary firewater. Liquid removal shall be provided through a sump in the floor. Mortared brick is not a suitable storage facility. State and federal regulations further guide the storage of chemicals.

Chemicals shall be mixed according to specifications and containers shall be inspected often. Empty containers shall be stored covered and appropriately removed promptly. There shall be a spill plan staff are trained to administer, as well as appropriate first aid and absorbent materials available.

Earthwork disturbance is to be limited, avoiding waterways and sensitive areas. Earthwork should be completed promptly. Exposed areas shall be stabilized. Runoff must be controlled and contained to remain on site.

Risk of contamination from pesticides can best be dealt with by minimizing their use. Non-chemical pest control methods are available (Sachs 2002). The least toxic and persistent pesticide should be selected. Applications and amount used should be limited.

Integrated Pest Management (IPM) is becoming increasingly refined through research and allows for the reduction of pesticides. With IPM biological controls such as predatory organisms, cultural controls such as plant rotation, physical controls such as barriers, targeted chemical control, and appropriate plant choice are all combined for effective pest control outcomes.

Fertilizers pollution of storm water runoff can be minimized by reducing spray drift, particularly onto paved surfaces. This is accomplished with correct nozzle and droplet size and the avoidance of application in the wind. Sandy golf course soils are unlikely to retain nutrients, so should be fertilized in small quantities more often.

Drainage channels should be avoided. Fertilizers must have low heavy metal content. Organic, non toxic, fertilization is a successful and viable alternative (Sachs 2002).

Irrigation saturation combined with storm water poses an increased risk of runoff. Covered in previous sections of the literature review, irrigation should be perfected so that irrigation scheduling and soil moisture control eliminates standing water that may become runoff. Plant species should be selected that use the least water. Irrigation should not be used in a storm event.

Mower clippings, in practice, are disposed of on the golf course. Clippings should be projected or dumped away from water or drainage pathways. Sensitive areas, buffer zones, and native vegetation must be made clear to maintenance personnel to avoid mowing. An unmown buffer strip should be included in the golf course design to protect water bodies from mower clippings and chemical applications. Clippings shall be removed from paved areas. Equipment shall be washed at the end of daily use in an area away from storm water runoff. The success of mowing practices in the overall storm water management plan largely depends on the education of maintenance personnel involved.

These cultural practices should be contained within the broader scope of a storm water management plan. Specific practices mentioned above were adopted from the New South Wales Environmental Protection Agency (Environmental Protection Agency 2000). The importance can not be underscored of consulting locally pertinent regulations.

Conclusion

Runoff occurs when the precipitation rate exceeds the infiltration rate. Storm water runoff on golf courses may pose a serious detriment to water conservation in the form of reduced water quality. Such pollution may occur from sedimentation, or chemical and nutrient contamination.

An effective storm water management plan that includes both the golf course and the golf course in the context of the region should be implemented. The major goal of a storm water management program is to reduce the velocity and volume of runoff, while avoiding contamination. Reduced runoff velocity and volume allows storm water to infiltrate the ground, where pollutants may be fixed biologically before dangerous concentrations occur, and allows sediment to settle. Storm water contamination may occur as a consequence of poor design for runoff velocity and volume considerations, or from flawed maintenance practices. A storm water management plan shall address site planning, landscaping practices, retention and detention facilities, wetlands, and cultural practices inherent in the day to day operation of the golf course. With proper design, management, and attention, storm water on golf courses can be utilized to conserve water resources.

Water Quality

Introduction

The quality of water on golf courses is affected by all of the topics covered to this point and warrants in-depth consideration on its own. Water quality is critical to freshwater conservation. Attempts to conserve and reuse water are futile if water becomes toxic or non-potable to all users of a living system. Additionally water saved by the alternate use of effluent or desalinated sources becomes a hindrance if groundwater, runoff, or water bodies are degraded. Degraded water is used inefficiently by plants resulting in increased water use and other maintenance expenditures.

This section synthesizes the literature on all facets of maintaining water quality as related to turfgrass management. Avoiding effluent contamination of the surrounding ecosystem allows for this valuable water source while avoiding freshwater degradation. Salt concentration is a major concern with effluent as well as an obvious concern for desalinated water and will be discussed. Wetlands serve an important role in maintaining water quality, but care must be taken to maintain their ability to function as a freshwater system.

Water sources affected by golf course practices are groundwater, standing water bodies, water held in plants, and stormwater. Water quality practices will be considered in reference to these sources.

Pesticide and Fertilizer Leaching

The United States Golf Association sponsored ten university research studies between 1991 and 1994 to examine the effect of pesticides and fertilizers on golf course water quality. These agents come into contact with the water supply through leaching and irrigation or stormwater runoff.

Leaching, as defined in the report, is the downward movement of a pesticide or fertilizer through the soil (U.S.G.A. 1995). Movement through the soil is necessary to prevent chemical runoff and to reach the plants root zone. However, excessive leaching poses risks of chemical contamination of groundwater.

Leaching is affected by environmental factors and pesticide or fertilizer product characteristics. Mature turf can slow leaching. Clay soils have more surface area and greater chemical charge than sandy soils and are more likely to tie up chemicals than allow their passage. The sandy soils common on golf courses have a greater potential for leaching. Organic soil amendments can reduce leaching in sand (U.S.G.A. 1995).

Pesticides and fertilizers are characterized by their binding properties, persistence, degrading properties, solubility, and use rates. Products that bind more leach less. *Koc* is a numeric value to represent binding potential. A Koc value of 300 – 500 is considered low and indicates a potential for leaching. Ethoprop and Fenamiphos are organophosphate insecticides for nematode control with weak binding potential, Koc 26 - 110 and 26 – 249 respectively (U.S.G.A. 1995).

Binding potential and persistence, how long it takes a product to break down, tend to be inversely related. The residual effects of persistent chemicals expose the risk of runoff or leaching from an unexpected storm event as well as any long term effects from chemical exposure. The buildup of persistent chemicals is a problem which may also cause compromised root systems, thatch buildup, and a decreased tolerance to environmental stresses. Persistent chemicals may be managed through careful observation of lower application rates (Bruneau 1995).

Chemicals break down, or degrade through photochemical processes (contact with sunlight), chemical processes (such as dissolving in water), volatilization (entering a gaseous state), and microbial processes. Degradation is expressed numerically by *half – life*, the period of time it takes for 50 percent of a chemical to break down into other products. Chemical degradation and plant success should be determining factors in selecting chemicals with a low use rate.

Water quality concerns with respect to runoff are covered in the storm water section of the literature review. Important factors for consideration are chemical use rate and appropriate application scheduling. The above mentioned USGA study cites heavy rainfall after application as the most common reason for runoff related contamination from pesticides and fertilizers.

Nitrogen and Phosphorous

Through runoff and leaching, nitrogen and phosphorus are the nutrients most likely to affect water quality. Phosphorous aids in establishing and rooting plants. However, phosphorous may also cause algal blooms and excessive growth of aquatic plants. Many water quality problems with phosphorous are due to erosion and sedimentation. This is because of the strong binding properties of phosphorous (Bruneau 1995). Nitrogen is required for plant growth. Deficiency may cause poor growth and susceptibility to stressors. Excess nitrogen may cause restricted root systems, increased disease frequency, and susceptibility to stress (Bruneau 1995). These chemicals commonly found in golf course fertilizers may be even more of a concern in effluent treated golf courses where they exist in substantial quantities (Watershed Protection and Development Review Department 2005). As well as being deleterious to plant growth, phosphorous and nitrogen may also be toxic to humans and fish.

Nitrogen and phosphorous groundwater contamination through leaching is a concern. One study found that turf was able to remove 90 percent of the nitrogen in wastewater, with 10 percent of available nitrogen leaching (Yates 1994). Nitrogen carriers with short residual effects and high leaching potential are ammonium and calcium nitrate. Slowly available nitrogen sources such as organic compost and urea are less likely to impact groundwater through leaching. Phosphorous generally has strong binding properties, but may leach in very sandy soils (Bruneau 1995).

Testing can properly determine a turf site's nutritional needs, limiting the use of phosphorous, nitrogen, and other plant nutrients to the effective minimums. Soil test reports and a plant tissue analysis should satisfy these needs. For a soil test take 15 to 20 representative soil cores at a uniform depth. Mix the cores in a plastic container and send the sample to an appropriate agronomic agency.

Effluent

As mentioned in the literature review of effluent, secondary or tertiary treated effluent water is suitable for use as golf course irrigation. There shall be no human contact with water treated to the secondary level. Water treated through the tertiary stage is suitable for tees and greens.

These treatment stages will remediate problems such as suspended solids. Still, the chemical and biological characteristics of effluent water can vary considerably among samples. High salt content and high sodium are the most common water quality problems of effluent. Effluent is notorious for high salinity. There is a negative correlation between soil salt concentration and rate of plant growth (Yates 1994). However, turf varieties vary in their salt tolerance. Among common warm season turfgrasses Seashore pasapalum and Bermudagrass are salt tolerant. Among cool season turfgrasses, Bentgrass is not salt tolerant (Yates 1994). Dilution with freshwater is the solution to saline effluent.

Closely related to salinity problems is high sodium, which may be found in effluent water. Sodium in the soil reduces its permeability. High sodium water is primarily a problem for clay soils, as sandier soils generally have no problem with permeability. The effects of sodium on impermeability are counteracted by high soluble salts concentration. Therefore, salinity and sodium concentration must always be considered together (Yates 1994).

