

Expert Input Regarding Dane County Phosphorus in Lawn Fertilizer Ordinance: Complete Responses to Questions

Dane County Lakes and Watershed Commission 11/13/03

In October 2003, the Dane County Lakes and Watershed Commission requested input from retailers/commercial interests and technical experts to inform the Commission's development of a county-wide ordinance restricting phosphorus in lawn fertilizers.

Unless otherwise noted, the responses below are exactly as provided by the experts, who are listed along with their affiliations below.

Armstrong = Dr. David Armstrong, Professor, UW Civil and Environmental Engineering

Bennett = Dr. Elena Bennett, Research Associate, UW Center for Limnology

Bannerman = Roger Bannerman, DNR runoff researcher

Boston/Steil = Steve Boston, Blain's Farm & Fleet Lawn & Garden Merchandise Manager for 3 state region, and George Steil, Jr. – Corporate Attorney, Janesville, WI

Carpenter = Dr. Steve Carpenter, UW Center for Limnology

Combs = Sherry Combs, Director, UW Soil and Plant Analysis Lab

Condon = Tom Condon, Home Depot Central Division lawn and garden manager, Arlington Heights, IL

Connors/Jones = Kevin Connors, Director Dane County Land Conservation Department; Sue Jones, Watershed Management Coordinator for the Dane County Lakes and Watershed Commission

Cooperband = Dr. Leslie Cooperband, Associate Professor, UW Soil Science

Good = Dr. Laura Ward Good, Research Associate, UW Soil Science

Johannsen = Karen Johannsen, owner Johannsen's Greenhouse & Gifts (Sue Jones notes from telephone interview)

Kussow = Dr. Wayne Kussow, Professor, UW Soil Science

Milles = Jeff Milles, Wisconsin Golf Course Superintendents, Big Bend, WI

Potter = Dr. Ken Potter, Professor, UW Civil & Environmental Engineering

Shepard = Tom Shepard, owner of Ace Hardware on Willy St. in Madison (Sue Jones notes from telephone interview)

Stier = Dr. John Stier, Associate Professor, UW Horticulture

Swingle = Brian Swingle, Executive Director, Wisconsin Landscape Federation, Greenfield, WI

USGS = collaborative response from the U.S. Geological Survey Water Resources Division in Middleton, submitted by Herb Garn

QUESTIONS FOR RETAILERS, GOLF COURSE MANAGERS, ETC

R1. What, if any, barriers would have to be overcome in order to make P-free fertilizer widely available locally; and to have citizens understand their fertilizer choices and consequences?

Boston/Steil

All the national branded suppliers they order from have developed low-P and 0-P fertilizer formulas. Scotts could ship P-free in 6 months. Scotts is a secondary brand for Farm & Fleet but they do sell a lot of it. Scott's has 3% P fertilizer today, and are formulating to 0% P (it may be available now).

There are lots of other national brand suppliers of P-free fertilizers, but few that can supply to a multistate organization like Farm & Fleet and meet their standards for quality and uniformity of product. Lester's (sold by Home Depot) would not meet their standards.

"Estate" is their registered private label trade name, which is manufactured for Farm & Fleet. There is no 0-P Estate right now (no customer requests for it). They would be able to supply this product, but it would take a year to repackage, and get State (DATCP) to approve bag and product.

Would have a concern about regulation of garden fertilizers, especially Miracle Gro and small companies with specialty products, and that don't provide P-free alternatives. Keep the focus on turf fertilizers, as the scientific community said runoff concern comes mostly from turf.

Key is user education. Customers will do the right thing, unless they don't know any better.

Condon

They already offer P-free fertilizer in WI.

In MN, Home Depot offers both P and 0 P fertilizers, displayed separately. They have 3-4 years of experience with MN local regulations. Doesn't think that customers must provide proof of need for purchase. Stores comply with local ordinances there – so in some stores they don't offer P product. Customers could still purchase it elsewhere and bring it in.

It is possible to block stores from ordering P-containing fertilizer (they have done this in MN where regulation requires it). Home Depot does not have a house brand fertilizer. Major brands do offer P-free fertilizer, so they can offer customer line that complies with local ordinances.

Johannsen

She works with different distributors; doesn't have any P-free fertilizer on shelves now because didn't sell awhile ago (cost was 2X regular fertilizer). Not a problem to get it now, just a concern with allowing adequate time for ordinance phase in.

P-free doesn't sell – costs 2X as much. Not finding the MN experience now in her store (in MN, P-free price became equal to P-containing fertilizer over time).

Milles

Time is the only barrier. Phosphorous free fertilizers are currently available, it is just necessary to provide enough time to allow ordering of these products and current inventory to be used up.

