# Nutrient Loss from a Golf Course Watershed

## Research on a Texas golf course underscores the importance of careful nutrient management.

BY K. W. KING AND J. C. BALOGH

Scientists from the USDA Agricultural Research Service and Spectrum Research, Inc., installed monitoring devices at the Morris Williams Municipal Golf Course in Austin, Texas, to investigate the nutrient concentrations that might be expected from typical management of municipal golf courses in a semi-arid climate.

Turf may be defined as the managed surface layer of soil, grass plants, and the plants' fibrous roots. In the U.S., there are an estimated 50 million acres of turf. The largest percentage of turf is found in home lawns, while approximately 10 million acres are located on roadside right-of-ways. Only 3% of the turf in the U.S. is managed as the nation's 17,000 golf courses.[6,19]

Environmentally sound management of golf course turf provides both public and private facilities with environmental, cultural, and economic benefits. Public demand is increasing for golf course managers to maintain high-quality turf on golf courses, but also to protect water and soil resources in the vicinity of these facilities. High-quality golf course watershed-scale data are needed to adequately address the issue of nutrient fate and transport on managed turf. The objective of this research effort was to quantify nutrient transport in surface and subsurface drainage waters from a golf course watershed.

### NUTRIENT LOSSES FROM TURF

Periodic nutrient applications are an integral and essential part of establishing and maintaining high-quality turf. However, these applications increase the potential for nutrients to be transported off site in surface runoff or through subsurface drainage features. Runoff and nutrient loss research from turf has been conducted at the field and, to a lesser extent, the watershed scale. Research on subsurface losses of nutrients generally has focused on leachate rather than the amounts moving laterally and returning to surface flow.

The general conclusions of the small-scale studies indicate that with well-maintained turf, the amount of runoff is small, and the concentrations of nutrients in the surface runoff are often below levels of major concern. However, while studies on small scales are valuable, they may not represent the diversity and connectivity associated with a watershed-scale system.

Watershed-scale golf course assessments indicate that concentrations of nutrients from water features on golf courses are generally consistent with those reported in plot-scale studies. Cohen et al.[3] reported that a survey of runoff on 17 golf courses in the United States did not contain any cases of $NO_3$-N (nitrate nitrogen) exceeding the drinking water standard of 10 mg $L^{-1}$. The median $NO_3$-N value recorded in that survey was 0.38 mg $L^{-1}$. Nutrient loading, however, is greater from the watershed-scale systems when compared to plot studies.

## EXPERIMENTAL SITE

A section of Morris Williams Municipal Golf Course (MWMGC) in Austin, Texas, managed by the City of Austin Parks and Recreation Department (PARD), served as the study site for this project. The study area on MWMGC is characterized by a series of grassed waterways, culverts, and casual water detention areas that cross the center of the course. The topography is such that the contributing area (72 acres) contains 10 greens (1.8 acres), 7 fairways (20.3 acres), and 7 tees (0.74 acre). The managed areas (greens, fairways, and tees) represent 32% of the total area. The contributing area also contains approximately 16 acres of reduced-managed rough, with the remainder comprised of unmanaged trees and shrubs. Surface runoff was measured at the inlet and outlet of the study area. Subsurface drainage was measured from the 15th fairway, tee, and green.

Surface and subsurface discharge and associated nutrient concentrations were recorded during a five-year period (April 1, 1998 - March 31, 2003) on MWMGC. Four sites within the study area were instrumented with automated samplers to collect periodic water samples. The four sites were identified as: Site 1 (surface water entrance to the study area), Site 2 (surface water exit from the study area), Site 3 (subsurface drainage for the fairway south of the stream and green of hole number 15), and Site 4 (the fairway north of the stream and tee area of hole number 15).

Each culvert was equipped with an area-velocity flow meter. Inflow to the course was measured by relating the stream depth collected every 15 minutes to area-velocity flow measurements for two entrance culverts. Likewise, Site 2 was characterized by a box culvert that drains water from the course. An area-velocity meter and crest stage gauges were installed to measure the discharge leaving the course.