Effluent warrants attention to achieve healthy turf. Problems with effluent water quality can greatly reduce water conservation. Saline soils demand increased water for adequate plant growth, while high sodium prevents water from reaching the soil root zone. In addition to impaired turf effluent poses some human risk as well. Marylynn V. Yates reports that contaminated or improperly treated ground water has caused 50% of the waterborne disease outbreaks in this country since 1920. It is a necessity to adhere strictly to backflow prevention and other codes concerning effluent water.

Wetlands

A golf course negatively impacts wetland water quality through poorly designed irrigation and storm water conveyance systems and failing to utilize effective buffer zones with chemical applications and irrigation overspray. Storm water runoff is not permitted off the golf course site. Effective grading and drainage protects the wetland from the risk of contaminated runoff.

Irrigation overspray, the spray that goes off the golf course, poses a danger to wetland quality. Effluent or fertigation, nutrient enhanced irrigation water, overspray brings to wetlands all the problems of excessive nitrogen, phosphorous, and other chemical contamination. One method to virtually eliminate overspray is to begin sprinkler head placement with part circle heads placed on the golf course / wetland boundary pointed in towards the golf course. This method is necessary for Audobon International certification for environmental stewardship on a golf course. The method does increase costs by raising the head count.

Vegetative buffer strips at a wetland edge filter contaminants to keep them from entering the wetland and damaging the fresh water supply. Various state regulating authorities, for instance New Jersey, require a buffer when developing at a wetland edge

Not to be discounted is the role of wetlands in improving water quality. Wetland vegetation can trap and remove pollutants from water. With this in mind, proposed wetland impact in a golf course development or alteration of the wetlands ecological components for perceived aesthetic benefit should be seen as a hindrance to golf course water quality and in turn water conservation.

Cultural Practices

Cultural practices fall into two categories. The first is those maintenance and management practices having direct impact on golf course water quality. Chief among these is Integrated Pest Management, or IPM. The second category has an indirect, yet integral effect on water quality. These are cultural values which can serve to improve, or harm golf course water quality.

Integrated Pest Management seeks to use ecological methods in combination with more entrenched chemical methods to control pests and improve turf quality. Critical to the success of IPM is the acceptance and tolerance of pests at a damage level which does not significantly reduce the acceptability of the turf (Bruneau 1995). Values underlying IPM are a knowledgeable superintendent, a written plan, defined pest threshold levels, appropriate agronomic practices, monitoring pest activity, and keeping records. For example, a sound agronomic practice would be to use chemicals more often in smaller amounts to reduce runoff and leaching.

Cultural practices indirectly affecting water quality center around aesthetic expectations. Unrealistic expectations of a lush green micro environment out of touch with its surroundings is the cause of water contamination from nitrogen, phosphorous, effluent, fertigation, and pesticide leaching and runoff. It has been shown that through ecological education cultural aesthetic preferences shift to favor healthy environments (Nassauer 1995). A starting point for education is the hydrologic cycle. By understanding how water interacts with humans and the environment, the case for conservation becomes readily apparent.

Conclusion

Water quality is of critical importance to freshwater conservation on golf courses. Conserved water is useless and may pose health risks to plant and animal life if it becomes contaminated. On a golf course, water quality faces threats from runoff, leaching, and irrigation overspray. These practices run the risk of chemicals or effluent water used in course maintenance coming into contact with the groundwater supply or a freshwater body.

Chemicals posing possible risks are pesticides, fertilizers, fungicides, and herbicides. The most notorious nutrients posing golf water quality concerns are phosphorous and nitrogen. Phosphorous aids in root establishment and nitrogen aids in overall growth. Excessive nitrogen may increase plant disease susceptibility. Excessive phosphorous causes algal blooms in water bodies. Both of these nutrients may be toxic to fish or humans in sufficient quantities. Leaching is particularly a concern with nitrogen. Slowly available nitrogen sources such as organic compost and urea are less likely to impact groundwater through leaching.

In addition to fertilizers, nitrogen leaching is also a concern in effluent water where it exists in high concentrations. Yates (1994) found that 10 percent of available nitrogen leached in wastewater. The most pressing concern for plant growth with effluent water is high salinity. High soil salt concentration is inversely related to plant growth. Dilution with freshwater can alleviate this problem.

Wetland water quality can be most easily impacted through runoff and irrigation overspray. When the site is engineered to specifications runoff should not be a problem. A method of insurance that is being legislated by many state governments is vegetated filter strips along the wetland edge. Overspray can allow fertigation water or effluent to enter the wetland. Sprinkler heads may be placed along the wetland with a semi-circle spray pattern to prevent overspray.

Sensitive golf course maintenance practices and a shift in aesthetic preferences are the best way to ensure golf course water quality. A carefully planned and instituted Integrated Pest Management Program for instance can control pests without abusing pesticides. Aesthetic preferences are geared towards appreciating health. Education can bring about a preference for a natural aesthetic that is not overly reliant on fertilizers, and in turn protect water quality.

Conclusion

The literature both points out the need for freshwater conservation and the real possibility of conservation. The nine areas covered were:

1. irrigation site design and management,
2. irrigation systems for water conservation,
3. effluent wastewater use on turf,
4. desalination,
5. wetlands,
6. cultural practices,
7. turfgrass water use,
8. stormwater management, and
9. water quality.

These areas cover the gamut of water use on golf courses.

Tangible steps were gleaned in each of these areas to conserve freshwater. In the next section knowledge from the literature survey will be organized and condensed to give working best practices for golf course use.

Best Management Practices are important to provide a course of action to conserve water. By acting, the ideas in the literature summary gain power and move towards water management solutions. People able to use the Best Management Practices are golf course maintenance staff, irrigation designers, golf course owners, golf course architects, developers, students, and policy makers.

Best Management Practices

I. Introduction

Water conservation is planned for and managed differently through the lifecycle of a golf course. It would not be an option to redesign a ten year old irrigation system for another ten to twenty years. However, that same system can become more efficient by scheduling irrigation runtimes to coincide with current evapotranspiration rates. Throughout, there is always something that can be done to conserve fresh water resources.

Oversimplified, there are three phases in the lifecycle of a golf course: planning, construction or renovation, and then operations and maintenance. The Best Management Practices will be considered within these three phases.

Pre-construction planning is the least physical in nature but perhaps the most important phase for water conservation. The irrigation system can be designed efficiently, perhaps without using fresh water. Wetland habitat is protected from disruption during construction and contamination from runoff and irrigation. A good plan runs the gamut from a course design that keeps prevents runoff to a chemical storage plan for the maintenance phase of the golf course.

Construction and renovation involves habitat disruption with earthmoving equipment on par with what our highways and urban infrastructures are built with. If water conservation is left unmanaged it may become a casualty to economics. Proper supervision from the irrigation designer and golf course architect can insure the design is implemented as planned. Wetlands must be marked and protected from construction equipment. Water from the construction site, likely sediment contaminated, must be kept out of the wetlands. A well managed construction site with alert regulatory agencies is an important step for water conservation.

Maintenance can be an opportunity for continuous improvement in the use of water resources. Critical are a competent superintendent and an environmentally conscious governing board. Water quality at the golf course and around the golf course is often directly related to maintenance practices. Lastly, cultural norms such as over-watering will affect maintenance practices and water conservation.

This is the framework in which freshwater conservation on golf courses would occur. The following Best Management Practices utilize this framework and the knowledge gathered from the literature summary.

II. Golf Course Planning, Construction, and Renovation

The following checklist is to be completed prior to the commencement of golf course construction.

Water Resource Protection – Storm water checklist

- Managing storm water consists of reducing runoff velocity and volume while improving water quality (Dines 2001). The velocity and volume of runoff is best controlled through promoting infiltration with vegetative swales and other infiltration devices. Water quality protection strategies focus on one inch rainfall events with techniques such as detention, filtration, and infiltration (Dines 2001).

● Major flood protection is carried out at the watershed level and is designed for 25, 50, and 100 year floods. A thorough site plan should balance the estimated precipitation and other water use of the golf course with the hydrologic capacities of the course to keep runoff on site. The hydrologic context of the golf course in the watershed should be considered in flood planning. Management and aesthetic goals will determine whether dry detention, or wet retention is called for. The volume and duration of flood storage should be determined early on.

x_____ A major flood protection plan is in place. The engineering consultant has stamped plans to prevent runoff from a 100 year storm from leaving the site. The plans specify the volume and duration of flood storage.

x_____ The golf course architect or owner has approved the decision to use dry or wet detention for major flood protection.

● Minor flood protection in the form of gutters, improved permeability, and swales protects against 2, 5, and 10 year storms. This conserves freshwater by protecting against erosion and sedimentation. Plan to hold the amount of impervious cover to a minimum. Fertilized areas should not be placed next to impervious cover. Imperviousness in parking lots should be determined with a realistic demand scenario instead of a highest demand scenario. For example, a parking lot should be sized to comfortably accommodate golfers for a typical Saturday, but not golfers for a major regional tournament. Where possible, vegetated swales should be used in parking lots to capture, clean, and slow runoff. For a vegetative swale to function as a biofilter and improve water quality it must be 200 feet long (to retain water for the necessary nine minutes) (Ferguson 1998). Vegetation selected for swales should be native to the area and have hydrophytic qualities. Native hydrophytic vegetation will tolerate saturation and seasonal dryness.