Most citizens do not understand fertilizer choices and consequences. If everyone understood the effects of fertilizers on turf, there would not be a need for this discussion. There are no negative consequences of applying fertilizers with phosphorus if properly applied. Miss application is the only source of phosphorus entering the waterways from fertilizers. Fertilizers containing phosphorus that is applied to hard surfaces such as sidewalks, roads, driveways, and directly into a waterway, is the only source of phosphorus from fertilizers. Phosphorus containing fertilizers help promote plant health and root growth. Without phosphorus, plant quality will decline over time causing an increase of sediment runoff into the waterways, which will lead to higher levels of phosphorus entering the lakes and streams.

Shepard

Education of consumers is key, although store serves a very environmentally aware area and people will try to do the right thing for the lakes.

Right now can't order P-free from Ace warehouse in LaCrosse (even though it is so close to MN where P lawn fertilizer restrictions are in place). All Madison stores order from same warehouse. Ace also has own fertilizer brand, and he will check to see if P-free available or there are plans to manufacture it, and get back to us.

They currently order non-P fertilizer from Renaissance Fertilizer (an Ace vendor), out of MN.

R2. When do retailers, golf courses, grounds managers etc. typically order their fertilizers for sale or use in the spring? What is the process for exchanging products once they are in the warehouse or at the golf course?

Boston/Steil

Spring 2004 fertilizer has already been purchased. Fall 2004 season will be committed in January and February. They do make additional orders throughout the year, but decide on items to sell at the fall and January commitment times.

It would be spring 2005 before Farm and Fleet would be 100% ready for P fertilizer restrictions.

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Don't know if can get 0-P for spring 2004, in a supplemental order. They would make space in the store for it if they could get it.

No exchanges or buybacks of fertilizers are possible – Scott's doesn't allow – others don't either. Reasons: shipping costs substantial, packaging degradation, storage in unknown conditions (from manufacturer's/distributor's point of view), low margins.

Condon

Store order for fertilizers has to be placed around January 1. Products are on shelves by 3/1 in spring. Once have product in stores – difficult if not impossible to return. Home Depot is very market sensitive and can react to local demand or regulation fairly quickly. Have had experience with complying with MN regulations.

Johannsen

Ordinance should not go into effect in spring 2004. She has already ordered (back in July) fertilizer for spring and fall 2004 sales. There are big discounts for orders placed in July. Need a good year for phase-in. They place supplemental orders throughout the year.

Small independent stores like hers order fertilizers from distributors in the Midwest (and not directly from manufacturers). Distributors also already have their orders in to manufacturers for 2004.

Once fertilizers are ordered she can't exchange them. Must sell products on shelves.

Milles

Most golf courses order their fertilizer between August 1 and December 31 for the following year. Fertilizer prices generally increase between November 1 and December 31. Suppliers offer pre-season discounts based on quantity, payment date, and delivery date. One supplier for the state, who also has a branch in the Madison area, offers the following program:

Quantity Discount	Cash Discount if paid by:	Desired Shipping Date	
		August - October	November - Dec.
40 bags Base	September 10, 2003	6%	4%
	October 10, 2003	5.25%	3.25%
80 bags 4%	November 10, 2003	4.5%	2.5%
	December 10, 2003	3%	2%
240 bags 9%	January 10, 2004	2.5%	1.7%
	February 10, 2004	1.75%	1.30%
440 bags	March 10, 2004	1.5%	.90%
	April 10, 2004	1.25%	.50%
	May 1, 2004	.75%	Net Due
	May 13, 2004	Net Due	

Notes from Milles on interpreting table:

Quantity Discount = discount based on size of order, must order at least 80 bags for a 4% discount.

Cash Discount / Delivery Date = additional discount based on payment date and delivery date. If fertilizer was ordered on August 1st and paid by September 10th with a delivery date between August – October a 6% discount was given

Based on this example you would receive a total of a 10% discount.

If you ordered 240 bags before November 1st when their price increases, had it delivered during November – December, and waited to pay until the course was generating revenue the following year, you would receive a 9% quantity discount and could delay payment till May 13th.

Basically, the more you order, the sooner you take delivery and pay, the more you save. Fertilizer products can also be combined. If you ordered 40 bags of fertilizer A and 40 bags of fertilizer B, I would still the quantity discount of 4%.

Once the product is at the golf course, exchanging product is very costly. If the product was a custom order, the supplier will not exchange the product. If the product was a standard item that is kept on hand at the supplier, restocking charges are then typically 20%. Exchanging product would also cause the consumer to loss any discounts due to the early order program. Exchanging fertilizer is not an option for golf courses and most golf courses do take advantage of the early order / early delivery discounts.

Shepard

Ace on Willy St. is a small hardware store that doesn't sell a lot of fertilizers. Their order for spring fertilizers would be soon (Feb March). Bigger stores serving area with many suburban lawns would have to order in late fall (for spring availability).

From Ace warehouse in LaCrosse (warehouse serves all Madison area Aces) – they get small orders in 2x/week (therefore supplemental orders can easily be made).