Subsurface drainage was measured from French drains located on the 15th hole. Nutrient concentrations in the drainage water from the two sites were measured daily from April 1999 to March 2003 using automated samplers programmed to collect one sample every 24 hours. Subsurface flow from the French drains at the sampling sites also was recorded. All samples were analyzed colorimetrically for $No_3$+$No_2$-N, $NH_4$-N (ammoniacal nitrogen), and $PO_4$-P (hereafter referred to as dissolved reactive phosphorus or DRP) concentrations.

**Table 1**

Statistical analysis* of nutrient concentrations (mg $L^{-1}$) in storm flow and baseflow for 5-year period of record (April 1, 1998, to March 31, 2003).

| | $NO_3$+$NO_2$-N | | $NH_4$-N | | $PO_4$-P | |
|---|---|---|---|---|---|---|
| **Storm Flow Concentrations (mg $L^{-1}$) (n = 1050 for Site 1, inflow; n = 1063 for Site 2, outflow)** | | | | | | |
| | **Site 1** | **Site 2** | **Site 1** | **Site 2** | **Site 1** | **Site 2** |
| Mean | 0.30 | 0.44 | 0.10 | 0.09 | 0.12 | 0.15 |
| Median | 0.23a | 0.35b | 0.05a | 0.04b | 0.10a | 0.13b |
| Maximum | 2.25 | 3.52 | 4.04 | 3.23 | 0.90 | 0.99 |
| **Baseflow Concentrations (mg $L^{-1}$) (n = 239)** | | | | | | |
| | **Site 1** | **Site 2** | **Site 1** | **Site 2** | **Site 1** | **Site 2** |
| Mean | 0.30 | 0.79 | 0.10 | 0.03 | 0.11 | 0.10 |
| Median | 0.27a | 0.73b | 0.08a | 0.02b | 0.10a | 0.10a |
| Maximum | 1.84 | 2.35 | 0.69 | 0.17 | 0.37 | 0.27 |

*Medians for each constituent followed by the same letter are not significantly different ($p < 0.05$) using Mann-Whitney nonparametric test.

## INPUTS

Annual precipitation during the five-year period ranged from 22.1 inches to 37.1 inches. The golf course was irrigated with a mixture of potable water from the city and water pumped from an onsite reservoir. Irrigation was applied on an as-needed basis, determined by course personnel, to replace evapotranspiration losses. The roughs and unmanaged areas were not irrigated.

During the study period, management practices were typical of municipal courses in the southern United States. Fairways and greens were established with a hybrid bermudagrass cultivar. Greens were overseeded in late fall with perennial ryegrass (*Lolium perenne* L.). Fertilizer was applied by both dry broadcast and spray techniques throughout the year as a combination of organic, bio-stimulant, slow-release, and fast-release formulations. Average annual N application mass for the study area (71.7 acres) was 40.8 lb. $acre^{-1}$, while P applications totaled 7.2 lb. $acre.^{-1}$

## NUTRIENT LOSSES IN RUNOFF

Based on the collected runoff event data (Table 1), the system contributed statistically significant increases in median $No_3$+$No_2$-N concentrations (+0.12mg $L^{-1}$) and $PO_4$-P concentrations (+0.03mg $L^{-1}$), and decreases in $NH_4$-N concentrations (-0.01mg $L^{-1}$). For the period of record, the estimated storm flow contributions for the study period due to course runoff were 1.2kg $ha^{-1}$ $yr^{-1}$ $No_3$+$No_2$-N, 0.23kg $ha^{-1}$ $yr^{-1}$ of $NH_4$-N, and 0.51kg $ha^{-1}$ $yr^{-1}$ $PO_4$-P. These storm flow amounts represent approximately 3.3% of applied N and 6.3% of applied P over the contributing area for the same period.

The relatively high percentage of applied-P losses in storm flow is surprising, considering the relative immobility of P in turfgrass soils. Current background levels of extractable P in the soil (0-6 inches) ranged from 9mg $kg^{-1}$ in the roughs to 44.5mg $kg^{-1}$ in the greens. Although the current management strategy is to use a low-level phosphorus fertilizer, the residual phosphorus in soil from previous heavy applications during course establishment is still available for low-level losses in storm flow.