In addition to adding vegetation, urban forestry is an important component of golf course design and maintenance. Benefits associated with over and understory trees include increasing the site's water storage capacity and preparing the soil for infiltration.

x_____ A minor flood protection plan is in place. The plan has been approved by the owner's representative and will guide all consultants. The plan addresses parking and hardscape, swales, and runoff management, setting standards to be verified by the owner's representative following construction.

● Retention, a permanent pool, improves water quality by lengthening residence time and allowing for continued settling and biodegradation (Ferguson 1998). Retention basins should maximize the length of residence time between the inlet and outlet, allowing pollutants and sediment to settle. These basins should expand in the direction of flow and have an irregular shoreline to displace existing water, preventing "dead zones." Basin depths should be greater than four feet to prevent elevating water temperatures (Strom 1998). Basins should be above the water table to allow recharge and prevent mixing with groundwater (Strom 1998).

x_____ Permanent pools are designed to have irregular shorelines and a maximized residence time between inlet and outlet. All basins are designed to be greater than four feet deep. The basins do not mix with groundwater. This has been verified by the consulting engineer.

- Detention, or dry basins need a stabilized inlet and outlet, a minimum of two percent slope towards the outlet, multiple depths, a stabilized embankment at the outlet, and an emergency spillway. The outlet shall be engineered to determine the length of pool existence. Like retention, detention basins should maximize the distance between inlet and outlet (Strom 1998). Low flow channels are desirable to accelerate drying time and allow for greater usability of the site. A wetland ecologist and an appropriately trained landscape architect can select appropriate hydrophytic vegetation for pollutant removal in basins.

x_____ Dry basins have a stabilized inlet and outlet with greater than two percent slope towards the outlet. Channels are low flow and have hydrophytic vegetation. Dry basin plans shall be approved by the engineer and a wetland ecologist.

- Consideration of maintenance and other cultural practices are critical to storm water planning. Materials stockpiles must be kept clear of drainage pathways, roadways, and slopes steeper than ten percent. Temporary material stockpiles should be covered in plastic and weighted down with sand bags or hay bails to prevent washing. Permanent materials stockpiles should be contained in concrete or other impervious storage. Integrated Pest Management (IPM) shall be enacted as the management techniques to control weeds and other pests. Fertilizer should not be applied in the wind and fertilization scheduling shall be matched to nutrient needs and soil perviousness. When available, organic fertilization methods should be chosen. Unmown buffer strips shall provide a barrier between the golf courses play area and bodies of water. Maintenance staff education on BMPs shall be part of the golf course management plan.

x_____ The golf course maintenance plan is prepared by the golf course architect and approved by permitting bodies to protect materials and chemicals from storm water. The maintenance facility design and location and stockpile locations are included in this plan.

Water Resource Protection – Wetlands checklist

● Legislation has given the federal and state government the final say on wetland use and development. Section 404 of the Federal Water pollution Control Act of 1972, renamed the Clean Water Act in 1977, and amended in 1987, gave the Corps of Engineers the ability to enact a permit system to regulate the dredging and filling of waters in the United States. Section 404b prohibits the granting of a dredge and fill permit if there is an alternative with a less adverse impact on the wetland. Section 404c gives the EPA veto power over the Corps of Engineers decision to issue a permit. State wetland regulations will also be present in the golf course planning, construction, and renovation phase.

x_____ The owner's representative has discussed wetlands regulations with the golf course architect, consulting engineer, municipal, county, state, and federal regulatory agencies. All regulations are understood.

- An active wetland management plan shall include provisions for wetland identification and golf course site selection, exotic species removal, promote the wetlands hydrologic function, and preserve the wetlands hydrologic context within the watershed. Golf course site selection shall maintain and enhance the wetlands ecological function. A wetland identification team includes a wetland ecologist, hydrologist, soils specialist, wetlands botanist, and landscape architect. Signage and barriers shall protect wetlands from the public. Runoff or basin outflow into a wetland is subject to strict control. The irrigation design shall utilize part circle heads on the wetland border to avoid overspray into the wetland.

x_____ A wetland management plan has been prepared by the golf course architect under the direction of a wetland ecologist. The plan will direct site selection, wetland protection, runoff, and the irrigation design.

- Wetland restoration requires reestablishing soils, plants and hydrology in existing or former wetlands at the site. Areas with hydric soils should be selected for restoration. Natural wetland vegetation regeneration should be promoted by locating restorations near existing wetlands.

x_____ Wetland restoration has been discussed with a wetland ecologist and takes into account the site's soils, plants, and hydrology.

- Wetland creation involves the creation of new wetland habitat with proper site elevation and hydroperiod. Hydrophytic vegetation shall be selected by a wetland ecologist or appropriately trained landscape architect to enhance the pollutant removal and other ecological functions of the wetland.

x_____ Wetland creation plans have been reviewed by a wetland ecologist to verify or establish a site at the correct elevation and hydroperiod.

Irrigation Design and Planning checklist

- The objective of irrigation is to replace the water used in evapotranspiration as efficiently as possible. Efficiency can be accomplished using *Xeriscape*™ landscaping principles. The *Xeriscape*™ principles are effective planning and design, soil improvements, efficient irrigation, plant zoning, turf alternatives, and appropriate maintenance. These serve as a framework for golf course irrigation system design and management.

- An Irrigation Master Plan shall include the water source and availability, topographic information, environmental zones, the local soil-plant-water-needs, and any other prerequisite data to guide the irrigation design process. Irrigation water demand, determined by evapotranspiration minus precipitation, is a prerequisite to finding the quantity of water needed. An adequate quantity and quality of freshwater or alternative sources must be available for a given project. Water demand and the available quantity of water determine water storage requirements and the need for alternatives such as effluent. Irrigation system scheduling shall be determined by a calculated irrigation water demand. The maintenance and golf design intent of all the course environments must be understood before undertaking the irrigation design. Codes and regulations (often municipal or county) pertaining to water use must be understood before the irrigation design process commences. The decision to participate in the Audubon Cooperative Sanctuary Program must be made before the irrigation design process commences.

x_____ The golf course's irrigation water demand has been determined by an irrigation design consultant. The landscaping plan used as a basis for irrigation design minimizes irrigated turf based on *Xeriscape*™ principles. After determining water demand, it has been determined an adequate quantity of water is available.

- Site soil information is necessary in the irrigation master plan for zoning and scheduling decisions. Soil types must be understood before the irrigation design process commences to assist in micro-environment zoning decisions. The soil infiltration rate must be known to avoid runoff with proper irrigation scheduling.

x_____ The irrigation design consultant has conducted a thorough analysis of the site's micro-environment. This shall be completed and reviewed before approval is given to commence with the irrigation design.

- Irrigation planning shall also include provisions for automatic and manual control, system construction and maintenance, and water use management. Budgeted control of the irrigation system shall increase with the scope of the project. Irrigation valving must differentiate the site's numerous micro-environments. Gate valve placement design shall work with the pipe routing to cost effectively minimize the isolated area of a shut down, while maximizing the operable area outside of the shut down. Irrigation system construction shall be supervised by the irrigation designer, or a qualified representative. Sprinkler head layout is a primary area for inspection. Golf course maintenance staff shall understand the layout of the irrigation system and, in addition to repairs, utilize a regular procedure of inspection and control. The water management program will record actual water use vs. planned use, actual rainfall, and actual ET for each micro-environment. Water and climate records will be used to create yearly and monthly water use projections.

- Efficient irrigation coverage is accomplished with sprinkler head selection and ensures turf needs are met with minimum water use. Sprinklers shall cover the required area evenly while controlling overthrow, and have low application rates. Maximizing the number of sprinklers with appropriate control avoids overthrow and promotes uniform watering. Rotating sprinklers, are favored over fixed head sprinklers on golf courses for their lower application rates, thereby reducing runoff. Water application rates can be further minimized by using smaller radius spacing and nozzle combinations.

x_____ An irrigation coverage plan has been provided by the irrigation designer. It has been approved by the golf course architect, or owner's representative as avoiding wetlands and other non golf areas. Uniform irrigation is evident on the coverage plan.

- Efficient water distribution is accomplished through multi-cycling, flow sensors, matched precipitation rate sprinklers, and wind considerations. Short, frequent watering, not to exceed the point of runoff, shall be used instead of deep watering. This practice is known as multi-cycling. Multi-cycling is best accomplished with a combination of automatic and manual irrigation methods. Flow sensors in the central control system shall be used to locate leaks and areas of abnormal flow. Where fixed head sprinklers are used instead of rotating sprinklers, matched precipitation rate nozzles shall be used. For example if a full circle head uses 4 gallons per minute, a quarter circle head in the same zone shall be specified at 1 g.p.m. A wind controller shall be used to shut off irrigation when winds exceed 10 m.p.h. Where prevailing winds of 5 to 10 m.p.h. are present, square spaced coverage shall be reduced from 45 percent of diameter overlap to 55 percent of diameter overlap.

The following irrigation components shall be specified in the irrigation design for their water conservation benefits: An excess flow sensor shall be used to shut the system off when water use is abnormally high. Rotating sprinklers shall be used over fixed spray sprinklers for their lower water application rate. Check valves shall be used to prevent drainage through the low head in a pipeline. Manual gate valves shall allow the manual shut off of the irrigation system or system segments. Rain, wind, and moisture sensors shall be used to prevent unnecessary irrigation.

x_____ A signed statement has been received from the irrigation designer verifying the use of best practices for efficient irrigation. In addition to this practicum, such practices are available from the Irrigation Association.