Fertilizers are not easily exchanged – cost of product is shipping and handling. would to have to pay shipping back.

R3. What factors would assist retailers in complying with an ordinance including a restriction on sales of P-free fertilizer unless a soil test shows that it is necessary?

Boston/Steil

Get city or county to create the exact statement about the ordinance and reasons for it that they want to provide to fertilizer purchasers. Take this to fertilizer manufacturers and ask them to create nicely-designed, eye-catching, easy to read signs that would be displayed with both products. (Most national companies have manufacturing facilities in Wisconsin or adjacent states.) Might get manufacturer to create educational handout –

ordinance info on one side; educational information on the other. This information would then be provided to every purchaser – even those outside area of restrictions. Ideally would have consistent signs and verbiage at all stores (not just Farm & Fleet, but all affected by ordinance).

They have no issues with posting educational info at point of sale, and want to help. Could provide info sheets to customers. There could be sign that says fertilizer with P couldn't be used on lawns in city/county with certain exceptions.

Average store trade radius is 35-40 miles, so they sell to customers inside and outside city of Madison and Dane County. They want to display and sell to people who can legally purchase P-containing products. Wouldn't want restrictions on display of P-containing fertilizer. Would like to see ordinance focused on user on application.

Would hate to be in position to determine whether or not customers have legitimate need for a P-containing fertilizer product (e.g. check to see if are out of county resident; someone establishing a new lawn; someone with a soil test result in hand to interpret). Cash register operators ring up anything in store, have no training in lawn and garden, and could not interpret a soil test result. Also the time issue – lines of customers could back up.

Wouldn't want to have to go the warehouse to get it if needed. Lots of people don't ask for help – customer assumes that store doesn't carry it if it's not on the shelf.

Condon

Would need to be made aware formally of regulation. Would need info to customers at point of sale. Display decisions (extensive product displays) made at Atlanta home office.

Johannsen

Ordinance wouldn't have a big effect on her business. Don't sell a lot of fertilizer. Small amount of fertilizer sales compared to other sales.

Not retailers' job to enforce ordinance. County should publicize ordinance and that it's up to customer (not the retailer) to comply. They have sales staff who can advise customers on products (as opposed to Farm & Fleet), but at busy times they're also just ringing people out at checkout.

For customers who need P – should be able to buy it in Dane County. Don't have time to go to back room for product containing P if customer needs it.

Requiring retailers to display info on ordinance and P effects is fine. 8*10 sheet posted and laminated – plus ring with tear off sheets for customers would be helpful. She doesn't have room for a larger display. This would be a reasonable way to emphasize that responsibility is on consumer for compliance.

Suggestions for ordinance development:

- Be clear that ordinance does not apply to gardens. People need high P for high fruit production - especially for plants grown in containers.
- Many products are clearly targeted for lawns, and there is no ambiguity on the product label about this. Others are not so clear – see discussion below.

Miracle-gro and Follett's Watch Us Grow are just 2 examples of fertilizers/plant foods that are not really targeted for lawn use. In fact, it would be quite impractical to apply them on a lawn by using a watering can, but lawns are mentioned on the label nonetheless. They could however, be applied by using a hose-end sprayer which mixes and applies products by using an applicator and garden hose.

Milorganite on the other hand is definitely targeted at lawns, but also gives "equal space" on its label for trees, shrubs, etc. It is also labeled for use on newly seeded lawns, which may be OK depending on how the ordinance is written. So, I would definitely want to stress that the retailer should only be held accountable to have proper posting of the ordinance and not be required to enforce how each individual customer will use a particular product.

It is imperative to word the ordinance so that it targets only products that are packaged and labeled primarily for lawn use, and exempt other products such as Miracle-Gro and other plant foods/fertilizers that just happen to list lawns on its label. The wording would have to be generic, however, because individual plant foods are constantly entering the market place, so it would be impossible to list them by name.

Milles

I am not a retailer, but I feel retailers should not have the burden of having to enforce a restriction on phosphorus fertilizers and loose possible sales to a neighboring competitor located just outside the county line. If a consumer wants a phosphorus fertilizer, he/she will either use what is available such as a starter fertilizer, a fertilizer with phosphorous containing some type of pesticide, or he/she will most likely go outside the county to purchase the necessary product.

Instead of banning phosphorus containing fertilizers, why not implement a tax at the retail level. This user tax would discourage people from buying phosphorus fertilizers and create a fund to help in other ways to protect water quality, such as purchasing more street sweepers. Just an idea.

Shepard

Ordinance wouldn't affect them a lot – they don't sell a lot of fertilizers.

County would have to decide if retailers would be expected to ask customers questions before P-containing fertilizer sale. Would retailers be able to rely on customer word about new lawn, soil test shows necessary, etc?

Education is a huge thing – people are very busy. Articles in newspaper about P and lawns have been good.

