CHAPTER 2: SOIL PHOSPHORUS LEVELS OF HOME LAWNS AND ATHLETIC FIELDS IN NEW YORK STATE

ABSTRACT

Turfgrass comprises a significant portion of the area of New York State (over 13,000 km^{-2}) and the US. Declining water quality in urban and suburban landscapes has drawn attention to phosphorus (P) losses from these areas and from homeowner lawns in particular. Recent legislation has aimed at reducing P losses from urban areas by limiting P fertilizer use, but a significant amount of P in runoff from turfgrass is from plant tissue and P already in the soil rather than newly added fertilizer. A dataset of agronomic soil test results from 3,803 home laws and athletic fields across NY State was analyzed to determine P levels of turfgrass areas. The findings indicate that 18% of home lawns and 41% of athletic fields would likely display a visual quality of growth response to a P fertilizer application, but additional P was not recommended for the remainder of the sites. Additional work is needed to determine the potential contribution of P from soil to runoff and drainage for turfgrass areas over a range of soil P levels.

INTRODUCTION

Turfgrass accounts for 1.8% of the total area of the United States (Milesi et al., 2005). Recent estimates suggest that between 6,320 and 13,874 km^2 of turfgrass are maintained in New York – or between 5 and 10% of the state's total area (New York Agricultural Statistics Service, 2004; Milesi et al., 2005). Home lawns account for over 90% of the maintained areas, while golf courses make up less than 3% of the maintained turfgrass area (NYASS, 2003).

The USEPA (2002) cites urban areas as a leading contributor to surface water impairment. Most impaired surface water bodies are hindered by excessive nutrient levels, resulting in a process called eutrophication. There is considerable evidence that P limits primary production in most lakes, rivers, and streams (Correll, 1998) and thus excessive inputs of P can result in a decline in surface water quality. The documented environmental benefits of turfgrass are numerous and have been summarized elsewhere (Beard and Green, 1994); however, because maintained turfgrass areas comprise such a large percentage of land in urban/suburban areas, it follows that they could have a large influence on the water quality in these areas.

Surface runoff can be an important pathway for P loss from turfgrass areas and originates from at least three sources: 1) fertilizer, 2) soil, or 3) living and decomposing vegetative tissue. In response to declining surface water quality, the state of Minnesota and Dane County, WI have restricted the application of P to turfgrass areas. However, restricting P fertilizer use will only reduce P losses from fertilizer. Studies have demonstrated that fertilizer may account for as little as 0% to as much as 90% of P in runoff from turfgrass areas (Schuman, 2002, Easton and Petrovic, 2004). Therefore, when fertilizer is not an important source of P in runoff from turf, sources such as soil and the turfgrass itself may be important. Although direct measurements of the relative contributions of soil and plant tissue to P runoff from turfgrass areas have yet to be done, plant tissue has been shown to contribute significantly to P in runoff from other crops such as cotton (Sharpley, 1981). Kussow (2004) demonstrated that Kentucky bluegrass (*Poa pratensis* L.) contains 0.6 kg ha^{-1} of water soluble P; an amount equal to 311% of annual P in runoff observed from simulated home lawns in the upper Midwest. The author concluded that turfgrass tissue likely accounts for a large amount of P in runoff. Agricultural studies have shown that soil P also has the potential to contribute significantly to the P in runoff (Pote et al., 1996; Sharpley, 1995) and it is generally accepted that P losses from agricultural fields increase with soil test P levels (Maguire et al., 2005). Further, Kleinman et al. (2000) identified a Morgan soil test P value above which losses of P from soil to runoff and drainage increase more rapidly. This suggests that this soil test P level could be used as an environmental threshold.

The objective of this study was to determine the extractable soil P levels of turfgrass soils throughout New York State. This information will be useful for determining what percentage of turfgrass areas would likely exhibit a positive growth or visual quality response to a P fertilizer application. In addition, it will also be used to determine what percentage of turfgrass areas are above a proposed environmental threshold – and may pose a risk to water quality. This information will be especially useful when more scientific information becomes available on the relative contributions of soil P to runoff from turfgrass areas.