Alternative Water Sources – Effluent checklist

- With drought, water shortage, and water restrictions, all golf courses should become equipped to handle reclaimed water. In California, the use of potable water is prohibited if reclaimed water is available at a similar cost. Effluent should be exploited in turfgrass for its ability to use the chemicals nitrogen and phosphorous found in wastewater. Economic incentives for using wastewater, such as free water from some municipalities should be exploited.
- Effluent concerns are from two sources: safety to humans and other animals, and the health of the plant community. Secondary treatment of wastewater is required, tertiary treatment where human contact may occur. Tertiary treatment consists of greater than 99 percent of solids removed, and low or no odor. Tertiary treatment shall be used for putting green and tee complexes. Total suspended solids level requirements are between five and ten milligrams per liter in most states. Because high TSS water may clog soil surface pores, golf tees and greens using effluent should be constructed with high sand content to assist infiltration. Routine aeration of the soil is necessary.

x_____ Monitoring wastewater and keeping accurate and complete records is the responsibility of the golf course superintendent or manager.

● Sodium and salt concentrations are the major turf viability concerns with effluent use. Dissolving gypsum in the effluent stream can partially offset the effects of sodium in irrigation water. Effluent dilution with fresh water is the best solution for unacceptable sodium and salt concentrations.

● Effluent contains essential nutrients for plant growth. Fertilization and turf management shall be modified to accommodate the nutrients found in the wastewater supply. To add wastewater into a fertilization program first find the concentration of a nutrient from a water quality test report. Convert the value to pounds of nutrient per acre-foot of applied water. Adjust values to 1000 square feet of turf and adjust fertilization as necessary.

x_____ Before the decision to use effluent has been made it has been verified that accurate and timely effluent chemical analysis is readily available.

● Typically the logistics of effluent usage requires that golf courses accept a certain amount of effluent each day. This requires storage capabilities. The optimal storage solution is an enclosed tank. Effluent storage ponds shall be at least six feet deep. Deeper ponds reduce sunlight penetration and keep water cooler, managing algae. Circulation and aeration help prevent algae and odor.

x_____ A water quality engineer has approved the effluent storage design.

● Runoff and percolation of effluent into the groundwater supply can be prevented through proper irrigation system design and scheduling. The outside of sprinkler throw shall be separated from potable wells and public areas by 75 feet. Part circle heads shall be used adjacent to wetlands and estuaries. There shall not be a cross connection with potable water systems. One foot vertical separation is necessary where potable and effluent water lines cross. Adjacent lines shall be ten feet apart. Effluent leaking is not acceptable.

x_____ The irrigation installation shall be per specifications with installation monitored by the designer.

Alternative Water Sources – Desalination checklist

● Turfgrass generally cannot tolerate high salinity, making desalination a necessary step for saltwater irrigation. Desalination technology is used in arid ocean regions, with brackish aquifers in the American west, or as an additional step in effluent treatment. Desalination is only feasible when economies of scale can be taken advantage of, with large scale plants serving governments, municipalities, or resort areas. Saudi Arabia is the largest user of desalination technologies.

● Distillation is the most commonly used method of desalination. In distillation, saline water is heated producing water vapor to be collected and a brine solution that must be disposed of. There are about 65 distillation plants in Latin America and the Caribbean. In Mexico distillation plants provide water to resorts in Baja California. Advantages of distillation are that it is cheaper than other desalination technologies, and can be combined with other processes such as using heat from a power plant. Disadvantages to distillation include high costs of desalination in general and the environmental costs of brine disposal.

x_____ A plan for the disposal of brine has been approved by permitting agencies.

- Reverse osmosis is a membrane process used for desalination. In RO the pressure difference between feed water and product water allows fresh water to pass through a membrane. Roughly 1000 psi is required for the pressurization of seawater, and half of this for brackish water. The four processes of a reverse osmosis system are pretreatment, pressurization, membrane separation, and post-treatment. Pretreatment consists of removing suspended solids and adjusting pH, while post treatment stabilization consists of degasification and pH adjustment from a five to a seven. RO desalination has been used for industrial and agricultural purposes. In the British Virgin Islands reverse osmosis desalinated water has been used for municipal water supplies.

Turfgrass Selection checklist

- The water-use rate is the amount of water required for turfgrass growth and the amount transpired from the grass and evaporated from soil surfaces. For water conservation, turf species and cultivars may be selected that have low water use relative to other species. Among warm season grasses, zoysiagrass, bermudagrass, buffalograss, and centipedegrass have low water-use rates. Although information is limited, cool season turf species tend to have higher water-use rates than warm season grasses.

- The evapotranspiration profiles of bermudagrass and zoysiagrass have been studied extensively. The variety of canopy structure and leaf area and density result in bermudagrass cultivars results in varying water-use. The ET rate in mm/day was 8.7 for Santa Ana Bermuda in Arizona, 5.9 for Tifway Bermuda in Texas, and 4.0 for common Bermuda in North Carolina. Note that water use is lowest in the Northern ranges of Bermuda use. The water-use of zoysia was not correlated to with the plants location and was 7.2 mm/day for Meyer cultivars and 4.8 for Emerald cultivars.
- Other warmseason golf turfs are seashore pasapalum and buffalograss. Seashore pasapalum is not as water-use efficient as Bermuda grass. However, pasapalum is the most salt tolerant turf. Buffalograss, native to semiarid regions of the United States, has a higher water-use rate than other golf turfs, but was the most drought tolerant.
- Limited research is available on cool season grasses. Fescue has a high 12.6 mm/day evapotranspiration rate, while Kentucky bluegrass had a 7mm/day evapotranspiration rate similar to warm season turf. However, fescue is often utilized in areas with a low need for supplemental irrigation.
- Turfgrass selection plays a role in golf course water conservation. Bermudagrass species have the lowest water-use rate among warm-season grasses. Buffalo grass is a good choice for non-irrigated turf areas. Insufficient evidence exists to make water-use selection practices for cool season grasses.

x_____ The golf course turf specified and an alternative have been evaluated for their water-use efficiency in the local environment.

III. Golf Course Maintenance and Operations

Water Quality checklist

- Pesticides and or fertilizers may come into contact with the water supply through leaching, downward movement through the soil, and runoff. Runoff is covered in the stormwater best practices. Environmental factors slowing leaching are mature turf and clay soils. Sandy soils common on golf courses may require organic amendments to prevent leaching.

- Pesticides and fertilizers are characterized by their binding properties, persistence, degrading properties, and use rates. Products that bind more leach less. *Koc* is a numeric value representing binding potential. Products with low to mid *Koc* values shall be avoided due to their leaching potential. Persistent chemicals do not break down easily and run the risk of leaching from unexpected precipitation and long term buildup. Chemicals degradation is expressed numerically by half-life. Degradation may be from sunlight, dissolution in water, becoming a gas, or from microbial activity. Low half-life chemicals shall be favored. Chemical application scheduling combines knowledge of binding, persistence, and degrading properties in determining beneficial use rates that do not pose a risk to water quality.

x_____ Pesticides and fertilizer alternatives shall be compared and those selected for use shall have higher *Koc* values, break down easily, and have a low half life.

● Nitrogen and phosphorous are the nutrients most likely to affect water quality. Phosphorous has strong binding properties and may pose a water quality concern where erosion and sedimentation are present. Nitrogen carriers with high leaching potential are ammonium and calcium nitrate. Slowly available nitrogen such as organic compost and urea shall be favored for their low leaching potential.

x_____ All nitrogen fertilizers to be used are classified slowly available

● Nutrient testing shall be part of the turf management program to determine the effective minimum use of nitrogen, phosphorous, and other nutrients. For a nutrient test gather 15 – 20 representative soil cores taken at a uniform depth, as well as plant tissues, and send the samples to a local agronomic agency.

x_____ Two local agencies have been found that can test for nutrients

● Wetland water quality is at risk from irrigation overspray and runoff. During the design phase of the golf course, steps shall be taken to prevent irrigation overspray off the golf course into the wetland. Vegetative buffer strips at the wetland edge shall be utilized to prevent contaminant migration through runoff. Many state agencies require this step.

x______ Maintenance staff have been educated as to the location of unmown buffer strips.

- The water quality benefits of Integrated Pest Management and adjusted societal expectations for golf are considered in the proceeding sections.

Cultural Practices checklist

- Integrated Pest Management, or IPM shall be implemented as a means of using ecological controls in combination with some chemical methods to control pests and improve turf. For IPM a 'damage level' shall be tolerated which does not significantly reduce the acceptability of the turf. Successful Integrated Pest Management requires a knowledgeable staff, accurate record keeping and monitoring, and sound agronomic practices.

x______ An IPM plan has been developed by the superintendent The golf course manager has read and understood the plan.

- Frequent mowing at extended heights will promote deeper root growth and minimize leaf area. Reducing excessive leaf area reduces evapotranspiration. Increased root depth increases soil-moisture extraction.

x______ A mowing plan has been prepared by the superintendent

- Fertilization practices influence plant water use. Water use continues to increase with increases in the nitrogen application rate. Nitrogen fertilization every other month, as opposed to monthly has been shown to lower water use up to 13.5 inches a year with negligible aesthetic differences. Kentucky bluegrass has shown more substantial drought recovery with fall fertilization rather than spring. Additionally, fall nitrogen fertilization has been shown to produce more root weight than spring application.

x_____ Nitrogen use is to be minimized to an acceptable level and seasonally optimized. A fertilization schedule is prepared based on nutrient testing and seasonal needs. The schedule is flexible.

- Irrigation practices have been covered in preceeding sections.