QUESTIONS FOR TECHNICAL EXPERTS

T1. What are the most significant factors that affect phosphorus surface water runoff?

Armstrong

The amount of phosphorus transported by surface runoff waters is influenced by several factors: Some of these are: (1) the phosphorus status of the surface soil; as the soil becomes more saturated, the concentration in runoff water tends to increase; (2) soil erosion; phosphorus is also transported in soil particles carried by the runoff; the greater the amount of erosion, the larger the amount transported; (3) land cover; vegetation reduces soil erosion and generally improves infiltration of water into the soil; (4) slope; increasing slope generally increases runoff and erosion; thus, retention ditches and rain gardens retain water and allow more infiltration; (5) the amount and intensity of precipitation; more runoff and erosion occurs during hard rains because of less time for infiltration.

Bannerman

If I understand the question, the two most important factors determining the amount of phosphorus in the runoff is the amount of phosphorus available for wash-off and the amount of water the surface generates. A forest floor is a surface that has a lot of phosphorus available for wash-off, but the amount of runoff is so low the phosphorus contribution to the receiving water is relatively low. If lawns produced as much runoff volume as streets they would be the largest source of phosphorus in an urban area. Instead, streets produce more the phosphorus than lawns, although the average phosphorus concentrations in lawn runoff are 2 to 10 times higher than that observed in street runoff.

Bennett

The most significant factors that affect P runoff are P concentrations in the soil, the amount of soil that is eroded, the presence of soluble P (such as in manure or liquid fertilizers), and the amount of water moving.

There are two broad categories of phosphorus (P) runoff: P that moves attached to soil particles when erosion happens (particulate P); and P that moves dissolved in water (dissolved P, can be in surface flow or groundwater). Particulate P runoff is dependent on two factors: the concentration of phosphorus in the soil, the amount of that soil that moves. Dissolved P runoff is dependant on the concentration of P in the water (which depends in part on the amount of P in the soil and in part on the amount of P in highly soluble forms such as manure), and the amount of water that is moved. Therefore, the most significant factors that affect P runoff are P concentrations in the soil, the presence of soluble P, the amount of soil that is eroded, and the amount of water flowing.

Carpenter

P runoff is a multi-step process which involves erosion of P-rich particles from land into water. P runoff is higher if (1) soil P content is high, (2) vegetation is sparse or disturbed, (3) soils are disturbed (e.g. construction sites), or (4) P is present in highly soluble forms on the soil surface, e.g. applications of manure or liquid fertilizers to frozen soil. Also, of course, runoff depends on significant amounts of precipitation or snowmelt.

Combs

I'm not entirely sure of the question. Phosphorus can enter surface water both attached to soil particles that erode and/or as soluble phosphate. Soil fixed P probably accounts for the majority of the loading, but soluble P may have as much/more impact because of its reactive form. Soils left with no vegetative cover because of spring tillage or construction, especially in spring when rains may be intense, are subject to severe soil erosion and therefore P loss. Well-managed soils with high P fertility levels will have potential for more P loss than other soils assuming the soil loading remains the same. Surface applied amendments such as P₂O₅ containing fertilizers, manure, and vegetation can contribute to the soluble P burden. Incorporation of these materials, either mechanically or by precipitation, would reduce potential P loss. Research many years ago by the Dept of Soil Sci at the Arlington Experiment Station showed soluble P released by alfalfa after a killing frost. I would expect soluble P to be released from leaves kept street-side, but since initial levels of plant P are much lower in leaves than alfalfa the quantity should be less. Any barrier between the edge of field/site and receiving water such as plant buffer strips, will help reduce the P burden actually entering surface water.

Good

Phosphorus (P) in surface water runoff can be either in dissolved form or as part of particles suspended in the runoff. Dissolved P is usually primarily inorganic phosphate (H_2PO_4^- or HPO_4^{2-}), the form of P used by plants. Particulate P can be chemically bound to eroded soil mineral particles or part of living or dead plant materials and microbes. The particulate P entering a water body has to be released from the particle as dissolved phosphate before it can be used by aquatic biota.

Mineral particulate P forms entering a water body will release (dissolve or chemically detach) phosphate if the phosphate concentration in the water is lower than the equilibrium concentration maintained by that specific P form in water. Conversely, if the concentration in the water is higher than the equilibrium concentration for that P form, then the particulates can sorb P from the water.

Where there is soil erosion, PP is usually the dominant form in runoff during the months when the soil is not frozen. In snowmelt, there is generally more DP than PP. In situations where there is permanent vegetative cover that keeps soil from eroding, DP can be the dominant form of P in runoff year round, although the majority of this P can come in the form of snowmelt.

