Constructed Wetland Filter Use for Controlling Nutrient and Sediment Runoff from Golf Course Developments

Yasin Çağatay Seçkin
College of Architecture
Istanbul Technical University
Turkey
cseckin@itu.edu.tr

Abstract: Interest in the control of pollution entering into waterways has risen significantly since the last quarter of 20th Century and golf course developments have been identified as areas that use some of the chemical pollutants found in these waterways. Runoff control of pollutants from golf course developments is vital in assuring clean waterway systems for the future. This study investigates the runoff issues that can be related to golf course turf grass systems and their control through use of wetland filters. Three issues addressed in this study are suspended sediment, nitrogen, and phosphorus levels contained in turf grass runoff. Sediment runoff levels were found to be low to moderate for turf grass systems, while nutrient transport in runoff from turf grass areas can become a significant problem. Constructed wetland filtration systems were investigated as one potential method for controlling turf grass runoff. The design and construction of these wetland filters was investigated to determine their potential for filtering runoff from golf course facilities. Data showed that significant levels of runoff sediment and nutrient pollution could be removed if proper design and construction processes are followed.

Information

The game of golf as it is known today originated in the British Isles hundreds of years ago (Love, 2008) and as knowledge of the game spread, it became increasingly popular, and by the early 1900s had begun to experience tremendous growth. Depending on this growth, the importance of the field of turfgrass science was realized, and the associations, such as USGA or EGU, began sponsoring publications and research through the embodied departments or independent organizations (Beard, 2002).

Since the beginning of this process, great steps have been taken to make turf grasses on golf courses the finest of all turfgrass areas. Intensive management practices have resulted in turfgrass areas becoming denser, softer, shorter and greener than previously thought possible. It is needless to say that, for reaching this result, considerable quantities of pesticides and fertilizers are used annually on golf courses throughout the World. The fate of these chemicals can be traced to the creeks, streams, lakes, and groundwater aquifers and the major environmental consequence of these intensive maintenance practices is the potential degradation of adjacent waterways and groundwater aquifers from chemical and nutrient runoff.

Runoff Issues

Runoff can be defined as any surface flow that may occur on turfgrass, soil, or other related surfaces after evaporation, interception, infiltration, plant uptake, and detention storage has been satisfied. Runoff events typically occur after:

- Extended periods of rain in which the soil profile becomes saturated and incapable of storing further water molecules.
- During rain or irrigation events in which precipitation rates exceed infiltration rates of soil.
- On areas with extreme slopes where gravity flow provides a quicker gradient for water movement than soil infiltration.
- On surfaces where soil structure is extremely exposed and compacted so that water cannot readily be absorbed.

These forms of surface runoff are typically the means by which pollutants from golf course developments enter into the waterways and groundwater aquifers. In most cases, sediment runoff is identified as a potential guilty in the pollution of these waterways and aquifers, but more serious problems are posed by the potential eutrophication of downstream lakes and slow-moving water bodies by the nutrients that attach themselves to these soil particles (Balogh et al, 1992).

Turfgrass management practices can have a direct effect upon runoff events and the levels of pollutants that they transport. Nitrogen (N), phosphorus (P), and potassium (K) are the nutrients most widely applied through use of fertilizers on golf course turfgrass areas. Especially, nitrogen (N) and phosphorus (P) are two of the most important nutrients used for the establishment and maintenance of golf course turf. Nitrogen is needed in the largest amount by turfgrass plants. This nutrient is essential for shoot growth, green-up, hardiness, rate of growth and shoot density. Phosphorus is vital to energy transformations in turfgrass plants and is key in turfgrasss establishment, rooting, growth and reproduction (Beard, 2003).

Ideally, all of the fertilizer applied on golf course turf has to be taken up by the plants. But, extended periods of rain, irrigation system malfunction, extreme slopes or extremely compacted soils can cause nutrient runoff into the waterways. It is very crucial to control this kind of runoff from polluting the waterways. According to an USGA-sponsored research, nutrient runoff poses a greater threat to water quality than leaching (Kenna and Snow, 2000) and wetlands provide an effective control of nutrients (Vadineanu, 2005).