IV. Socio–Cultural Norms checklist

- High water and chemical use on golf courses is in part due to unrealistic aesthetic expectations. A shift in cultural values must take place to ultimately lower golf course water use. Golfers use their wallets to influence the aesthetic conditions required on many golf courses.
- Cultural expectations may be shifted through education. An educated public is more likely to accept and deem beautiful the aesthetic implications of water conservation.

● The basis of a public education program is an understanding of the hydrologic cycle. The cycle shall be explained and understood in a local context. Human use of water should be included in the cycle.

x_____ Public education efforts teach local hydrology. The reasons to conserve water are given the same educational emphasis as how to conserve water.

● One solution, worth becoming an educational focus, is to embrace *Xeriscape*™ guidelines. *Xeriscape*™ emphasizes reducing the total amount of irrigated turf and promoting native and drought tolerant vegetation. This lays the groundwork for the shift in cultural expectations necessary to realize meaningful water conservation.

x_____ *Xeriscape*™ principles are used to teach how to conserve water in a landscape context.

V. Conclusion

Water comes to the golf course as precipitation or in a pipeline, and will either be stored or be in transit. Storage may occur in plants, soil, retention ponds, wetlands and groundwater. While in storage water interacts with its environment. Runoff, leaching, and evaporation are methods in which water moves through the golf course. While moving, water may be affected by vegetation and other ground covers as well as chemicals such as fertilizers and pesticides. Knowledge of the plant / hydrologic relationship forms the basis from which water conservation practices are created.

Water conservation requires a commitment to management and education during the golf course planning, construction, and operations phases. The three phases work together. With good planning, but poor construction or maintenance practices, it is impossible to realize planned conservation. With poor planning golf course maintenance personnel may be significantly crippled in their water conservation efforts. Followed diligently, these best practices will significantly benefit freshwater conservation on golf courses.

Case Study[1]

The Preserve Golf Club - Vancleave, Mississippi

[1] Steve Dana, Senior Design Associate with Jerry Pate Golf Design, was interviewed for this case study November 21, 2007.

Introduction

The Preserve Golf Club is exemplary with regards to wetland, storm water, and irrigation Best Management Practices. The course avoids runoff into wetlands and has efficient irrigation coverage. This was possible through diligent planning and multidisciplinary collaboration.

Best practices aim to keep pollutant laden storm water and drainage out of wetlands. This protects wetland water quality and preserves wetland ecological function. At the Preserve, drainage and runoff is directed to infiltration basins for cleaning and infiltration. Water does not flow into wetlands and other natural resource areas.

Irrigation coverage best practices were mandatory in the design process. No sprinkler overspray was allowed into wetlands, or any other non-golf area. The *Xeriscape*™ principle of reducing the amount of irrigated turf was utilized. Only golf play areas receive supplemental irrigation, while non-golf are maintained natively.

Background

After surviving Hurricane Katrina to open in 2006, The Preserve Golf Club in Vancleave, Mississippi was designated an Audubon International Silver Signature Sanctuary in May 2007. The Preserve is one of only 21 golf facilities in the world to receive this designation. Certification does not happen by accident. The voluntary Audubon Signature Program requires rigorous water conservation planning among other environmental measures. This case study illustrates the certification process with correspondence between consultants and Audubon International. Practices and procedures used by the golf course architect and other consultants to maximize water conservation are highlighted.

The course owner is Bill Mason. He purchased the golf course property because it was a large tract of land available near Biloxi, Mississippi. The development became affiliated with the Palace Casino in Biloxi during the financing process. The 245 acre golf course is adjacent to an 1800 acre long-leaf pine savannah owned and forever preserved by the Nature Conservancy. On the golf course site, 60 percent of the 245 acres are wetland. In a land swap, Mason traded a wetland tract of his property for a small upland portion of the Nature Conservancy property. This is the site of holes 14 and 15 today. Bill Mason envisioned the golf course as preserving its largely natural setting and leaving a small environmental footprint.

Jerry Pate Golf Design was brought into the project when problems were encountered routing the golf course with minimal wetland impact. The Corps of Engineers agreed that a maximum of seven acres of wetland impact would be sufficient for permitting. When the JPGD design called for 5 acres of impact, Ron Crizman, Chief of the Mobile, Al Regional Corps, agreed that this was a project that should be permitted. Wetland impact was later reduced to 3.5 acres (Dana, 2007).

To ensure permitting agencies this was a responsible project, Audubon International was brought in to oversee and eventually certify the golf course. Audubon International is a non-profit, environmental education organization. Its self stated mission is to be, “dedicated to educating, assisting, and inspiring millions of people from all walks of life to protect and sustain the land, water, wildlife, and natural resources around them.”

The Audubon Silver Signature program begins when a development project registers in the planning stages of the development. The program covers construction, the grand opening, and long-term management. The program begins with a site assessment conducted by Audubon International. A Natural Resources Management Plan is developed to serve as a construction and operations manual for the property. Audubon International conducts site visits throughout the project and trains construction and maintenance personnel. After opening, an on-site audit checks for compliance with Signature program requirements. Contingent upon audit results, a development may then become certified. Remaining certified depends on long-term management to Audubon Signature standards (Audubon International, 2007)

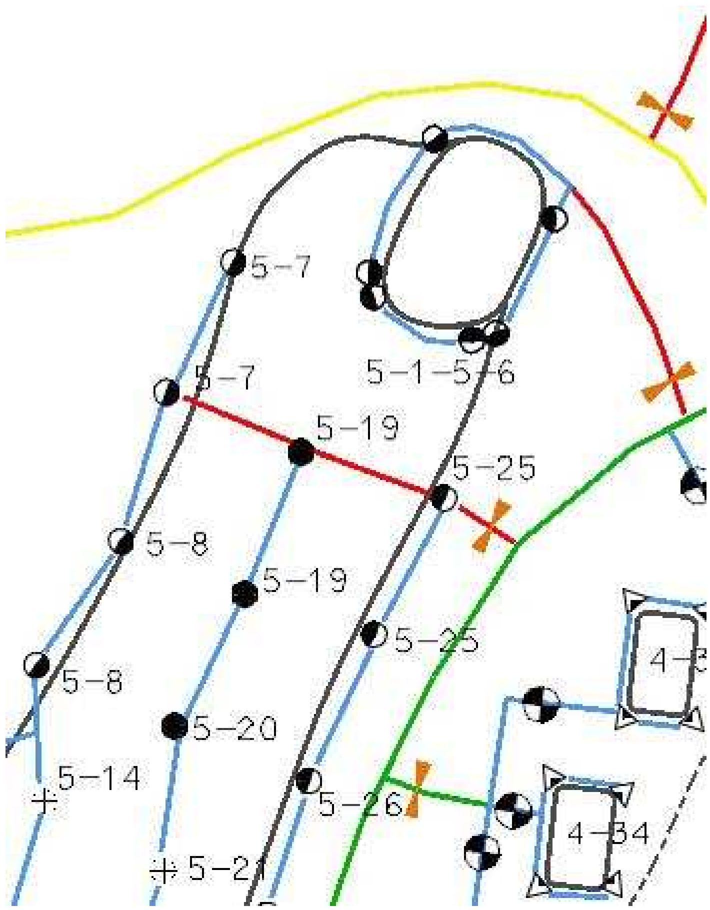
Planning and construction

The golf course irrigation system was designed by Jerry Pate Turf and Irrigation. JPTI distributes Toro irrigation and offers complementary design services. The company shares common ownership with Jerry Pate Golf Design. On May 7, 2003 Audubon International sent Jerry Pate Turf and Irrigation and Jerry Pate Golf Design a list of ten general minimum ways to achieve Signature certification. Requirements pertaining to water were: identifying and protecting habitats during and after construction, protect

Preserve GC and Nature Conservancy property, Winter 2007. © State of Mississippi

water quality during and after construction, minimize intensive maintenance and non-renewable resource use in course management, and install a proper irrigation system (Audubon Int'l 2002).

The irrigation plan was a subject of close scrutiny. An Audubon memo dated August 2003 to the irrigation design staff reported: "Many of the irrigation heads appear to throw water into the natural resources that we are trying to protect at the course. … Our goal for the irrigation system is that it puts the right amount of water in the right place, and hopefully, the superintendent will put water on the course at the correct times and in the correct quantity." Later the memo advises that golf course tee boxes can be covered more efficiently with four smaller heads placed at the corners of the tee than with one large head (Smart, 2003). To meet Signature program requirements overspray was not allowed into lakes, wetlands, or natural resource areas. Essentially the only area to receive irrigation water was the golf course play area.