The amount of dissolved P (DP) that enters a water body is a function of the volume of water entering the water body and the average concentration in the runoff:

$$DP \text{ load} = \text{Runoff volume} \times \text{Runoff P concentration}$$

To lower DP loading, you need to reduce runoff volumes and/or runoff P concentrations. Runoff volume is affected by the volume of precipitation and the proportion of that precipitation that infiltrates the soil. Runoff P concentrations are determined by the propensity of the soil, vegetation, and other materials the runoff water comes in contact with to release or sorb P.

The amount of particulate P (PP) entering a water body is a function of the mass of sediment in the runoff and the average P concentration in the sediment.

$$PP \text{ load} = \text{Delivered particles} \times \text{Particulate P concentration}$$

To lower PP loading, you need to reduce the movement of particulates/sediment and/or reduce the concentration of P in the sediment.

There are numerous articles on the factors affecting phosphorus transport to water from agricultural soils. One is: N.C. Hansen, T.C. Daniel, A.N. Sharpley, and I.J. Lemunyon. 2002. The fate and transport of phosphorus in agricultural systems. Journal of Soil and Water Conservation. 57 (6): pp 408-417.

More information on phosphorus in soil and phosphorus transport can be found at http://www.soils.wisc.edu/extension/p_roundtables/title.htm in the Phosphorus Roundtable Archives in Wes Jarrell's July 11, 2001 presentation on P forms and their bioavailability and Leslie Cooperband's January 8, 2003 presentation

Kussow

The most significant factor affecting quantities of P in runoff water is the amount of runoff per se.

Potter

I am not sure of the meaning of this question. Clearly the factors affecting availability of phosphorus and the amount of runoff are critical.

Stier

Each lake is different due to a number of factors such as source of incoming water, development surrounding lake, etc. 1) Sediment loss/erosion, 2) Runoff volume and rate (inches/hr)---the more runoff that occurs, often the more P that runs off, 3) Animal waste, domestic and wild (e.g., geese), possibly including manure application to frozen soils, 4) Atmospheric deposition (pollen, dust)--in some lakes, accounts for up to 25% of P loading, 5) Underlying geology of the watershed.

Swingle

I am attaching a paper that is a literature review of current data on lawns and phosphorus. A quick summary of the sources of P in urban runoff can be summarized in one sentence: the major sources of P are natural sources that find their way onto impervious surfaces that lead to municipal storm water systems that empty into streams

and lakes. These sources would include soil erosion from construction, urban vegetation such as leaves, flowers, pollen and seeds, pet waste, waterfowl, and highway deicing compounds.

[NOTE: Attached paper was: The Scotts Company. 2003. Phosphorus and urban runoff: a discussion about phosphorus and the relative contributions of various sources to urban runoff as they relate to the growth of algae and aquatic weeds. Marysville, OH]

In addition, a very important source of P that is often overlooked is Eurasian water milfoil that has long contaminated the lakes of Dane County. This invasive aquatic weed is very capable of mobilizing significant amounts of sediment-P and redistributing this nutrient back into the water column to fuel the growth of algal glooms that require the more soluble forms of P. Phosphorus is taken up from sediments by EWM and is released back into the water column when the vast amount leaves and stems produced by this fast-growing weed dieback and are degraded via microbial decomposition. (see copy of paper attached by Smith and Adams U of WI, Madison, 1986.)

[NOTE: Attached paper was: Smith, C.S. and M.S. Adams. 1986. Phosphorus transfer from sediments by *Myriophyllum spicatum*. *Limnology and Oceanography* 31: 1312-1321.]

USGS

The goal of the proposed phosphorus fertilizer ordinance is to improve the quality of the waterbodies in the county. Reducing the phosphorus loads reaching the waterbodies is the way to achieve that goal. The load of phosphorus is a function of two factors, runoff concentration and runoff volume. So, to reduce loads of phosphorus, either or both of the factors can be reduced. Applying this specifically to lawns, it is preferred to have lawns that have both low runoff concentrations and volumes. An ordinance restricting phosphorus in fertilizers would most likely reduce the concentration of phosphorus in lawn runoff. However, there is the possibility that the ordinance could lead to thinner, less-healthy lawns, which may lead to increased runoff volume. This increased volume could offset the effect of the reduced concentrations. It is quite possible that it is not necessary to have phosphorus in fertilizers to have a lush, low runoff-producing lawn, but that has not been investigated by the USGS and is outside our area of expertise. If it is possible to have thick, healthy lawns without phosphorus in fertilizers, more people may fertilize their lawns, especially if they were advised that they would be helping the lakes and improving their lawns by using phosphorus-free fertilizers.

Additional controlled paired-basin studies are needed to determine phosphorous loads (concentrations and amount of runoff) in runoff from phosphorus fertilized and phosphorus-free fertilized lawns under a variety of environmental and anthropogenic situations (slope, runoff intensity and duration, lawn maintenance practices, etc). Additionally, if the ordinance to limit phosphorous in fertilizers is passed it would be worthwhile to conduct a study to determine the impacts of the ordinance.