Sediment and Nutrient Removal by Wetland Systems

By definition, wetlands are regions that are flooded or saturated by either surface water or ground water often and long enough to support both flora and fauna specially adapted to saturated soil conditions (LaFlamme, 2005). They receive water from surrounding lacustrine systems, precipitation, groundwater and runoff. They act like a giant sponge absorbing water during wet periods and releasing water during dry periods of the year. In addition, wetlands can be considered as the kidneys of the planet since they have the ability to filter out pollutants, transform nutrients and serve as sinks for many compounds (Jordan et al., 1999).

As well as natural wetlands, there exist constructed wetlands. These wetlands are mainly constructed with the purpose of treating wastewater. Constructed wetlands are capable of providing many of the same basic operational benefits of a natural wetland, but with a much greater degree of efficiency and control (Dodson, 2005).

Natural wetlands have been used as convenient wastewater discharge sites for as long as sewage has been collected. But, wetlands constructed for the purpose of treating water have a much shorter history. The worldwide spread of this technology originated from research conducted at the Max Planck Institute in West Germany, starting in 1952 (Bastian and Hammer, 1993; Sakadevan and Bavor, 1998; Verhoeven and Meuleman, 1999) and in the western hemisphere during the 1970s. Implementation of wetland technology has been accelerating around the world since 1985 and now there are many thousands of treatment wetlands across the globe (Kadlec and Wallace, 2009).

Constructed wetlands control water runoff velocities so effectively that they can provide major sinks for suspended sediment. The removal of sediment from golf course watersheds is the first step in providing cleaner water to adjacent ecosystems.

Recently, the use of construction wetlands as a means of reducing NPS pollution has garnered more attention. Constructed wetlands assimilate nutrients at remarkable levels and utilize added nutrients to increase net wetland productivity. The rate at which wetlands are able to assimilate these nutrients is dependent on four basic factors (Bayley, 1985):

- The hydrologic cycle or regime.
- The oxidation-reduction state of the soil.
- The nutrient levels currently in soil.
- The soil organic material content.

If properly designed to satisfy these four factors, the wetland filtration system can be efficient in the removal of nutrient pollutants. However, to be truly effective, constructed wetlands must be carefully designed, constructed, monitored, and maintained.

Guidelines for Constructed Wetlands on Golf Courses

For any constructed wetland filtration system to operate correctly, it must be first sited and designed properly. The design process used by many golf course architects is a viable means of accomplishing this goal. The basic design process involves the following steps: (1) inventory, (2) analysis, (3) design, (4) construction, and (5) management. If these five steps are correctly instituted into the use of wetland filtration systems on golf courses, it will insure the designer of an efficient wetland filter design, effective incorporation into the golf course facility, and the most cost effective wetland filter location.

Inventory

The designers use the inventory process to identify existing site features and site conditions. These features and conditions are important for developing a wetland filtration system.

First of all, determination of the effective drainage area that any wetland system will be filtering is a critical factor in the overall design process. The effective drainage area is the land from which water will runoff into a water body in a typical year. This must be identified for runoff calculation and wetland sizing purposes. Effective drainage area is one of the important parameter of the Rational Method, which is widely practiced in runoff calculation and the formulation is presented as follows (Seçkin, 2004):

$$Q = 0.00277\ C\ i\ A$$

Q = peak flow (m^3/s)
C = runoff coefficient (dimensionless)
i = precipitation intensity (mm/h)
A = effective drainage area (ha)

After calculating the runoff, next challenge is to find out how big a constructed wetland will be necessary to treat the first flush of polluted runoff from the golf course. As well as turfgrass or meadow areas, residential and commercial neighborhoods may also be located in the same watershed as the golf course facility, and may contribute significant nutrient loading levels to wetland filtration systems. Therefore, watershed areas that contain man-made landscapes such as residential neighborhoods, commercial developments or roadway systems must be included in the sizing of any wetland filter. If wetland filtration systems receive excess nutrient loading, the efficiency level of pollutant filtration will drop in significantly.

Soil type and existing site vegetation also needs to be included in this inventory activity. The location of these features is needed to assist in determining the best wetland filtration system location. In addition to these, the golf course's hole routing will play a major role in the location of a wetland filtration systems. Wetlands should be located as amenities to the golf course, thus proper hole location is critical for identifying runoff problem areas and creating strategic golf hole layouts.