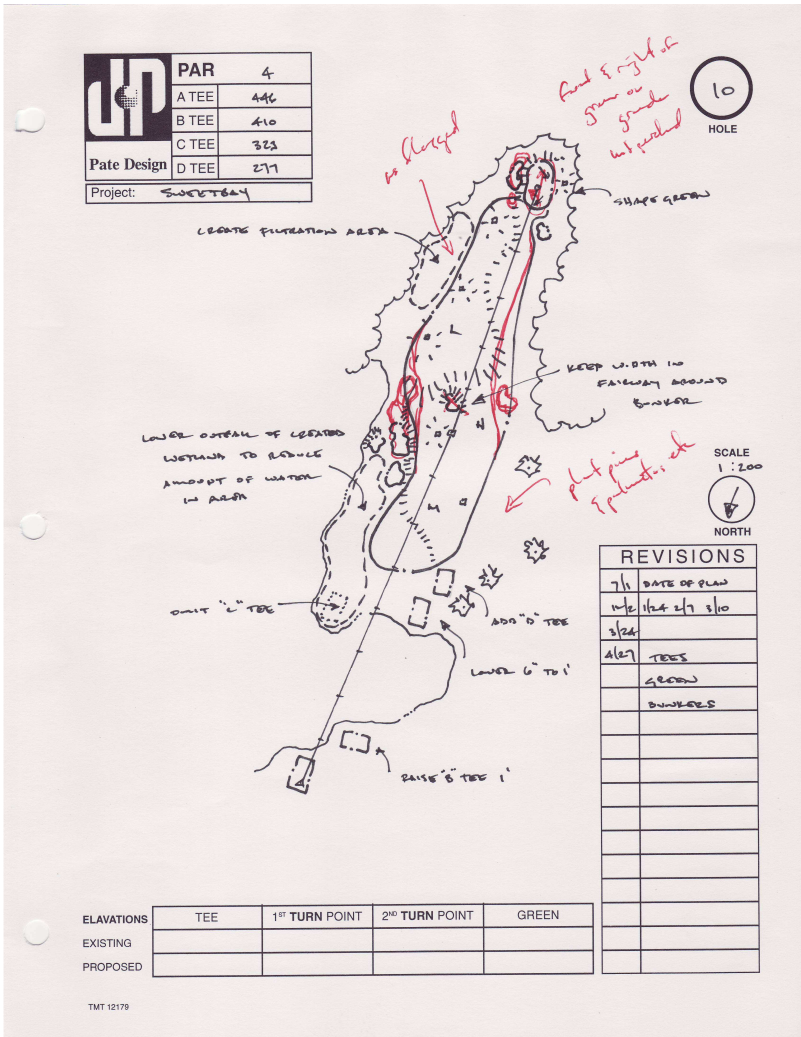


Portion of Preserve irrigation design © Jerry Pate Turf and Irrigation

In this example from the Preserve's irrigation design note that sprinkler heads 5-8 are placed on the edge of the golf play area throwing in. Full circle heads such as 5-20 are only used in the center of the play area where they will not throw off the golf course. Steve Dana reiterated that Audubon International was very concerned that *only* portions of the golf course in play would receive irrigation water. Sprinkler heads 4-34 illustrate a golf tee box irrigated by four small sprinkler heads throwing in. The importance of this design feature is that water meant for the tee box will only fall on the tee box.

In order to help the superintendent use the correct amount of water, a weather station was required for the irrigation system. The station chosen was a Campbell Scientific T-106. The station can measure local evapotranspiration and connect to the irrigations system's central controller to set precise watering schedules. It has rain and wind sensors to eliminate irrigation during inappropriate weather.

Dana noted the most difficult challenge with the project was finding enough drainage filtration basins. Audubon International did not want water leaving the golf course into wetlands or other protected areas. Water drained from the golf course must remain on the golf course. The solution was to daylight drain pipes into created wetlands where outflow could be slowed, cleaned, and infiltrated. Native seed was collected from the adjacent Nature Conservancy property to appropriately vegetate the new wetlands.



© Jerry Pate Golf Design

In this field note for the tenth hole, wetlands to be created are shown on the lower left and upper left of the fairway. Drainage basins, shown as a very small square, flow into these created wetlands. Surface drainage is directed into them as well (Dana 2007).

The hallmark of the Audubon certification process was the cooperation required from all parties. Agents from all consultants, contractors, permitting bodies, the Nature Conservancy, and Audubon International met often to plan and share information. This allowed the Preserve Golf Course Development to be managed effectively to minimize its environmental footprint.

Case Study

The Heritage at Westmoor Golf Course – Westminster, Colorado

Introduction

The Heritage provides a glimpse at effluent irrigation at a well managed, environmentally conscious golf course constructed in the late 1990s. As is the case with regulatory price supports in California, effluent irrigation here is more expensive than fresh water would be.

Several best management practices for effluent are utilized at the Heritage. Foremost is the attention given to safety. An aggressive employee and public risk education system is in place. Nutrient testing is a hallmark of the superintendent's maintenance process. The testing allows for soil additives and fertilization adjustments. Storage capacity is generous to allow for shortage and mandatory water receipt.

Background

The Heritage at Westmoor is an 18 hole municipal golf course in Westminster, Colorado, part of metro-Denver. A development company created a public-private partnership with the city. The company created an upscale office park and deeded adjacent land to Westminster. In return the city was required to build and operate a golf course on the property.

The course was designed by Michael Hurdzan and opened in September of 1999. Most of the golf course inhabits an open, prairie-like environment with a mountainous backdrop. Part of the site is leased from the local airport and must remain undeveloped. The remaining portion of the site was deeded by the developer and is designated as open space in the city charter (Hurdzan, 2007).

© HurdzanFry 2007 Hole 9

On the site, 90 acres are irrigated turf and 127 acres are native grasslands and open space. The golf course has been successful at getting migratory waterfowl to use the adjacent Walnut Creek shoreline, and 4.5 acres of interior lakes. A great blue heron rookery can be seen near Walnut Creek as evidence of this success. In October of 2002 the Heritage at Westmoor was designated a Bronze Audubon Signature Sanctuary (Audubon International, 2007).

Effluent Irrigation at the Heritage

The Denver area climate is semi-arid with an average annual precipitation of 14 inches. Drought conditions have been present from 2001-2007. During this period the population grew rapidly. This combination added to the already significant strain on local aquifers and surface water bodies. Before the drought, in the 1990s, the City of Westminster began a long range plan to incorporate effluent into its water use. It was felt this would help ease the demand on local freshwater resources. The city's new reclaimed water treatment facility began supplying water to the Heritage in September of 2000.

The golf course uses 90,000,000 gallons of effluent annually and no potable water for irrigation.

The use of reclaimed water was planned for from the initial stages of the project. During construction, when large quantities of purple pipe were not available, purple tape was used to mark trenches that would carry effluent. Valve boxes and sprinkler heads were also purple-coded. The irrigation system was designed to eliminate overspray off the property and minimize public contact with the system (Audubon International, 2007).

An irrigation lake was designed that would hold 10 million gallons of water. This provides a margin of safety when the effluent treatment facility is not in operation, and also allows the treatment facility the opportunity to serve other customers. The lake is lined in PVC and is not permitted to overflow except in the case of exceptional storm events (Johnson, 2007).

Public education and relations have been necessary to bring acceptance and added safety to the use of recycled water. Pamphlets providing information on the irrigation system are available in the pro shop. Signage throughout the site alerts people to the use of effluent. Course employees are alerted to the dangers of recycled water contact through brochures, while golfers are warned on the scorecards.

Contrary to many municipalities where effluent water is provided free of charge, recycled water carries significant costs at the Heritage. During the first year, with potable water, the course paid $70 an acre foot for water. In 2000 recycled water was $180 an acre foot and in 2007 the cost was $365 an acre foot. This created significant strain on the budget as the demand for effluent increased in the municipality and the number of rounds played has remained close to the same (Johnson, 2007).

Agronomically, high pH, high sodium, and elevated carbonate and bicarbonate levels were consistently present in the soil, requiring major adjustments. Reclaimed water is received with a pH value of 7.5. As the water sits in the irrigation lake this value may increase to 10, causing dry spots and poor soil permeability on the course. In an attempt to mitigate the effect of high pH, a sulfur burner was installed. The sulfuric acid generated controlled pH while significantly reducing carbonate and bicarbonate levels. A beneficial side effect was less algae in the lakes. High sulfur content in the soil had to be managed. Gypsum applications move remaining unwanted salts through the soil.

Nutrient levels in the recycled water have to be monitored closely to determine the correct nitrogen content for fertilization. Excess fertilization results in extra growth. When this occurs extra labor is required in the form of mowing, grooming, and top dressing. A black layer has been a predominate issue in putting green soil profiles that have significant surface drainage. Algae, solids in the water, sodium, and higher sulfate levels all contribute to the problem. Aerification, lime and gypsum applications, and extra flushing are all required to return the soil to a healthy medium for plant growth.

© Johnson 2007

To partially alleviate nutrient problems, Westminster is planning a 44 million dollar expansion to its wastewater treatment facility. In part to meet new regulations, the expansion will include a Biological Nutrient Removal process. This process will oxidize biomass to release ammonia and nitrogen into the atmosphere rather than the water supply (Johnson 2007).

Case Study

Water Education Program – Albuquerque, New Mexico

Introduction

Albuquerque's Water Education Program is exemplary with regards to best management practices. In addition to teaching how to conserve water, the program gives an understanding of why there is a water shortage. Targeted at youth, the program seeks to change cultural preferences in regards to water use.