T2. What are the relative sources of phosphorus to Dane County waters? Please be as specific as possible and provide citations in your answers, and address the following sources and others that you are aware of:

lawns, gardens, atmosphere, pets, urban wildlife, cropland, barnyards, construction sites, streambanks, uplands

Armstrong

Phosphorus is transported to the lakes from both the rural and urban parts of the watershed. The rural contributions include crop land and animal holding areas with smaller amounts from grass land, pasture and forested areas. Urban sources include streets, lawns, leaching from the leaves, especially after leaf fall during the fall season, and other smaller sources. I think others are responding about studies of the amounts coming from these sources.

Bannerman

The importance of each source of phosphorus may vary with receiving water. Determinations of the sources of phosphorus should be calculated for each drainage area. This is already done for locations with a priority watershed plan, such as the Lake Mendota Watershed and the Yahara-Monona Watershed. A process to evaluate the sources should include a comparison of urban versus rural, determination of loads for different types of urban land uses, a comparison of loads for each type of source area (e.g. crops versus barnyards, or streets versus lawns), evaluations of the activities that may increase the phosphorus loading from these source areas (e.g. applying fertilizer), and a determination of the loading from point sources, especially sewage treatment plants. All these estimates should be done so as to reflect the benefits of existing management practices. It is not necessary to include rainfall as a source, since most previous work shows the wet fall is a relatively minor source.

It is possible to make some generalizations about the sources of phosphorus for different types of watersheds. These generalizations are based on previous efforts to model the sources of phosphorus. In most cases the agricultural areas produce more phosphorus than the urban areas. For Dane County the contribution of the urban areas is somewhat related to the percentage of the watershed occupied by the urban area. In a watershed with about 20% urban area and 80% agricultural area, the urban portion will probably produce a little less than 20% of the annual phosphorus load. This assumes no urban controls. I think the estimate of urban phosphorus contribution in the Mendota Watershed Plan is probably low. The plan estimates 5%, I think it is closer to 15%.

For the agricultural part of the watershed the upland sources will probably produce more phosphorus than the barnyards until the barnyard density reaches a higher amount. We know the application of fertilizer to farmers' fields can increase the amount of phosphorus attached to the soils washed off the fields.

Residential areas in the established urban portions of the watershed will probably produce the greatest amount of phosphorus and the commercial will produce the next largest amount. Streets and lawns will together produce over 50% of the phosphorus from the urban area with streets producing the most. Lawns might produce about 20%

of all the phosphorus from an urban area. We know tree canopy plays an important role in why streets are an important source of phosphorus. It is much more difficult to identify the importance of applying fertilizer to lawns. Since some of the phosphorus in fertilizer is attached to the soils on the lawn, it must be washed off with some of the suspended solids we observe in the lawn runoff.

A secondary sewage treatment plant can produce a lot more phosphorus than the runoff from the urban area it is serving.

Bennett

There are recent studies of this that have been completed for the Priority Watershed Project. Someone involved with those studies would be better able to answer these questions than I am.

Carpenter

I can provide rough estimates based on our analyses (published in Soranno et al. 1996). Using those data (from the 1976-1990 period), I calculated that urban sources accounted for 19% of loading under median conditions. The range is wide, however (10.5% to 32%). "Urban sources" is the total of all urban sources, including lawns, gardens, autumn leaf fall in urban areas, pets, and urban wildlife.

Atmospheric inputs are negligible for the purposes of our discussion of the contribution from lawn fertilizer.

It is important to note that much more detailed analyses of P load to Lake Mendota, using more recent data, have been done in support of the Priority Watershed Project. It would be important for the committee to consider these more recent and more detailed analyses.

Carpenter response to a follow-up question on phosphorus transfer from sediments by Eurasian water milfoil, and other internal (in-lake) sources of phosphorus:

Yes, there is lots of internal P loading in Lake Mendota. In small lakes, it is possible to attack eutrophication by reducing internal P loading. This can be done by, for example, treating the entire bottom with aluminum sulfate, aerating the entire hypolimnion with injections of air or liquid oxygen, or pumping the entire hypolimnion of the lake through a sewage treatment plant to precipitate the P. In a large lake like Lake Mendota, it would be extremely expensive to treat the internal loading directly by these sorts of mechanisms. It is much more cost-effective to decrease the external load, which will eventually cause the internal load to decrease.

The rule of thumb for internal load is "3 flushes and you are out". Stop the external load, flush the lake 3 times, and the internal load falls to a low level. It takes 6.5 years to flush Lake Mendota, so it will take about 20 years for internal load to fall, after we control the external load.

You can think of internal load as the flywheel of eutrophication, and the external load as the engine that drives the flywheel. Once you stop the engine, the flywheel will stop eventually.