Analysis

The location of existing site features and their potential relationship to the golf course and watershed areas is a key element in this process. Environmentally sensitive areas and natural drainage systems must be evaluated and identified so that proper wetland location and integration into the golf course development can occur. Calculation of nutrient removal levels to determine the feasibility of utilizing a wetland filtration system on a golf course development is a key evaluation step in this process. Here, it is important to note that there must be enough water in the wetland to maintain saturated soils and emergent plants. Additional volume within the wetland may be needed if the frequency of runoff will not create continuously moist soil conditions to provide habitat in which emergent plants can flourish (Melby and Cathcart, 2002).

Storage volume and water elevations can be calculated using the following formula (Hammer, D, 1997):

$$\Delta V = V + I - E$$

$$\Delta L = L + \Delta V / A \times D$$

V = volume of storage
I = inputs, E = exports
L = water level or elevation
A = area of the wetlands

D = depth

Design

The design process involves the actual implementation of the site inventory and site analysis information. Once the ideal site is found and the wetland filter size figured, incorporation of the wetlands into the golf course can begin.

Wetland features can serve as excellent hazards on golf course facilities, and the interaction of wetland and golf course correctly can greatly enhance the strategic aspects of the golf course and the enjoyment of a round of golf. These interactions should be diagrammatically highlighted since alteration of the course or wetland may be necessary to achieve the desired results.

Wetland vegetation selection is one of the most vital components of design process. Vegetation plays a vital role in wetlands, as they provide a suitable environment for microbial growth and filtration. The vegetation provides oxygen to the bacteria located in its root zone. It also maintains the permeability of the growth media. The stem and leaves in the water column promote sedimentation and provide a substrate for the growth of beneficial microorganisms (State of Georgia, 2002). In addition, plants add greatly to the aesthetic value of the wetland (USDA, n.d.).

Besides vegetation, many factors should be evaluated and incorporated into the process, when designing a wetland filtration system. Some of the more critical factors are listed below (Mitsch, 1993):

- Utilize the natural energies of the watershed systems.
- Incorporate the wetland system into the existing landscape.
- Provide sufficient buffering from areas, which experience heavy pedestrian or vehicular traffic.
- Design the system for ease of maintenance.
- Orient the wetland filtration system so that the greatest level of runoff flow runs parallel to the wetland.

If these factors are met in the design layout, the incorporation of the wetland filter into the landscape could easily be provided as well as successful filtration of runoff.

Construction

After the site inventory, analysis and design processes have been completed; the site can be directly evaluated for construction purposes. Existing topsoil may be suitable as a substrate base for wetland filtration systems. If the topsoil is not predominantly clay or sand then it will most likely work as an effective rooting base. This soil should be scrapped from the site and stored in an appropriate location for later use. Reuse of this soil will drastically reduce construction costs.

In addition, to protect existing environmentally sensitive areas and to prevent excessive soil erosion into adjacent drainage ways, proper Best Management Practices (BMP) for erosion control must also be instituted before any construction begins.

Wetlands are frequently constructed by excavating, backfilling, grading, diking and installing water control structures to establish desired hydraulic flow patterns. If the site has highly permeable soils, an impervious, compacted clay liner is usually installed and the original soil placed over the liner. Wetland vegetation is then planted or allowed to establish naturally (U.S. EPA, 2004).

After initial plant selection and rough grading of the site, any stockpiled topsoil material can be distributed in the planting zone areas. The best soil for plant establishment is usually a fertile loam or organic soil with a little sand content. Heavy clays should be avoided due to natural settling and compaction, which can make initial vegetation rooting and eventual spreading difficult. The plants should be well established before any wastewater is added to the system. A minimum of 4 to 6 weeks should be allowed for plant establishment after planting before wastewater is added to the wetland (State of Georgia, 2002).