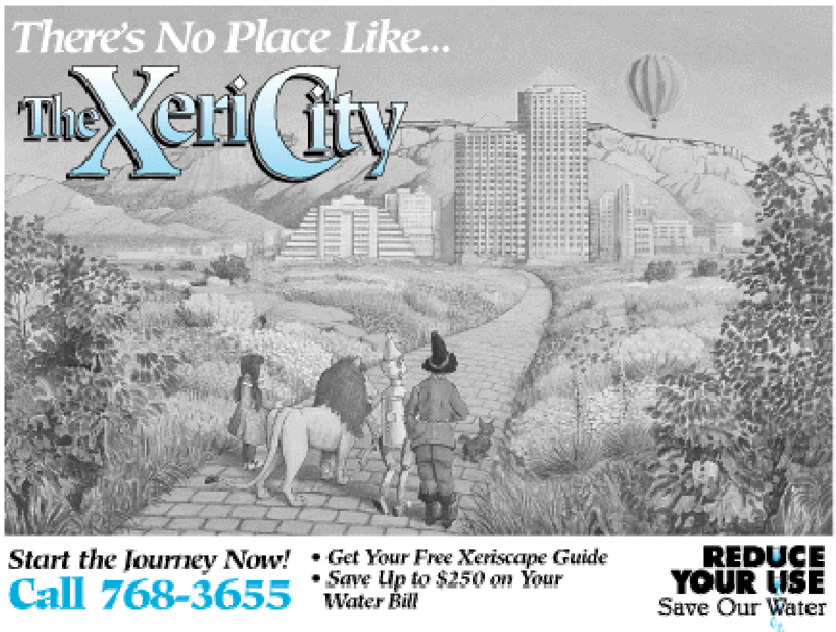
Perhaps the most exemplary education program focuses on the hydrologic cycle. This knowledge is presented in a local context so that it is personal. There is not a lot of water available to Albuquerque through the water cycle and conservation needs become readily apparent.

Background

The City of Albuquerque, through its Water Resources / Water Conservation Program, has a Water Education Program. The program, aimed at youth, seeks to change attitudes and perceptions on water use by teaching the hydrologic cycle.

Ground water is the only source of water for the City of Albuquerque. Considered desert, the city receives less than nine inches of rainfall a year. Only ten percent of this precipitation moves through the soil surface into the Albuquerque aquifer. Most of the water in the aquifer comes from snow melt in mountainous Colorado and northern New Mexico. The snow makes its way into the Rio Grande where it may penetrate the river bed to become a part of the aquifer. People in Albuquerque are currently using more water per capita than many other major cities in the southwest. The water from the aquifer is being depleted (Earp, 2006).

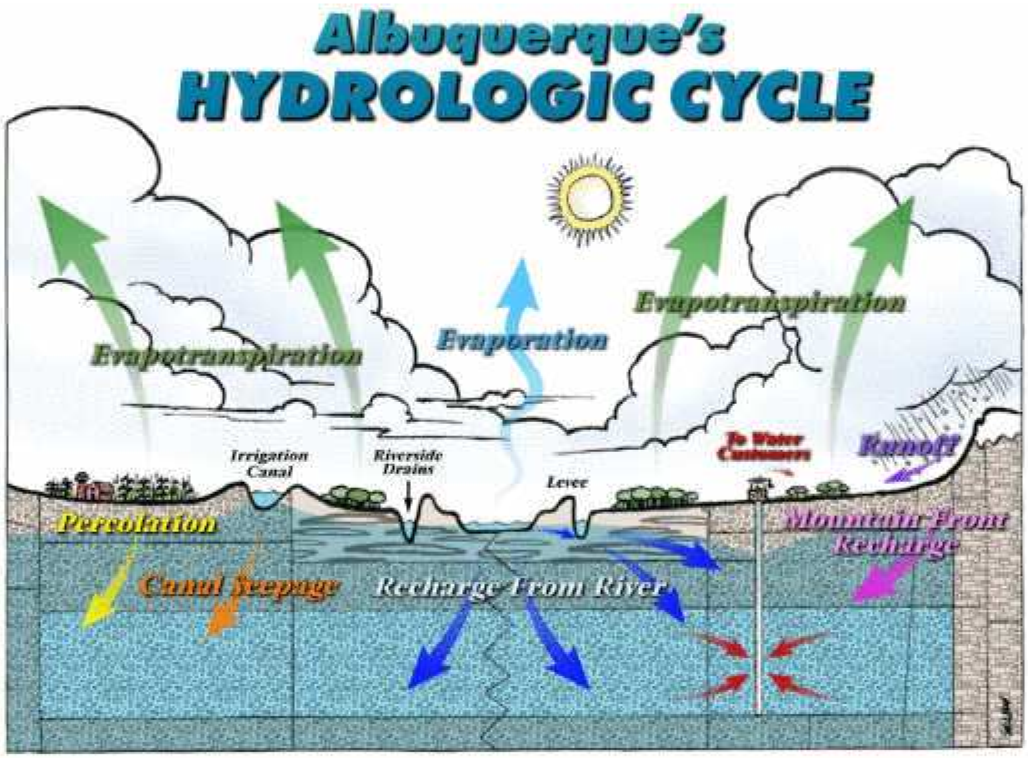
The city has both direct and indirect strategies to reduce water consumption by 30 percent. Direct, active strategies, include an amendment to the Plumbing Code requiring low flow fixtures in new residential construction; a toilet rebate program replacing over 22,000 toilets, , and a free water audit/retrofit program. A *Xeriscape*™ Incentive Program started in 1996 targets the estimated 30 percent of the city's water that goes to irrigation.



Water Education Program

These direct measures do not change the culture that led to overuse of water resources. This culture is changed through water conservation education. The city believes their water future depends on developing healthy habits and attitudes towards water use and protection. The Water Resources Division, through its Water Education Program, is placing an emphasis on educating young people. Presentations using groundwater flow models help students understand how the Albuquerque Aquifer recharges and stores water. This knowledge allows students to understand *why*, in addition to *how*, to conserve water.

The program began in 1994 and targets local elementary, middle, and high schools. Presentations are grade level appropriate and cover Albuquerque's water cycle, conservation, groundwater protection, and the city's long range water strategy. Various materials used for education are coloring books, a water cycle poster, and logo pencils and stickers (American Water Works Association, 2007).



© Friends of Albuquerque's Environmental Story, 2006

The Water Education Program costs $95,000 annually and has one full time employee. It is funded through city water utility revenue. The stated objectives of the program, listed in Council Bill No. R-173, are a long term water conservation strategy and to reduce water consumption by 30 percent.

The program's contact person, Roberta Haynes-Sparks, notes that there are many effective components being utilized. Reading and coloring materials specific to Albuquerque are popular among students. Hands-on activities such as making mini aquifers allow students to easily grasp the groundwater flow model. Live theater productions related to water conservation tour the local schools for five to six weeks each year. The program is rated for effectiveness by teachers and students annually.

Haynes-Sparks notes that the Water Education Program could be improved by adding a teacher training component (American Water Works Association, 2007).

With public education efforts such as Albuquerque's, golf course aesthetic expectations will become more sustainable over a generation. To fast forward the cultural change process, education efforts targeted at youth can be supplemented with educational efforts directed specifically to golfers. Keeping in mind the successes of the Water Education Program, such educational efforts should teach local, golf course specific, site hydrology. Golf course specific water conservation education can use graphics to communicate water-use statistics. These statistics and graphics can then be adjusted to paint a picture of a more water-wise golf course aesthetic.

Conclusion

Integrating water conservation strategies that incorporate emerging technology and proactive design and management is necessary to combat freshwater shortages. The nine areas of freshwater conservation on golf courses identified are:

1. irrigation site design and management
2. irrigation systems for water conservation
3. effluent wastewater use on turf
4. desalination
5. wetlands
6. cultural practices
7. turfgrass water use
8. stormwater management
9. water quality

The Best Management Practices, by going in depth in each of these nine areas, give a practical, achievable plan for water conservation.

The hydrologic cycle is the basis for water management practices. Water falls on the golf course as precipitation or irrigation. It will either infiltrate or run off. Water that infiltrates the surface may be stored in soil for use by plants, or percolate beyond a usable point for plants and perhaps flow into groundwater. Runoff may be slowed by vegetation and infiltrate or evaporate. Runoff may flow into a surface water body. Surface water bodies receive subsurface groundwater flow in addition to surface runoff. Surface water evaporates, flows off the golf course, or is collected by man.

Water on golf courses may be wasted at every point in the hydrologic cycle. Precipitation and irrigation shall be combined in a manner that water infiltrates only to the plant root zone in the amount necessary for healthy growth. Irrigation can be fine tuned with equipment, design, and management to make this very precise.

Aggressive efforts should be made to reduce and eliminate runoff. Where runoff does occur in minor or major flood events, it shall be slowed and contained. This assists infiltration and promotes clean water. Water quality faces serious risks from chemical and sediment pollution during runoff events on a golf course. A chemical management program is critical to protect against water pollution. Appropriate vegetation slows runoff and cleans pollutants.

Surface water bodies serve a vital cleaning and storage function. Wetlands should be managed to have hydrophytic vegetation to clean pollutants. They shall be buffered from the golf course proper. At a minimum a golf course should store flood events at pre-development levels. Protection against 100 year storms is preferred.

Freshwater may be further conserved by not using it on a golf course. Recycled water is viable for use in golf irrigation. Effluent presents water quality and plant health risks, and must be well managed.

Responsible water use on golf courses has been hit and miss in the past. The case studies identify golf courses and a city where best management practices are being used. The Preserve Golf Club demonstrates that different water conservation principles are very closely related. Containing storm and drainage runoff and limiting irrigation to only golf each help to keep wetlands pristine. This illustrates that golf courses are part of a system. For meaningful conservation to occur, attention can not be given to only one aspect of water conservation, but instead to the entire system. Albuquerque, New Mexico has an excellent public education system in place that teaches water use as a cycle, or system. By teaching how human over-consumption of water resources makes the hydrologic cycle unsustainable, cultural preferences are changed for generations.

