Buffer Strips, Runoff, and Leachate

Research compares nutrient loading in runoff and leachate when buffer strips are used alongside golf course fairways.

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Federal mandates to decrease nutrient pollution of water supplies are resulting in various local and state regulations aimed at reducing phosphorus (P) movement into surface waters and nitrogen movement into groundwater. Some regulations aim to reduce nutrient and sediment loading into surface waters based on the idea that "native" or prairie vegetation should be used as buffer strips between mowed turf and natural areas or surface water.

The slower establishment of prairie vegetation allowed annual weeds and grasses to dominate in the research buffer strip plots.

Some research indicates that dense turf vegetation is more effective at reducing runoff and nutrient leaching than other strategies, including mulched landscaped beds. Data are just starting to be published that report on the effectiveness of prairie buffer strips to reduce nutrient loading in water runoff and leachate relative to turf. Also unknown is the size requirement of buffer strips relative to the area they are to be buffering.

Turf is often used as a ground cover throughout inhabited areas, including golf course roughs, because it is relatively easy to establish and maintain, provides contiguous ground cover throughout the year under traffic and mowing, and the low mowing height facilitates human activity while discouraging vermin and insect pests. The various turf species allow some type of turf to be established across a diversity of situations, including moist or dry soils, and moderately shaded to full-sun conditions.

Prairie plantings are being increasingly promoted as a low-cost alternative to managed turf. They are also seen as "native," while most cool-season turf species were introduced from Eurasia. Although management is usually much less intensive than turf, establishment of prairie vegetation is not necessarily less expensive than turf, as prairie seed may cost considerably more. Prairie establishment may take years, during which time weeds, especially noxious weeds, must be regularly controlled. Lastly, prairie plantings are not necessarily suited for many habitats, such as wooded golf courses. A number of golf courses utilize fine fescues as low-maintenance roughs, which receive almost as little attention as prairie areas, yet establish quickly and easily. Generic regulations that require the installation of prairie buffer strips can be costly, reduce valuable golf turf areas, and promote the assumption that turf has inherently negative environmental consequences.

Data from various projects suggest that annual nutrient loading from mowed turf may be similar to that from prairies, as most of the nutrient loss occurs when nutrients are leached from dead foliage. When we began the study in 2003, there were no data that directly compared the efficiency of turf to prairie vegetation for its ability to minimize runoff and leachate pollution, particularly during the establishment phase, which can last for two to three years.

The project goal was to compare the relative amount of nutrient loading in runoff and leachate when prairie and fine fescues were used as buffer strips

Table 1
Vegetative buffer strip treatments at Wisconsin River Golf Club, Stevens Point, Wis.

Vegetation Type	Ratio	Mean Area (m^2)
No buffer, fairway only (annual bluegrass)	Not applicable	12.45
Fairway: prairie (narrow buffer strip)	8:1	14.01
Fairway: fine fescue (narrow buffer strip)	8:1	14.01
Fairway: prairie (medium buffer strip)	4:1	15.58
Fairway: fine fescue (medium buffer strip)	4:1	15.58
Fairway: prairie (wide buffer strip)	2:1	18.68
Fairway: fine fescue (wide buffer strip)	2:1	18.68

alongside golf course fairways. We also wanted to determine the effect of three different ratios of buffer strips relative to the fairway area draining into the buffer strips. The information will be useful for predicting effectiveness of different vegetation types and buffer strip sizes on golf courses.

GROWING BUFFER STRIPS AND INSTALLING WATER SAMPLERS

Research plots were constructed in 2003 at the Wisconsin River Golf Club (WRGC) in Stevens Point, Wis. The golf course is adjacent to and drains into the Wisconsin River. Two large natural areas exist within the course and the course is surrounded primarily by forest with a small amount of agricultural land. The plots were developed in the roughs that drain fairways 4, 8, and 9. Fairways were approximately 85 feet wide and crowned in the middle with 1-2% slopes. Fairway turf was predominantly annual bluegrass (*Poa annua* L.).

Buffer strip plots were installed at the edge of the fairways and had slopes ranging from approximately 1 to 4%. Plots on fairway 9 were in full sun, plots on fairway 8 were in slight shade, while plots on fairway 4 were moderately shaded. Treatments included 2:1, 4:1, and 8:1 fairway-to-buffer-strip ratios, with one ratio each of prairie or fine fescue mixtures (Table 1). A seventh treatment in each replicate was a no-buffer-strip plot.