MATERIALS AND METHODS

Between Jan. 2001 and July 2005, 3,803 unsolicited soil samples from home lawns and athletic fields were received by the Cornell Nutrient Analysis Laboratory in Ithaca, NY. Home lawns accounted for 87% of the submitted samples during this period. Soil samples were oven dried at 55°C overnight, then ground and passed through a 2 mm sieve. The soil was shaken for 15 min in a 1:5 (v/v) ratio of soil to Morgan's (1941) solution (1 *N* sodium acetate, buffered at pH 4.8). The soil and solution were passed through a Whatman #2 filter and the solution P content was analyzed colorimetrically (Murphy and Riley, 1962) using an Alpkem 320 continuous flow analyzer (Alpkem, Silver Springs, MD).

Submitted soil samples were classified by soil management groups listed in Fig. 2.1. Management groups are classified according to soil texture and soil parent material. Group I represents fine-textured soils formed from lake sediments, Group II represents medium- to fine-textured soils formed from calcareous glacial till or recent alluvium, Group III represents moderately course-textured soils formed from glacial till or recent alluvium, Group IV is composed of course-textured soils formed from glacial till or glacial outwash, and Group V contains coarse- to very coarse-textured soils formed from sandy glacial outwash. Submitted samples were distributed fairly evenly among 4 of the 5 management groups (Group II, 20.4%; Group III, 27.7%; Group IV, 38.8%; and Group V, 31.7%). No samples from group I were submitted.

Although the soil management zones are not strictly based on geographical zones of New York, Group II soils are mostly found in central NY extending from Buffalo to Syracuse; Group III soils represent southern NY, Groups IV and V are found in the southeastern part of the state, including Long Island. Over 70% of the soil samples submitted originated from the later area, which is more urbanized and accounts for a large proportion of the maintained turfgrass areas in New York (Milesi et al., 2005).

Limitations of this study include a relatively small sample size, the possibility that some geographical areas are over- or under-represented, and the fact that the sample is not random. We feel that the extractable soil P levels of the samples included in this study are likely biased to be higher than the true average, because a homeowner concerned enough to soil sample is also likely to apply fertilizer to meet N requirements on a regular basis. This opinion is also based on the difficulty of finding commercially available P-free lawn fertilizers in major retail centers.

Descriptive statistics were calculated using the UNIVARIATE procedure in SAS STAT software (Version 9.1, SAS Institute Inc., Cary, NC). The non-parametric