One of the reasons Albuquerque's Water Education Program has been successful is that it is presented in a local context, making it more personal. The need for a local, adaptable focus is a fact of life for turfgrass managers. At the Heritage at Westmoor Golf Course effluent creates highly unique nutrient content in the water. Testing indicates the need for soil additives and fertilization adjustments. To take advantage of the freshwater conservation benefits of effluent a proactive approach depending on complete knowledge is necessary.

All of the case studies bear testament that Best Management Practices, when followed, do have water conservation benefits. The Preserve and Heritage relied on guidelines set forth by the Audubon Cooperative Sanctuary program. The city of Albuquerque, by necessity, has had to create its own guidelines.

Irresponsible water use combined with persistent drought has brought water conservation to the forefront of peoples' minds. In the last decade Lake Mead in Nevada has faced historic water shortages. In the summer and early fall of 2007 Lake Lanier, Atlanta's drinking water source, neared its record low. As states and municipalities deal with water shortage, golf courses quietly wonder where they fit into the picture. Courses can and should conserve more water than they are currently. Whether in time of shortage or flood, water is not a renewable resource. Two philosophies from the literature summary, *Xeriscape*™ and adjusting cultural norms, bear repeating as the essence of the BMPs.

Xeriscape™ is a combination of the landscaping principles planning and design, soil improvements, efficient irrigation, zoning of plants, turf alternatives, and appropriate maintenance. Combined, these principles ensure that the water required for a healthy, natural golf landscape is at a bare minimum.


Lake Mead, August 2003. © K. Dewey, High Plains Regional Climate Center

A shift in cultural values must take place to ultimately lower golf course water use. The current expected aesthetic for golf courses is a lush, green, artificial carpet. This is out of line with nature, unsustainable, and different from the game's Scottish origins.

●

Cultural expectations may be shifted through education. An educated public is more likely to accept and deem beautiful the aesthetic implications of water conservation.

●

December 9, 2007

The practices herein reflect the best steps for freshwater conservation on golf courses to my knowledge at this time. Best practices will undoubtedly change over time. There is a demand for improved water-use efficiency that is being met. Sources at Toro

Irrigation[2] tell me research is being conducted on placing computer chips in sprinkler heads. Water use restrictions may soon eliminate the option of using potable water for golf courses. The practices outlined are meant for use today.

Golf course owners and developers have the authority to see that these BMPs are utilized. At a developer's request, consultants, golf course management, and the site superintendent will all play a role in ensuring progressive water management one golf course at a time.

In addition to the course owner, golf course architects and irrigation designers are obligated to see that best practices are followed for their client. Environmental education organizations should use these practices as a reference as they create more customized and applied practices for clients. Lastly, the golf course manager and superintendent, by following these BMPs in everyday operations, will ensure a future for golf in a time of water shortage.

---

[2] Jerry Pate Turf and Irrigation, my employer, is a distributor of Toro products.

References

Allen, Jesse. 2003. Drought Lowers Lake Mead. NASA Earth Observatory. www.earthobservatory.nasa.gov/study/LakeMead.

American Water Works Association. Case Study: Albuquerque, New Mexico's Water Education Program. www.awwa.org/waterwiser. 2007.

Arizona Department of Water Resources (1999). Third Management Plan 2000-2010 Phoenix Active Management Area. Phoenix, Arizona.

Audubon International. 2007. www.auduboninternational.org/programs/signature.

Balogh, J. C., and J. Watson (1992). Role and Conservation of Water Resources. Golf Course Management and Construction: Environmental Issues. J. C. Balogh, William J. Walker. Chelsea, MI, Lewis Publishers.

James Barrett. a Vinchesi, Brian. a. Dodson, Robert. a. Roche, Paul a. Zoldoske, David (2003). Golf Course Irrigation: Environmental Design and Management Practices. Hoboken, New Jersey, John Wiley & Sons, Inc.

Beard, J.B. (1985). An assessment of water use by turfgrasses. Turfgrass Water Conservation. V. B. Y. a. S. T. Cockerham. Oakland, California, Cooperative Extension University of California.

Beard, J.B. (2002). Turf Management for Golf Courses. Chelsea, Michigan, USGA.

Bruneau, A. H. (1995). Water Quality and Golf Course Superintendents. Raleigh, North Carolina, North Carolina Cooperative Extension Service.

Buros, O.K. e. a. (1982). The USAID Desalination Manual. Englewood, N.J., IDEA Publications.

Cowardin, L. M., V. Carter, F.G. Golet, E.T. LaRoe (1979). Classification of Wetlands and Deep Water Habitats of the United States. U. S. F. a. W. S. Publication, FWS/OBS-79/31.

Dana, Steve. 2007. Interview by Eric Schade, November 21, 2007.

denverwater.org (2004). Xeriscape Principles. Accessed 10/30/2004, http://www.denverwater.org/cons_xeriscape/cons_xeriscapeframe.html.

Dines, N. a. K. B. (2001). Landscape Architect's Portable Handbook. New York, McGraw - Hill.

Earp, Doug. Albuquerque's Environmental Story: Educating for a Sustainable Community. Friends of Albuquerque's Environmental Story, Albuquerque. www.cabq.gov. 2006.

Environmental Protection Agency, N. (2000). Stormwater Management for Golf Courses. Sydney, Australia, Environmental Protection Agency, New South Wales**:** 9.

Robert Evans and Sneed, R. E. a. Hunt., J.N. (1996). Irrigation Strategies to Improve Water and Energy Use Efficiencies, North Carolina Cooperative Extension Service, AG 452-5.

Ferguson, B. K. (1998). Introduction to Stormwater. New York, John Wiley & Sons.

Garrett Gill and Rainville, D. (1994). Effluent for Irrigation: Wave of the Future? Wastewater Reuse for Golf Course Irrigation, United States Golf Association.

Hammer, D. A. (1997). Creating Freshwater Wetlands. Chelsea, MI, Lewis Publishers.

Hurdzan, Michael. www.hurdzanfry.com. 2007.

Johnson, Lance. 2007. Reclaimed Water Use at the Heritage at Westmoor Golf Course. www.eifg.org. Golf Course Superintendents Association of America.

Kneebone, W. R. a. Pepper, I.L. (1982). "Consumptive water use by subirrigated turfgrasses under desert conditions." Agronomy Journal **74**: 419-423.

Koelzer, V. A. (May 1972). Desalting. National Water Comission.

Kosian, P. A., M Balogh, R Tietge (1992). Wetlands and Golf Courses. Golf Course Management and Construction: Environmental Issues. J. C. Balogh, William J. Walker. Chelsea, MI, Lewis Publishers.

Libby, G., D. F. Harker, Kay Harker (2004). Managing Wetlands on Golf Courses. Hoboken, N.J., John Wiley & Sons.

Long, T. (1994). Barton Creek Wastewater Case Study. Wastewater Reuse for Golf Course Irrigation, United States Golf Association.

McCarty, L. B. (2001). Best Golf Course Management Practices. Upper Saddle River, New Jersey, Prentice Hall.

Jewell L. Meyer and Camenga, B. C. (1985). Irrigation systems for water conservation. Turfgrass Water Conservation. San Antonio, Texas, ANR Publications.

Nassauer, J . (1995). Cultural Sustainability: Aligning Aesthetics and Ecology. Placing Nature. Joan Nassauer. Washington D.C., Island Press.

National Research Council (1992). Restoration of Aquatic Ecosystems. Washington D.C., National Academy Press.

Olson, C. O. (1985). Site design for water conservation. Turfgrass Water Conservation. San Antonio, Texas, ANR Publications.

Peacock, C. H. (1994). Wastewater Irrigation for Golf Courses: Advantages versus Disadvantages. Wastewater Reuse for Golf Course Irrigation, United States Golf Association.

"Permit problems getting serious, say architects." (1990). Florida Green (Summer: 16-18).

Reisner, Marc. Cadillac Desert: The American West and Its Disappearing Water. New York: Penguin, 1993.

Rossillon, J. P. (1985). Water: Whose is it and who gets it? Turfgrass Water Conservation. San Antonio, Texas, ANR Publications.

Sachs, P. a. L., Richard (2002). Ecological Golf Course Management. Chelsea, MI, Sleeping Bear Press.

Shearman, R. C. (1985). Turfgrass culture and water use. Turfgrass Water Conservation. V. B. Y. a. S. T. Cockerham. Oakland, California, Cooperative Extension University of California**:** 61-70.

Smart, Miles. 2003. Letter to Bill Mason, 25 August 2003. Jerry Pate Golf Design records.

Stormwater BMP Handbook (2003). California Stormwater Quality Association.

Strom, S. a. Nathan, K. (1998). Site Engineering for Landscape Architects. New York, John Wiley & Sons.

Thompson, J. W. a. Sorvig, K. (2000). Sustainable Landscape Construction: A Guide to Green Building Outdoors. Washington, D.C., Island Press.

UNEP (1997). Source Book of Alternative Technologies for Freshwater Augmentation in Latin America and the Caribbean. Washington D.C., Unit of Sustainable Development and Environment. General Secretariat.

U. S. Congress, (March 1988). Using Desalination Technologies for Water Treatment. O. o. T. Assessment, U.S. Government Printing Office. **OTA-BP-O-46**.

U.S.G.A. (1995). Golf and Water Quality.

Watershed Protection and Development Review Department, City of Austin. (2005). Preliminary Report on Storm Water Runoff from Effluent- Irrigated Golf Courses. Austin, TX.

Yates, M. V. (1994). Monitoring Concerns and Procedures for Human Health Effects (Effluent). Wastewater Reuse for Golf Course Irrigation, United States Golf Association.