Runoff collection flumes (1-meter width) were installed at the lower end of each buffer strip plot. Each collection flume had a cover to prevent debris from falling into the flume, while a screen-covered slit at the soil surface allowed runoff water to enter. Leachate was collected in each buffer strip, using a low-tension lysimeter installed just upslope of the runoff-collection weir.

Plots were dormant-seeded in October, as recommended for prairie plantings, and they were covered with a biodegradable wood fiber erosion control blanket. Prairie plots were planted to a commercial prairie seed mixture that included flowers and grasses (Table 2). Fine fescue plots were seeded to a commercial seed mix containing Chewings, creeping red, blue, and hard fescues.

None of the plots were irrigated, treated with pesticide, or fertilized during the study. Plots were mowed (clippings returned) at 30-inch height in early spring 2004 and 2005 to encourage new growth in accordance

Table 2
Species and cultivars used for vegetative buffer strips at Wisconsin River Golf Club, Stevens Point, Wis.

Perennial Flowers

Species*	Blooms Color	Blooms Month**
Asclepia incarnata (Red Milkweed)	Pink/Red	6-7
Aster novae-angliae (New England Aster)	Purple	8-10
Iris shrevei (Wild Iris)	Blue	5-8
Liatris pycnostachya (Dense Blazingstar)	Purple	8-9
Lobelia siphilitica (Great Blue Lobelia)	Blue	8-9
Lobelia cardinalis (Cardinal Flower)	Scarlet	7-8
Eupatorium purpureum (Woodland Joe Pye Weed)	Pink	7-8
Monarda fistulosa (Bergamot)	Purple	7-9
Rudbeckia subtomentosa (Sweet Black-Eyed Susan)	Yellow	7-10
Verbena hastate (Vervain)	Purple	7-10
Vernonia fasciculate (Ironweed)		
Zizia aurea (Divided Leaf Golden Alexander)	Yellow	5-6

Grasses and Sedges

Andropogon gerardi (Big Bluestem)	*Elymus canadensis* (Canada Wild Rye)
Carex vulpinoidea (Fox Sedge)	*Glyceria striata* (Fowl Manna Grass)

Fine Fescue Mixture

Species/Cultivar	Scientific Name	% in Mix
Creeping Red Fescue (SR5210)	*Festuca rubra* ssp. *rubra*	19.6
Slender Creeping Red Fescue (Dawson)	*F. rubra* ssp. *litoralis*	19.6
Blue Fescue (SR3210)	*F. glauca*	14.7
Chewings Fescue (SR5100)	*F. rubra* spp. *commutata*	14.7
Chewings Fescue (Sandpiper)	*F. rubra* spp. *commutata*	9.8
Hard Fescue (SR3150)	*F. longifolia*	9.8
Hard Fescue (Scaldis)	*F. longifolia*	9.8

*Quantity of species varies depending upon that year's seed production and harvest; was supposed to include at least 12 perennial flower species. Due to the nature of prairie seed production and collection, certified seed is unavailable.

**Number corresponds to month of year, e.g., 7 = July, 8 = August, etc.

Establishing buffer strips around natural water features on a golf course has long been recommended to protect water quality and improve wildlife habitat. Research indicates that dense turf vegetation is effective at reducing runoff.

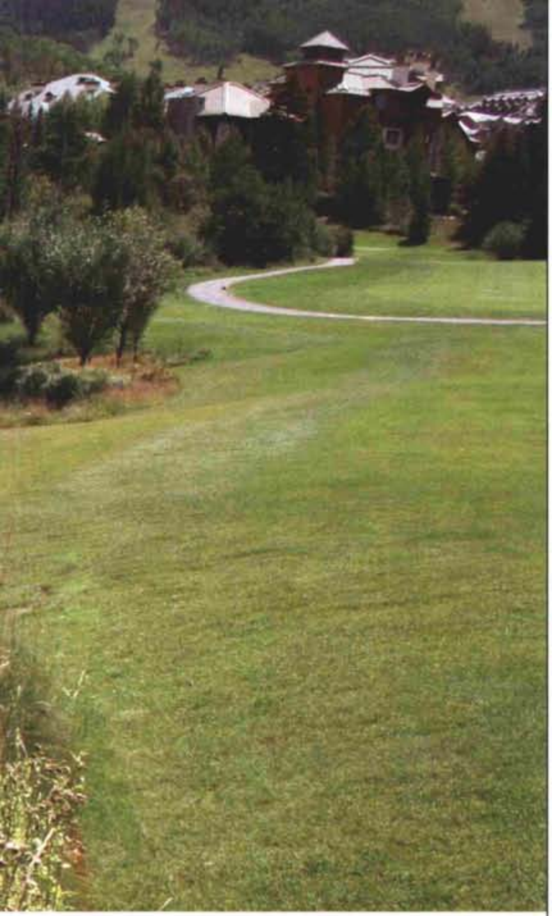
with recommendations for prairie establishment. Fairways received 108 to 216 lb. N acre^{-1} annually in one or two applications (spring and fall), with approximately 5.5 to 11 lb. P acre^{-1} each year. Fairways received little to no irrigation, so snow melt and rainfall provided the source of runoff water. The 9th fairway remained flooded from excessive rainfall throughout most of 2004 and part of 2005 and was dropped from the study.