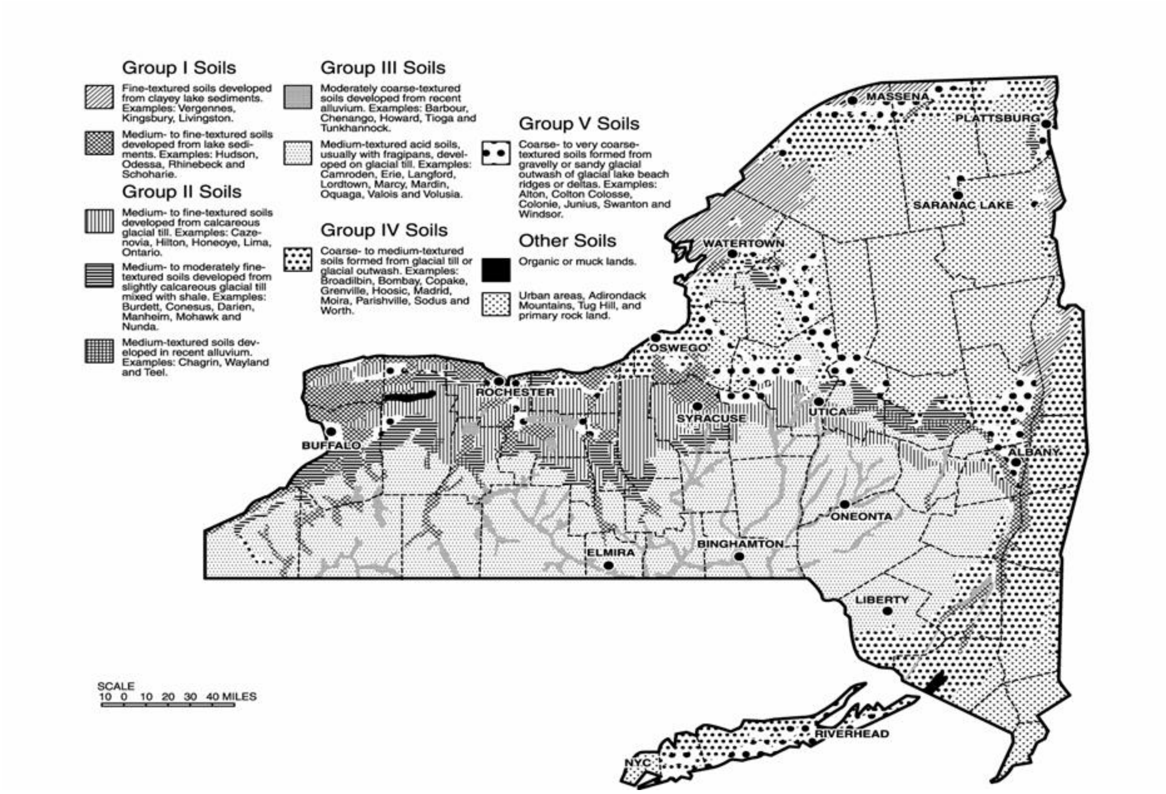

Figure 2.1 Soil management groups of New York (Cornell Cooperative Extension, 1987).

Wilcoxon scores were calculated using NPAR1WAY and used to test differences between lawns and athletic fields, as the assumption of normality could not be met regardless of transformation.

RESULTS AND DISCUSSION

No significant differences in extractable soil P levels of athletic fields and home lawns existed (p=0.83). Medians were identical for each turf type, larger variance and maximum values that were observed for home lawns can be attributed to the larger sample size (Table 2.1). Because the groups were similar, they were combined for all other statistical analyses.

Differences existed with respect to soil P levels among the 4 soil management groups represented in this survey (Table 2.2). Based on 95% confidence limits of the median, Soil Management Group IV had a significantly greater median extractable soil P level than Groups II and III. Group IV soils consist of the majority of Long Island plus most of the land to the east of the Hudson River which we believe generally have a higher level of turfgrass maintenance. All other groups were statistically similar with respect to extractable soil P levels.

Within each soil management group, extractable soil P levels were classified in terms of P fertility as very low, low, medium, high, or very high according to Cornell University Morgan soil test interpretations for turfgrass (Table 2.2, Fig. 2.2). These response classifications were originally derived for agronomic research based on the probability of a crop yield response following a P fertilizer application, and later applied to turfgrass. The classifications imply that the probabilities of a positive response to a P application for soils testing high and very high in P are considered low and very low, respectively. For most field crops in New York, the critical soil test P level beyond

Table 2.1. Descriptive statistics for soil samples from home lawns and athletic fields submitted to Cornell Nutrient Analysis Laboratory between 2001 and 2005 for soil phosphorus levels.

Statistic	Athletic Fields	Home Lawns	All Samples
Sample size	500	3303	3803
Median, mg kg^{-1}	6.4	6.4	6.4
Mean, mg kg^{-1}	11.9	14.1	13.8
Standard error of mean	1.01	0.58	0.52
Standard deviation	22.6	33.5	32.3
Variance	510	1120	1040
Coefficient of variation, %	189	237	233
Minimum, mg kg^{-1}	0.35	0.30	0.30
Maximum, mg kg^{-1}	308	973	973
25^{th} percentile, mg kg^{-1}	2.7	2.2	2.2
75^{th} percentile, mg kg^{-1}	13.8	16.1	15.9

Table 2.2 Mean and median soil P levels and classifications of soil samples from home lawns and athletic fields according to current Cornell University soil test interpretations for phosphorus levels.

				Soil phosphorus level classification†				
Soil Mgmt. Group	Sample Size	Mean P Level	95% CI of Median P Level	VL	L	M	H	VH
		mg kg^{-1}	mg kg^{-1}			%		
Group II	775	11.1	5.2 - 6.6	2.6	9.5	29.1	42.4	16.4
Group III	854	16.4	5.7 – 7.5	2.0	12.9	25.3	39.7	20.1
Group IV	1196	16.0	7.1 – 8.4	1.2	10.0	23.5	41.4	23.8
Group V	978	11.2	4.1– 6.0	5.0	27.1	16.7	37.5	13.7
All Groups	3803	13.8	6.1 – 6.8	2.6	15.0	23.3	40.2	18.9

† VL = very low, L = low, M = medium, H = high, and VH = very high, the ranges of extractable soil P levels associated with these classifications can be found in Table 2.3.