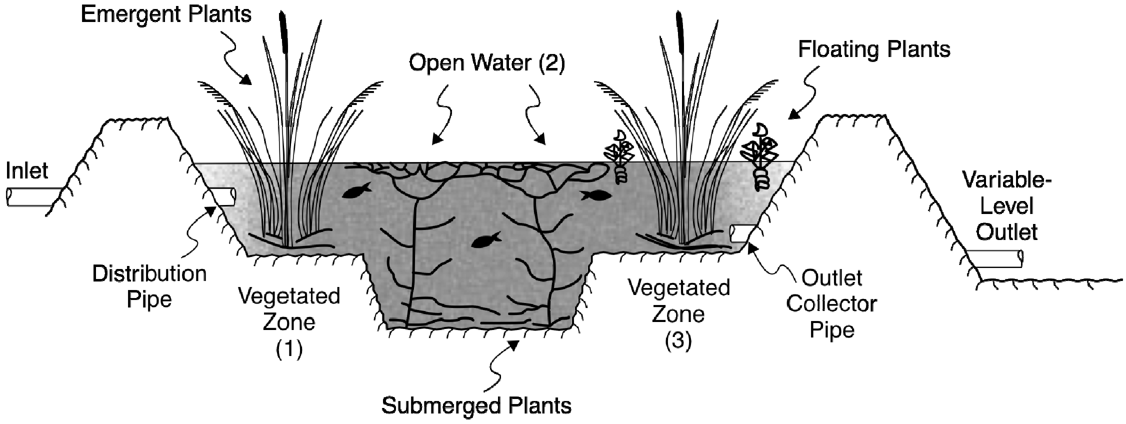

Figure 1: Profile of a free water surface (FWS) constructed wetland (U.S. EPA, 2000).

Management

Wetland management is vital issue for assuring proper wetland filter function. Wetland systems are not capable of establishing themselves within short periods of time. For example, additional vegetation planting may be required to speed plant coverage, replace damaged plants or to try more suitable varieties. Maintenance may also be needed to control the spread of undesired plant species. In addition, inlets and outlets can become blocked with debris, which will require periodic removal. Inlet and outlet structures should be inspected regularly and especially following big storm events (Jones, 1997). Furthermore, proper turfgrass management practices must occur so that the wetland filtration system does not experience extreme sediment or nutrient loading.

Conclusion

Water bodies are important strategical areas on most all golf course facilities. These water bodies can provide the golf course architect with a potentially beautiful amenity to use in creating their golf course design goals. To the player, these can become strategical features that must be negotiated in order to achieve an acceptable score. These water bodies can also act as signatures by which the golf course would be remembered, carrying its influence beyond the property of the facility. In other words, water features have and always will be important features in a golf course development; this includes wetlands.

Constructed wetlands have been implemented as wastewater treatment facilities in many parts of the world and the wetlands used on a golf course have the potential for accepting, storing and filtering runoff from within the course and from neighboring areas. Today, some golf course developments are experimented with wetlands to filter irrigation runoff for reuse on the course, but the environmental significance of this type of use of constructed wetlands is minor at best. Golf course architects and superintendents must do more to insure the safety of the waterways. It is one of the important jobs of every superintendent to insure that the level of runoff is minimized as much as possible. This is where wetland filtration systems become a valuable amenity on golf course developments. It is time that the golf industry makes an effort to support the study and development of methods for controlling runoff from golf course turfgrass systems, so that the future popularity of the game of golf and the health of our environment will be assured.

References

Balogh, J.C., Gibeault, V.A., Walker, W.J., Kenna, M.P. & Snow, J.T. (1992). Background and Overview of Environmental Issues, In J.C. Balogh & W.J. Walker (Ed.), *Golf Course Management & Construction: Environmental Issues* (pp.1-38). Boca Raton, FL: CRC Press.

Bastian, R. & Hammer, D. (1993). The Use of Constructed Wetlands for Wastewater Treatment and Recycling, In G. Moshiri (Ed.), *Constructed Wetlands for Water Quality Improvement* (pp.59-65). New York, NY: CRC Press.

Bayley, S.E. (1985). The Effect of Natural Hydroperiod Fluctuations on Freshwater Wetlands Receiving Added Nutrients, In P.J. Godfrey, E.R. Kaynor, S. Pelczarski & J. Benforado (Ed.), *Ecological Considerations in Wetlands Treatment of Municipal Wastewater* (pp.180-189). New York, NY: Van Nostrand Reinhold.