ANALYZING WATER QUALITY AND VEGETATION

The leachate water samples were analyzed for nitrate- and ammoniacal-N and soluble phosphorus. Runoff samples were analyzed for three P types: soluble P, biologically active phosphorus (BAP), and total phosphorus (TP), which were extracted from both sediment in the water as well as the water itself. Sediment in runoff was collected and quantified. Turfgrass and prairie plant stands were analyzed two to three times each year by determining the percentage of desirable plants (turf or prairie), weeds, and bare soil.

Figure 1

Type and amount of vegetative cover in fine fescue and prairie buffer strips following seeding in October 2003, Wisconsin River Golf Club, Stevens Point, Wis. **A** and **D** show ground cover in fine fescue and prairie plots, respectively, in August 2004. **C** and **D** show ground cover in fine fescue and prairie plots, respectively, in June 2005.



are not favorable are likely to result in unwanted vegetation and/or exposed soil that will not necessarily decrease nutrients in runoff or leachate.

In our study, less than 5% of the total rainfall during the sampling period in 2004 ran off fairway and buffer strip surfaces, while less than 1% of rainfall ran off during 2005 (Tables 3 and 4). The minimal slopes of the fairways (1-2%) likely helped infiltration to occur by reducing speed of runoff despite periods of heavy rain. The nearly complete ground cover was likely just as, if not more, important for reducing runoff by slowing its rate and allowing it to infiltrate into the soil.

None of the buffer strips changed runoff or phosphorus loading compared to the fairway alone, indicating fertilizer was not an important source of phosphorus (Table 4). Total phosphorus losses on a land area basis were similar, or less than, the annual 0.1 kg P ha^{-1} loss reported for native prairie in Minnesota when rainfall-induced

Table 3
Monthly rainfall (mm) during runoff sampling periods at Wisconsin River Golf Club, Stevens Point, Wis.

Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Total
				2004				
32.3	222.0	171.7	148.8	121.7	30.2	132.8	48.3	907.8
				2005				
92.5	73.9	167.1	33.3	151.9	188.0	32.3	83.1	822.1

Table 4
Total annual runoff volumes and phosphorus (P) losses from *Poa annua* fairways with or without various buffer strips of either prairie or fine fescue, Stevens Point, Wis.

Buffer Treatment[1]	Water Runoff (mm)	Total P (kg ha^{-1})	Bioavailable P (kg ha^{-1})
	2004[2]		
No buffer	36.6	0.12	0.04
Short, Prairie	42.9	0.17	0.03
Short, Fescue	45.6	0.19	0.04
Medium, Prairie	50.1	0.17	0.04
Medium, Fescue	38.1	0.16	0.04
Long, Prairie	36.6	0.12	0.03
Long, Fescue	50.2	0.22	0.02
Significance ($P \leq 0.05$)	ns	ns	ns
	2005[3]		
No buffer	3.5	0.04	0.01
Short, Prairie	4.2	0.03	0.02
Short, Fescue	4.6	0.04	0.03
Medium, Prairie	5.5	0.04	0.02
Medium, Fescue	5.5	0.05	0.02
Long, Prairie	3.5	0.03	0.02
Long, Fescue	4.1	0.02	0.02
Significance ($P \leq 0.05$)	ns	ns	ns

ns = not significant at $P \leq 0.05$.
[1]Short buffer = 8:1 fairway:buffer length, medium = 4:1 fairway:buffer, long = 2:1 fairway:buffer.
[2]May through October.
[3]April through November.