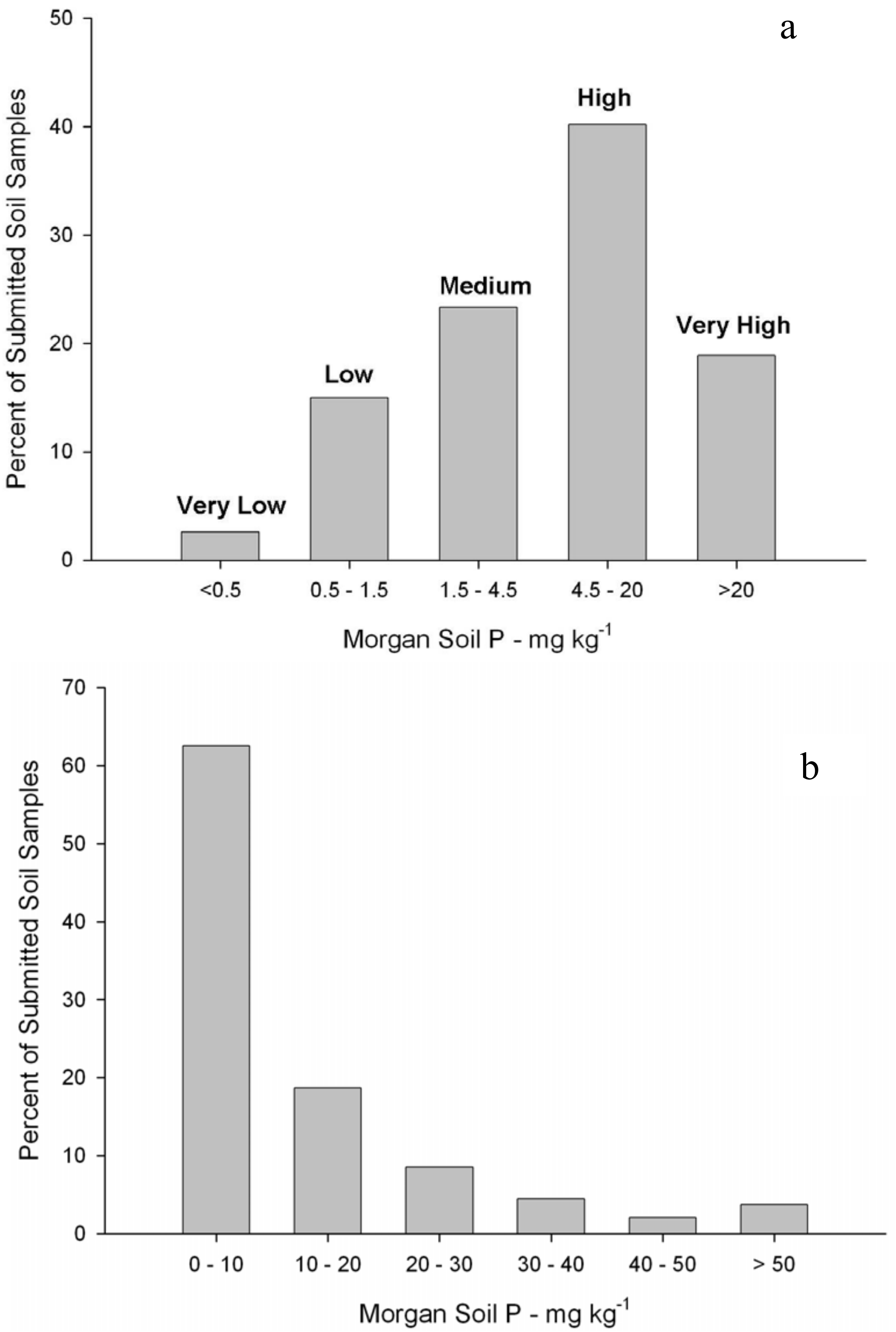

Figure 2.2 Agronomic (a) and equal bin size (b) frequency distribution of all submitted soil samples.