Connors/Jones

There is no county-wide summary of relative sources of phosphorus delivered to county waterbodies. Although in our response to question 3 we make it clear that a number of priority watershed projects have been completed for county waters, only the Lake Mendota project included a detailed analysis of sources of phosphorus in the watershed and the relative percentages those sources contribute, based on published literature and models to predict contributions from major land uses. We can be very confident in those numbers since they were within 10% of actual monitored data collected by the USGS. The Lake Mendota analysis of phosphorus delivery is reproduced below.

source	phosphorus delivered to Lake Mendota	percentage of total	Land use (includes portion of Col. County)
uplands	35,030 lbs	48%	64.3%
streambanks	4,608 lbs	6%	NA
barnyards	14,986 lbs	21%	NA
transitional areas (under construction)	13,911 lbs	19%	.3%
existing urban	3,740 lbs	5%	19.8%
total	72,275 lbs	100%	

Therefore, for the Lake Mendota watershed, transitional areas (becoming urban) and existing urban areas account for 24% of the phosphorus delivered to Lake Mendota.

A major source of P to our waterbodies is internal recycling of P. Lakes experiencing spring and fall turnover release P into the water column which become bioavailable and fuel weed and algal growth. The lakes (particularly the Yahara lakes) have been severely abused since initial settlement.

It would be very difficult to determine P values for gardens, pet waste, and urban wildlife.

Kussow

As for the relative sources of P, I only have knowledge of one source of information. In 2001 Carolyn Betz, DNR Watershed Planner, reported 1997 estimates of the P loadings in the Lake Mendota Watershed. the contributors were: cropland - 48%; existing urban - 6%; construction sites - 19%; barnyards - 21%; and streambanks - 6%. Reference: Betz, C.R. (ed). Nonpoint Source Control Plan for the Lake Mendota Priority Watershed Project. Wisconsin DNR. WT-536-00 REV. I'm not aware of comparable data for the other Madison lakes. When Mr. Barten spoke in Madison on Oct. 6, he handed out data for the Twin Cities Metropolitan Area. The breakdown on urban residential runoff was: Streets- 44%; Driveways - 20%; Roofs - 1%; and lawns - 39%. I find the street

contribution interesting because DNR/USGS studies here in Madison have shown that virtually all of the P in runoff from streets can be attributed to P coming from trees, either directly leached from leaves during the growing season or from fallen leaves in fall.

Potter

The Dane Co. modeling numbers are probably as good as any. In general I rank the sources as follows:

- construction sites
- croplands
- barnyards
- urban greenspaces (lawns, leaves, etc.)

Stier

Again, sources vary in each lake. It should also be noted that the first algal bloom was recorded in Lake Mendota in the 1880s.

Swingle

See literature review attached.

[NOTE: Attached paper was: The Scotts Company. 2003. Phosphorus and urban runoff: a discussion about phosphorus and the relative contributions of various sources to urban runoff as they relate to the growth of algae and aquatic weeds. Marysville, OH]

USGS

There are many sources of phosphorus to the lakes in Dane County. These include, but are not limited to, runoff of agricultural, lawn, and garden fertilizers, animal waste, vegetative/organic detritus, erosion of soils and sediment, input from wastewater-treatment plants, and atmospheric deposition.

T3. What is currently being done to control those sources?

Armstrong

I believe most of the current control is voluntary, based on education and information programs. There are some programs that provide incentives for such things as best management of animal wastes. Again, others will have specifics on these programs.

Bannerman

There are a number of federal and state programs working on the reduction of phosphorus from different sources. Nutrient control in urban areas is part of NR151 to be implemented next year. Our best example of fertilizer control is the rules written for Minnesota.

Bennett

I think a policy expert would better be able to answer this question. I am aware of programs to control agricultural runoff, like the Priority Watershed Program, and some efforts to control erosion from construction. I am not aware of any programs that specifically address urban runoff.

Carpenter

County administrators are more qualified to address this question than me.

As a scientist observing the watershed, my qualitative impression is that, aside from municipal sewage treatment, there is only minimal regulation of P runoff to Dane County lakes. For example, Dane County's regulation of P input to its lakes is less than one finds in countries such as Chile, Germany, Japan, the Netherlands or Sweden, or in states such as Minnesota and Washington.

Combs

The NRCS 590 Nutrient Management Standard has been a voluntary standard for managing mainly manure and fertilizers for WI farmers for about 10 years. The 590 Standard became mandatory when farmers chose to participate and accept cost-sharing in specific programs offered by DATCP, DNR or NRCS. Tremendous amounts of educational programming has been initiated by the Soil Sci Dept, UW-Madison and related programs including Nutrient and Pest Management and Discovery Farms. Programs have focused on commercial manure haulers, farmers and their advisors and agency staff. Educational programming that also includes some emphasis on nutrient management is also offered for Master Gardeners and commercial interests (turf care, golf courses, arborists society etc.) on an annual basis by soil, horticulture and other specialists in UW Madison/UWEX Cooperative Extension

Connors/Jones

The county Land Conservation Department focuses primarily on sediment and water quality through a variety of programs, because these are two very important components affecting water quality. Other pollutants are reduced when sediment and water quantity are controlled.