RESULTS AND DISCUSSION

Fine fescues covered nearly 40% of the ground by early May 2004, while weed seedlings were the only vegetation on the prairie plots. Fescue cover was excellent by August, while annual weeds covered 80% of the ground in prairie plantings (Figures 1A, 1B). A few prairie plants were present, but they comprised less than 1% of the ground cover. By June 2005, fescue cover remained dense and prairie vegetation had increased to 18%, though weeds still covered more than three quarters of the plot area (Figures 1C, 1D). Several of the prairie flower species were evident by summer 2005, though few bloomed that year. None of the prairie grasses were ever observed, consistent with several of our other establishment projects using similar prairie seed mixtures. Prairie plots on fairway 4 had more weeds, especially *Poa annua*, than plots on fairway 8 that were less shaded. Regulations requiring *native* vegetation for buffer strips in situations where climatic conditions

Table 5
Mean monthly soluble phosphorus (P) and total nitrogen (N) in leachate under *Poa annua* fairway and prairie or fine fescue buffer strips, Wisconsin River Golf Club, Stevens Point, Wis.

Buffer Treatment[1]	Soluble P (mg L^{-1})	Total N (mg L^{-1})
	2004[2]	
No buffer	0.33	2.89
Short, Prairie	0.32	7.60
Short, Fescue	0.12	32.08
Medium, Prairie	0.24	7.05
Medium, Fescue	0.05	30.15
Long, Prairie	0.13	6.28
Long, Fescue	0.07	25.66
Significance (P≤0.05)	ns	ns
	2005[3]	
No buffer	0.58	3.91
Short, Prairie	0.56	4.15
Short, Fescue	0.36	5.02
Medium, Prairie	0.20	2.33
Medium, Fescue	0.36	4.00
Long, Prairie	0.26	3.61
Long, Fescue	0.49	3.72
Significance (P≤0.05)	ns	ns

ns = not significant at P≤0.05.
[1]Short buffer = 8:1 fairway:buffer length, medium = 4:1 fairway:buffer, long = 2:1 fairway:buffer.
[2]May through October.
[3]April through November.

runoff averaged 6 mm per year, and similar, or less, than the 0.18 to 7.04 kg P ha^{-1} in surface runoff from a variety of grazing lands in Oklahoma.

Phosphorus runoff in our study was more than 20 times less than that reported for wheat production, probably due to greater vegetative cover in the golf course system. Phosphorus sources in our study likely included natural sources such as vegetation, soil, and precipitation. We've found similar results when comparing Kentucky bluegrass (*Poa pratensis*) and prairie buffer strips for controlling urban runoff.

A growing body of evidence indicates that when ground is well covered by vegetation (e.g., 70%), total P losses may be much reduced compared to predominantly exposed soil. In exposed soil situations, sediment-bound P is often the primary type of P. Vegetation greatly reduces total P runoff by reducing both runoff volume and sediment, though soluble P may increase as it leaches from vegetation and organic P-containing particles move in runoff. Prairie plants may be especially prone to P loss from vegetation, as they are predominantly C_4 plants with foliage that dies in early autumn, while C_3 turf foliage may survive the winter and has a steady but low turnover rate coupled with less abundant above-ground biomass than prairie vegetation.

In our study, about 25-50% of the total P in runoff was bio-available P (BAP). This is the type that stimulates algae blooms in ponds, lakes, and rivers. Values in our study were at least 20 times less than BAP in wheat field runoff and similar to BAP runoff from native grassland. Our data are important because they represent natural background levels of phosphorus. Consequently, regulations to limit phosphorus fertilization would in this case be ineffective at reducing phosphorus loading. Ultimately it is impossible to achieve zero P runoff.

Buffer strips did not affect phosphorus or nitrogen leaching below the soil surface (Table 5). Nitrogen is the most important nutrient contaminant in leachate water because excessive levels in drinking water may have adverse human health effects, such as blue baby syndrome. The U.S. Environmental Protection Agency sets the drinking water limit at 10 parts per million (ppm) nitrate-nitrogen. In our study, this level was exceeded in 2004 under the fine fescue plots, but the results were not statistically different from leachate under prairie plots or fairway alone. The higher concentrations in 2004 were likely due to soil disturbance effects from the establishment process and lack of vegetative cover until May 2004. In 2005, all nitrogen concentrations were below 10 ppm and were likely lower than 2004 because more vegetation existed in the second year.