which is response to additional P is not likely is 4.5 mg kg^{-1}. Petrovic et al. (2005) examined the growth and visual quality responses of simulated home lawns to soil P levels in several locations across New York. The authors reported that tissue P content is likely to increase in response to a P fertilizer application when Morgan-extractable soil P levels fall below 2 mg kg^{-1}. These results suggest that the critical soil test level beyond which a desirable response is not expected is 2 mg kg^{-1} rather than the 4.5 mg kg^{-1} currently employed (Table 2.3). Phosphorus fertilizer is recommended for lawns when soils test very low or low, and when very low, low, and medium for athletic fields (Table 2.3). The difference between P recommendations for lawns and athletic fields are due to the greater uptake of P driven by greater N fertilization rates employed to encourage re-growth in traffic-damaged areas of the fields. According to these interpretations, 18% of lawns and 41% of athletic fields would benefit from a P application. For most agricultural crops in New York, a small starter P application is also recommended for soils that test high in P (Ketterings et al., 2003; Ketterings et al., 2005). If this were the case for turfgrass, P fertilizer would be recommended for over 81% of the sites represented by these soil samples. On the other hand, based on the data from Petrovic et al. (2005), if fertilizer is required when soil P levels fall below 2 mg kg^{-1}, then 22.8% of sites would require a P fertilizer application. Based on current Cornell University recommendations 59% of the lawn and athletic field soil samples were classified as high or very high in P based on the soil test P classifications in Table 2.3. This is higher than the 47% (of 119,326 samples from agricultural fields and submitted to CNAL from 1995 – 2001) that tested high or very high in P reported by Ketterings et al. (2005). Twenty-eight percent of agricultural soils were very low or low compared with 18% of turfgrass sites. The percentages of soils testing medium in P were similar in both studies. These results are contradictory to those of Bennett et al. (2004) who found in a study with a randomized sampling design that Bray-1 P soil

Table 2.3 Current Cornell University soil P interpretation and fertilizer recommendation for established home lawns and athletic fields.

Morgan Soil P	Classification	Fertilizer recommendation for athletic fields	Fertilizer recommendation for lawns
mg kg^{-1}		kg P_2O_5 ha^{-1} yr^{-1}	kg P_2O_5 ha^{-1} yr^{-1}
≤ 0.5	Very Low	49 – 147	49 – 147
0.6 – 1.5	Low	49 – 147	49 – 147
1.6 – 4.5	Medium	49 – 147	0
4.6 – 20	High	0	0
> 20	Very High	0	0

levels of home lawns were significantly lower than those of dairy and cash grain soils in Wisconsin.

Agricultural studies have shown extractable soil P levels are good predictors of P concentration in runoff (Sharpley, 1995). Yet, agronomic interpretations of soil P levels (low, medium, high and very high classifications) are based on expected crop response, and should not be equated to environmental P loss predictors. For 59 samples from agricultural fields in the Delaware River Watershed of New York State that were analyzed for Morgan extractable P and 0.01 *M* $CaCl_2$ extractable P (as indicator of P directly available for runoff or drainage loss), Kleinman et al. (2000) identified a Morgan soil test P value of 16 mg kg^{-1} as a change point above which P was bound less tightly to soil. Above this soil test P level, 0.01 *M* $CaCl_2$ extractable P levels increased faster per unit change in Morgan P than below it. Kleinman et al. (2000) suggested that for their study, a Morgan soil test P value of 16 mg kg^{-1} could be used as an environmental threshold. If we can apply these finding to turfgrass and expand to soil and environmental conditions represented by the 3,807 samples in our dataset, 75.3% of samples would fall below this threshold. Group IV had the lowest percentage of soils below the change point, 70.5%; while Group V had the largest percentage, 80.1%. However, the use of this particular change point in determination of this environmental threshold across fields differing in texture, mineralogy, organic matter, and pH needs to be investigated as suggested by Kleinman et al. (2000) and currently an official environmental threshold for soil P does not exist in New York. It is apparent from the distribution of soil P levels from NY State lawns and athletic fields that most areas do not require P fertilizer, yet most also have soil P levels below the environmental threshold suggested by Kleinman et al. (2000) and the 20 mg kg^{-1} level above which a yield response is unlikely for corn. It is likely that P fertilizer bans will address only a small part of the P loss issue from turfgrass. Greater reductions in P loss from turfgrass areas may be achieved by obtaining a greater understanding of the relative contributions of P fertilizers, tissue P, and soil P levels to P in runoff from turfgrass areas. In addition, reductions in P runoff losses could be achieved by focusing on management practices that reduce runoff from turfgrass areas.