Similar findings have been reported from agricultural land use areas.[8,24,25] This may account for the higher percentage of phosphorus losses compared to current application levels. The movement of residual soil phosphorus may be a result of both elevated surface runoff and subsurface lateral flow losses of phosphorus during and after storm flow events. The results of this study suggest that soils with relatively high background levels of phosphorus may have the potential for low, but significant, contributions of phosphorus to surface water.

## NUTRIENT LOSSES IN STREAM BASEFLOW

Based on grab sample data, the golf course contributed a significant increase in median concentration of $No_3$+$No_2$-N (+0.46mg $L^{-1}$) to baseflow exiting the course (Table 1). $NH_4$-N concentrations were reduced in baseflow (-0.06mg $L^{-1}$), and the course had no significant effect on $PO_4$-P concentrations in baseflow (Table 1). These results were similar and consistent with storm-flow concentration contributions.

Seasonal trends of $No_3$+$No_2$-N in the baseflow were observed. $No_3$+$No_2$-N levels in baseflow at the downstream site were consistently higher than at the upstream site, with differences being greater from fall to spring, which is the period of overseeding establishment and bermudagrass dormancy. In contrast, $NH_4$-N levels were consistently higher at the upstream site, and no seasonal patterns were observed. $PO_4$-P concentrations were similar at both sites and steady throughout the year.

**Table 2**

Statistical distribution of measured daily nutrient concentrations (mg $L^{-1}$) in subsurface drainage water.

| | Site 3 Lateral Flow Concentrations (mg $L^{-1}$) (n = 1339) | |
|---|---|---|
| | $NO_3$-N | DRP |
| 25th percentile | 0.69 | 0.09 |
| Median | 1.27 | 0.11 |
| 75th percentile | 1.58 | 0.15 |
| Maximum | 3.94 | 0.99 |
| Mean | 1.15 | 0.13 |
| | **Site 4 Lateral Flow Concentrations (mg $L^{-1}$) (n = 1461)** | |
| | **$NO_3$-N** | **DRP** |
| 25th percentile | 0.20 | 0.07 |
| Median | 0.32 | 0.09 |
| 75th percentile | 0.64 | 0.11 |
| Maximum | 3.07 | 0.62 |
| Mean | 0.47 | 0.09 |

## NUTRIENT LOSS IN SUBSURFACE FLOW

For the four-year period of subsurface sample data collection, measured median $NO_3$-N concentration at Site 3 was 1.27mg $L^{-1}$, while median DRP concentration was 0.11mg $L^{-1}$ (Table 2). Measured median concentrations at Site 4 were 0.32mg $L^{-1}$ $NO_3$-N and 0.09mg $L^{-1}$ DRP (Table 2). $NO_3$-N and DRP concentrations from Site 3 were significantly greater than concentrations detected at Site 4. Greater $NO_3$-N and DRP concentrations measured at Site 3 are indicative of greater and more frequent fertilizer applications to greens compared to fairways.

There was a weak relationship between daily discharge and $NO_3$-N concentration at Site 4; however, no relationship was detected for DRP and discharge at Site 4. A similar analysis conducted for Site 3 showed no relationship between drainage discharge and $NO_3$-N or DRP.

The estimated average annual combined load of $NO_3$-N in the drainage water associated with Site 3 (0.77kg $ha^{-1}$) and Site 4 (1.92kg $ha^{-1}$) was 2.7kg $ha^{-1}$ (approximately 2.5% of the amount of nitrogen applied on the study area). This amount is comparable to, but less than, the value of 3.8kg $ha^{-1}$ $yr^{-1}$ reported by Mitchell et al.[18] on a grass system in Illinois and the value of 10.7kg $ha^{-1}$ $yr^{-1}$ documented by Ruz-Jerez et al.[22] for intensively managed ryegrass in New Zealand. In contrast,

**Table 3**

Selected studies identifying nutrient and sediment concentrations (mg $L^{-1}$) in surface waters from grassed and wooded catchments.