Phosphorus has generally been regarded as having little movement in soil and so most leaching studies do not measure phosphorus. However, increasing awareness of ties between ground and surface water may soon require additional knowledge of phosphorus leaching. Easton and Petrovic reported more than 50% of P applied to turf from swine compost leached below the surface, while synthetic fertilizer sources had significantly lower leachate losses. Our study indicates that an unfertilized prairie stand has similar levels of P leachate compared to unfertilized fine fescue turf and fertilized *P. annua* fairways. Phosphorus and nitrogen contamination of runoff and leachate water from golf course fairways was similiar to natural background levels reported for non-fertilized native prairies and was not affected by buffer strip type or size.

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CONNECTING THE DOTS

A Q&A with Dr. John Stier, *University of Wisconsin, regarding the use of prairie versus fescue buffer strips to minimize nutrient and sediment fairway runoff.*

Q: *Your article points to recent regulations that buffer strips, to reduce nutrient and sediment loading into surface waters, should use native, or prairie, vegetation. How do you think regulators chose to stipulate prairie vegetation for this purpose? Is there scientific data to show that a prairie strategy is effective for this purpose?*

A: Regulators chose prairie vegetation for use as native buffer strips because much of the southern part of Wisconsin was largely prairie (e.g., oak savannah) before the 1800s. The other alternative is trees, which because of their height and relatively slow growth are illogical to meet immediate needs, even though the northern half of the state is naturally forested. We decided to investigate the utility of prairie buffer strips to control runoff specifically because no previous scientific data existed.

Q: *Given the differences in speed of establishment of fescues (and other turfgrasses) versus prairie ground cover, do you think that using prairie vegetation for fairway buffer strips is a sound strategy?*

A: While prairie ecosystems can take several years to become established, we found that the annual weeds that developed in the prairie plots functioned as well as fescues to mitigate runoff and sediment loss. The question is, will people accept weeds as a vegetative cover during the years required to establish a prairie ecosystem? We also noticed that in one of the sites, heavily shaded by trees, the prairie plants did not establish as well as the site with more sunshine.

Q: *In your study, less than 5% (in 2004) and 1% (in 2005) of the total rainfall ran off the fairway and buffer strip surfaces. Do you think the differences in sediment and nutrient losses between prairie and fescue buffers would have been greater if the plots had been tested on a golf course receiving greater rainfall or having more severe slopes?*

A: The differences might have been greater if slopes were more severe. As for rainfall, factors to consider include pre-existing soil moisture at the time of rainfall and rate of rainfall compared to infiltration rate. For example, if the soil is saturated from previous rainfalls, even a minor rainfall might cause runoff, while a more severe rainfall may not cause any runoff if the soil is dry at the time of rainfall.

Q: *It was interesting that your research showed that applied fertilizer did not appear to be an important source of runoff phosphorus. Do you think the extent that significant phosphorus runoff comes from dead or dormant vegetation (i.e., C_4 prairie plants) is well understood by regulators?*

A: Unfortunately, the idea that vegetation itself can serve as a source of nutrients does not appear to be well understood by regulators or the general public — it would be interesting to survey scientists to determine their understanding of vegetation as a source of nutrients in runoff. The idea is not completely new, as several studies have shown that nutrients can be leached from tree leaves.

Q: *Your study demonstrated that bio-available phosphorus runoff from WRGC fairways was 20 times less than that reported for wheat production. Do you sometimes get the feeling that regulators target golf courses rather than conventional agriculture, where the cumulative runoff from row-crop, small grain, forage production, and pasture and feed-lot operations seem to be a much greater threat to surface water quality?*

A: The turf and allied green industries do not seem to have the political infrastructure that organized row-crop agriculture has. Also, most of the public is very familiar with urban landscapes because the vast majority of U.S. residents live in urban areas: they are unfamiliar with row-crop agricultural systems.

Q: *What is the the take-home message for golf course superintendents from this work?*

A: Well-vegetated areas, regardless of the species, are important for minimizing runoff and sediment losses. There will always be a background level of nutrients in runoff water because the vegetation itself may serve as a source of nutrients in addition to atmospheric deposition and other sources unrelated to fertilizer.

Jeff Nus, Ph.D., *manager, Green Section Research.*

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Editor's Note: A more complete version of this report can be found at USGA Turfgrass and Environmental Research Online: http://usgatero.msu.edu/v05/n22.pdf.

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