REFERENCES

Barten, J.M., and E. Jahnke. 1997. Suburban lawn runoff water quality in the Twin Cities Metropolitan Area, 1996 and 1997. Suburban Hennepin Regional Park District, Water Quality Management Division, Maple Plain, MN. 17p.

Beard, J.B., and R.L. Green. 1994. The role of turfgrasses in environmental protection and their benefits to humans. J. Environ. Qual. 23:452-460.

Bennett, E.M., S.R. Carpenter, and M.K. Clayton. 2004. Soil phosphorus variability: scale-dependence in an urbanizing agricultural landscape. Landscape Ecology. 20:389-400.

Cornell Cooperative Extension. 1987. Cornell Field Crops and Soils Handbook. 2nd edition.

Correll, D.L. 1998. The role of phosphorus in the eutrophication of receiving waters: A review. J. Environ. Qual. 27:261-266.

Easton, Z. M., and A.M. Petrovic. 2004. Fertilizer source effect on ground and surface water quality in drainage from turfgrass. J. Environ. Qual. 33:645-655.

Ketterings, Q.M., K.J. Czymmek, and S.D. Klausner. 2003. Phosphorus guidelines for field crops in New York. Department of Crop and Soil Sciences Extension Series E03-12.

Ketterings, Q.M., S.N. Swink, G. Godwin, K.J. Czymmek, and G.L. Albrecht. 2005. Maize silage yield and quality response to starter phosphorus fertilizer in high phosphorus soils in New York. J. Food Agric. Env. 3:360-365.

Ketterings, Q.M., J.E. Kahabka, and W.S. Reid. 2005. Trends in phosphorus fertility of New York agricultural land. J. Soil Water Conserv. 60:10-20.

Kleinman, P.J.A., R.B. Bryant, W.S. Reid, A.N. Sharpley, and D. Pimentel. 2000. Using soil phosphorus behavior to identify environmental thresholds. Soil Sci. 165:943-950.

Kussow, W.R. 2004. Phosphorus runoff lossess from lawns. Better Crops. 88:12-13.

Maguire, R.O., W.J. Chardon, and R.R. Simard. 2005. Assessing potential environmental impacts of soil phosphorus by soil testing. p 145 – 180. *In* J.T. Sims and A.N. Sharpley (ed.) Phosphorus: Agriculture and the environment. Agron. Monogr. 46. ASA, CSSA, SSSA, Madison, WI.

Milesi, C., S.W. Running, C.D. Elvidge, J.B. Dietz, B.T. Tuttle, and R.R. Nemani. 2005. Mapping and modeling the biogeochemical cycling of turf grasses in the United States. Env. Management. 36:426-438.

Morgan, M.F. 1941. Chemical soil diagnosis by the universal soil testing system. Connecticut Agricultural Experimental Station Bulletin 450.

New York Agricultural Statistics Service. 2004. New York Turfgrass Survey. New York State Department of Agriculture and Markets. Albany, NY.

Petrovic, A.M., D. Soldat, J. Gruttadaurio, and J. Barlow. 2005. Turfgrass growth and quality related to soil and tissue nutrient content. Int. Turfgrass Soc. Res. J. 10(2):989 - 997.

Pote, D.H., T.C. Daniel, A.N. Sharpley, P.A. Moore Jr., D.R. Edwards, and D.J. Nichols. 1996. Relating extractable soil phosphorus to phosphorus losses in runoff. Soil Sci. Soc. Am. J. 60:855-859.

Sharpley, A.N. 1995. Dependence of runoff phosphorus on extractable soil phosphorus. J. Environ. Qual. 24:920-926.

Sharpley, A.N.1981. The contribution of phosphorus leached from crop canopy to losses in surface runoff. J. Environ. Qual. 10:160-165.

Shuman, L.M. 2002. Phosphorus and nitrate nitrogen in runoff following fertilizer application to turfgrass. J. Environ. Qual. 31:1710-1715.

University of Wisconsin. 2001. 1999 Wisconsin Turfgrass Industry Survey. 16 pp. Madison, WI: University of Wisconsin, Madison, UW Extension, and Wisconsin Agricultural Statistics Service.

USEPA (United States Environmental Protection Agency). 2002. National water quality inventory 2000 report to congress. EPA-F-00-005. Office of Water, Washington DC.