| Reference | Land Use | Area | $NH_4$ | $NO_3$+$NO_2$ | TN | DRP | TP | Duration | Study Location |
|---|---|---|---|---|---|---|---|---|---|
| Gaudreau et al., 2002[7] | Common bermudagrass | 6 $m^2$ | — | 1.30 | — | 4.20 | — | 8 events | College Station, Texas |
| Morton et al., 1988[20] | 90% Kentucky bluegrass, 10% red fescue | 32 $m^2$ | — | 0.87 | — | — | — | 2 years | Kingston, R.I. |
| Easton and Petrovic, 2005[5] | 80% Kentucky bluegrass, 20% perennial ryegrass | 37.2 $m^2$ | 1.44 | 10.1 | — | 0.50 | — | 18 months | Ithaca, N.Y. |
| Linde and Watschke, 1997[16] | bentgrass and ryegrass plots | 123.5 $m^2$ | — | 1.47 | — | 4.06 | — | 2 years | State College, Pa. |
| Winter and Dillon, 2005[27] | 13 sites on 5 golf courses | — | — | 0.30 | 0.94 | — | 0.03 | 2 years | Ontario, Calif. |
| Starrett and Bhandari, 2004[26] | Native prairie<br>Golf course construction<br>Golf course | —<br>—<br>— | —<br>—<br>— | —<br>—<br>— | 1.18<br>3.94<br>1.91 | —<br>—<br>— | 0.39<br>0.93<br>0.51 | 3 months<br>20 months<br>4 years | Manhattan, Kan. |
| King et al., 2001[14] | Golf course storm events<br>Golf course baseflow | 29 ha | —<br>— | 0.30<br>0.86 | —<br>— | 0.00<br>0.01 | —<br>— | 22 events<br>13 months | Austin, Texas |
| **This study** | **Golf course storm events**<br>**Golf course baseflow** | **29 ha** | **0.00**<br>**0.06** | **0.12**<br>**0.46** | | **0.03**<br>**0.00** | | **5 years** | **Austin, Texas** |
| Kunimatsu et al., 1999[15] | Golf course | 53 ha | 0.30 | 0.29 | 1.30 | 0.05 | 0.10 | 2 years | Japan |
| Malin and Wheeler, 2000[17] | Golf course<br>Golf course<br>Golf course<br>Golf course<br>Golf course | 54 ha<br>53.7 ha<br>NA<br>46.4 ha<br>111.7 ha | 0.04<br>0.03<br>0.23<br>0.03<br>— | 0.32<br>0.32<br>1.46<br>0.06<br>0.11 | —<br>—<br>—<br>—<br>— | 0.019<br>0.008<br>0.005<br>0.056<br>0.004 | —<br>—<br>—<br>—<br>— | 1 year<br>1 year<br>9 months<br>1 year<br>1 year | New Hanover Cty., N.C.<br>New Hanover Cty., N.C.<br>Brunswick Cty., N.C.<br>New Hanover Cty., N.C.<br>New Hanover Cty., N.C. |

the average $NO_3$-N loading from corn and corn/soybean crop production systems is reported to be in the range of 5-100kg $ha^{-1}$ $yr^{-1}$.[9,13,21]

The estimated average annual combined DRP load transported through the French drains at Site 3 (0.08kg $ha^{-1}$) and Site 4 (0.38kg $ha^{-1}$) was 0.46kg $ha^{-1}$ (an amount equivalent to 2.0% of the applied P). This amount is considerably greater than loadings recorded from drainage water on a corn production system (0.04kg $ha^{-1}$ $yr^{-1}$).[9]

DRP losses in subsurface drainage water can be substantial when conditions for leaching are favorable or promoted or when preferential flow is present.[4,10,12] The soil present in this study area is susceptible to preferential flow[1] and may explain the greater transport of DRP. In addition, leaching can be substantial in sandy soils like those found in the green.

While only a few studies have been conducted on watershed-scale turf systems, it is important to understand how this study's data compare with other studies. The $NO_3$-N and DRP concentrations measured in this study are on the low end of the range of concentrations reported from other plot- and watershed-scale turf studies (Table 3). Measured nitrate-$NO_3$-N concentrations on this golf course never exceeded or even approached the EPA 10 ppm standard for drinking water. However, measured DRP concentrations often exceeded 25 ppb, a level associated with eutrophication and biology disruption (Walker and Branham, 1982; Keeney, 1982; and Koehler et al., 1982). Nutrient loadings measured in this study are also comparable to those reported from both plot- and watershed-scale turf studies (Table 4). DRP loads were on the high end of the range of reported loads.