Beard, J.B. (2003). *Turfgrass: Science and Culture,* USA: Pearson US Imports & PHIPEs

Beard, J.B. (2002). *Turf Management for Golf Courses*, Chelsea, MI: Ann Arbor Press.

Dodson, R.G. (2005). *Sustainable Golf Courses: A Guide to Environmental Stewardship*, Hoboken, NJ: John Wiley & Sons.

Hammer, D.A. (1997). *Creating Freshwater Wetlands*, Boca Raton, FL: CRC Press.

Jones, W.W. (1997). *Design Features of Constructed Wetlands for Nonpoint Source Treatment*, USA: U.S. EPA and the Indiana Department of Environmental Management

Jordan, T., Whigham D., Hofmockel, K. & Gerber, N. (1999). Restored wetlands in crop fields control nutrient runoff. In J. Vymasal (Ed.), *Wetlands-Nutrients, Metals and Mass Cycling* (pp.49-60). Leiden, The Netherlands: Backhuys Publishers.

Kadlec, R.H. & Wallece, S.D. (2009). *Treatment Wetlands*, Boca Raton, FL: Taylor& Francis.

Kenna, M.P. & Snow, J.T. (2000). The United States Golf Association Turfgrass and Environmental Research Program Overview, In J.M. Clark & M.P. Kenna (Ed.), *Fate and Management of Turfgrass Chemicals* (pp.2-35). Washington DC: American Chemical Society.

LaFlamme, C. (2005). *Nutrient removal using a constructed wetland in Southern Québec*, Montreal, Canada: McGill University.

Love, B. (2008). *An Environmental Approach to Golf Course Development*, Brookfield, WI: American Society of Golf Course Architects.

Melby, P. & Cathcart, T. (2002). *Regenerative Design Techniques: Practical Applications in Landscape Design*, New York, NY: John Wiley and Sons.

Mitsch, W.J. (1993). Landscape Design and the Role of Created, Restored, and Natural Riparian Wetlands in Controlling Nonpoint Source Pollution, In R.K. Olsen (Ed.), *Created and Natural Wetlands for Controlling Nonpoint Source Pollution* (pp.43-70). USA: U.S. EPA Office of Research and Development and Office of Wetlands, Oceans and Watersheds.

Sakadevan K. & Bavor, H. (1998). Phosphate adsorption characteristics of soils, slags and zeolite to be used as substrates in constructed wetland systems, *Water Research*. 32(2): 393-399.

Seçkin, Ö.B. (2004). *Peyzaj Konstrüksiyonu*, İstanbul, Türkiye: İstanbul Üniversitesi.

Seçkin, Y.Ç. (2009). Sustainable Redevelopment of Sanitary Landfills as Future Golf Courses, In H. Padem (Ed.), *International Symposium on sustainable Development ISSD 2009 Science and Technology Proceedings,* Volume 3, June 9-10, 2009, Sarajevo, Bosnia Herzegovina: IBU Publications.

State of Georgia, Department of Natural Resources, Environmental Protection Division (2002). *Guidelines for Constructed Wetlands for Municipal Wastewater Facilities*, USA: State of Georgia.

USDA-Natural Resources Conservation Service and the US EPA-Region III (n.d.) *A Handbook of Constructed Wetlands*, Volume 1, USA: USDA & US EPA.

U.S. EPA Office of Water (2004). *Constructed Treatment Wetlands*, USA: US EPA.

U.S. EPA (2000). *Constructed Wetlands Treatment of Municipal Wastewaters*, USA: U.S. EPA.

Vadineanu, A. (2005). Identification of the Lagoon Ecosystems, In İ.E. Gönenç & J.P. Wolflin (Ed.), *Coastal Lagoons: Ecosystem Processes and Modeling for Sustainable Use and Development* (pp.7-42) Boca Raton, FL: CRC Press.

Verhoeven J.T.A & Meuleman, A.F.M. (1999). Wetlands for Wastewater Treatment: Opportunities and Limitations. *Ecological Engineering*. 12: 5-12.