Turf managers are often faced with multiple options for managing turf. They are asked to balance turf quality and growth with climate, soil, vegetative conditions, and management practices. Their choice of management practices is critical for controlling and/or reducing surface runoff and potential for nutrient transport.

*Editor's Note:* A complete version of this paper can be found at *USGA Turfgrass and Environmental Research Online* (http://usgatero.msu.edu). The specific URL for this paper is http://usgatero.msu.edu/v05/n06.pdf.

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**Table 4**

Selected studies identifying nutrient loads (kg/ha/yr) in surface waters from grass plots and golf courses.

| Reference | Land Use | Area | $NH_4$ | $NO_3$+$NO_2$ | TN | DRP | TP | Duration | Study Location |
|---|---|---|---|---|---|---|---|---|---|
| Gross et al., 1990[11] | 60% tall fescue, 40% Kentucky bluegrass: fertilized | 10 $m^2$ | 0.09 | 0.06 | 0.17 | 0.05 | 0.02 | 18 events | Upper Marlboro, Md. |
| | 60% tall fescue, 40% Kentucky bluegrass: non-fertilized | | 0.05 | 0.04 | 0.08 | 0.02 | 0.01 | | |
| Schwartz and Shuman, 2005[23] | Tifway bermudagrass | 25.2 $m^2$ | — | 3.05 | — | — | — | 4 years | Griffin, Ga. |
| Easton and Petrovic, 2005[5] | 80% Kentucky bluegrass, 20% perennial ryegrass | 37.2 $m^2$ | 0.35 | 0.90 | — | 0.12 | — | 18 months | Ithaca, N.Y. |
| Birdwell, 1995[2] | Golf green (bermudagrass) | 0.025 ha | — | 0.52 | — | — | — | 3 months | College Station, Texas |
| | Golf fairway (bermudagrass) | 1.57 ha | — | 0.96 | — | — | — | | |
| King et al., 2001[14] | Golf course: storm events | 29 ha | — | 2.10 | — | 0.30 | — | 22 events | Austin, Texas |
| | Golf course: baseflow | | — | 4.30 | — | 0.05 | — | 13 months | |
| **This Study** | **Golf course: storm events** | **29 ha** | **0.23** | **1.20** | **—** | **0.51** | **—** | **5 years** | **Austin, Texas** |
| Kunimatsu et al., 1999[15] | Golf course | 53 ha | 1.70 | 3.70 | 13.5 | 1.60 | 3.04 | 2 years | Japan |


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**Scientists from the USDA Agricultural Research Service in Columbus, Ohio, and Spectrum Research, Inc., monitored the Morris Williams Municipal Golf Course in Austin, Texas, to study the nutrient concentrations in water. Findings included:**

- Approximately 3.3% of the nitrogen and 6.3% of the phosphorus applied to the study area contributed to the nutrients found in the storm flow water.
- The golf course contributed a significant increase in the median concentration of $NO_3$+$NO_2$-N in the water exiting the course, reduced levels of ammoniacal nitrogen ($NH_4$-N), and had no effect on dissolved reactive phosphorus concentrations.
- Nitrate nitrogen ($NO_3$-N) concentrations moving through the subsurface drainage water were approximately $\frac{1}{10}$th of the concentrations typically reported for tile drainage from row crop agriculture.
- Time of the year influenced the data. Nitrate nitrogen was present in greater concentrations in the surface and subsurface drainage water during the winter months when there were periods of greater rainfall, the turfgrass was dormant, and microbial activity was reduced than when compared to spring and summer.
- Dissolved reactive phosphorus (DPR) concentrations in the subsurface drainage water from the golf course were greater than concentrations reported measured in agricultural tile drains. These values could pose a potential threat of providing excessive nutrients to surface waters, such as ponds, resulting in excessive plant growth.
- The timing and magnitude of nitrate nitrogen and DPR moving through subsurface drainage from the golf course turf were dependent on temperature, precipitation, and turf management factors such as the magnitude and timing of applied fertilizer. At the more intensively managed site, higher levels of nitrate nitrogen and DPR were measured when compared to the less intensively managed site.


Surface water samples (storm flow and baseflow) were collected throughout the study period using automatic collection systems installed on the course.