The following sections describe P reduction accomplishments and activities as part of Lake Mendota and other priority watershed projects, and county-wide activities to reduce phosphorus loads.

Overall progress toward Lake Mendota Priority Watershed Goals (1997-2002)

Work on the Lake Mendota Priority Watershed Project began in 1997. 2003 marks the 6th year of implementation of this 11-year program.

For most of the measures of progress noted below, there was not a specific phosphorus reduction goal established in the priority watershed plan; nor is there an available estimate of the amount of phosphorus runoff prevented by these actions. However, these practices do have phosphorus reduction benefits.

For 2002 crop year, 14,918 ac of cropland developed nutrient management plans. This represents 18.3% of cropland within the watershed. Cumulative figures for the project

are not available. The goal of these plans is to match nutrient applications to the needs of the growing crop.

Since 1998, 148.9 acres of cropland have been seeded to grasses to establish buffers along surface water. (Assuming average width of 100 ft., this represents about 12.3 miles of surface water with buffers installed.)

Wetland restoration:

- 3 cropland sites consisting of 8.5 acres have been restored to wetlands.
- 5 cropland sites consisting of 102.3 acres are planned to be restored to wetlands in 2003.

89.6 % of the cropland within the watershed is farmed at or below tolerable (T) soil loss levels.

Office staff continues to promote federal programs such as the Conservation Reserve Program (CRP), Conservation Reserve Enhancement Program (CREP) and Environmental Quality Improvement Program (EQIP) when meeting with landowners and producers within the watershed.

Under CREP, county-wide for 2002 and the first 6 months of 2003, 1810 acres are under contract; with 3900 lbs of phosphorus reduced; 2150 lbs of N and 2158 tons of sediment reduced from delivery into the stream network.

The municipalities of DeForest, Waunakee, Middleton, and Sun Prairie continue to contract with the Dane County Land Conservation for erosion control plan review and inspection services. Although not required at plan adoption, all five municipalities did amend their ordinances to reflect stricter erosion control standards. To date, all five municipalities in the watershed have met new County requirements for stormwater management as well. Modeling for the Lake Mendota Priority Watershed Project showed that transitional land (under development) comprised 0.3% of the watershed, but delivered 23% of the sediment and 19% of the phosphorus from the watershed to the lake.

Planned reductions in phosphorus loading from barnyards over the project total 12,429 lbs of phosphorus. As of 12/31/02, plans have been completed to reduce 6376 lbs (51% of the goal).

Phosphorus reduction from other priority watershed projects:

From 1992-1999, landowners in the Yahara-Monona Watershed participated in activities to reduce sediment and associated pollutants from entering water resources. One of the priority watershed project goals was a 50% reduction in phosphorus delivery to the waters from barnyard sources. Actual reduction accomplished was 208 lbs of barnyard phosphorus, or 61% reduction in phosphorus delivery. This was 122% of the goal. Other project practices contributed to additional phosphorus reduction.

The Black Earth Creek Watershed project ran from 1989 to 2001. One of the project goals was a 50% reduction in phosphorus delivery to the waters from barnyard sources. Actual reduction accomplished was 3248 lbs of barnyard phosphorus, or 87% reduction in phosphorus delivery. This was 173% of the goal. Other project practices contributed to additional phosphorus reduction.

The Dunlap Creek Watershed project began in 1993 and is scheduled to end in 2004. The pollutant reduction goal for phosphorus is 36% from barnyards. Other project practices contributed to additional phosphorus reduction.

Additional County-wide activities to reduce phosphorus loads

The following practices, county-wide, result in phosphorus load reductions:

- implementation of the county-wide erosion control requirements (LCD staff will develop an estimate of the phosphorus reduction benefit of implementing this ordinance.
- Infiltration practices (3-5 of them) planned for mitigation of MGE Co-generation plant water withdrawal. These will remove hundreds of acres of watershed area from contributing surface water runoff to Lake Mendota (including the P that would have otherwise be contributed to the lake).
- implementation of nutrient management plans, county-wide. For 2004, the Land Conservation Department has 7,737 acres scheduled for Nutrient Management plans based on the P standard. There is not a specific P reduction goal associated with the program. The goal of a P based nutrient management plan is to maximize economic return to producers while maintaining fertility levels that reduce the potential for impacts to ground and surface waters. UWEX recommendations suggest nutrient additions only to achieve and maintain soil test levels in the optimum range for crops to be grown. Under a nutrient management plan, P applications maybe limited if soil test P is high.
- Lakes and Watershed Commission information and education publications, articles, and work with the media and local watershed groups to promote lawn care practices for reducing phosphorus runoff
- Dane County UW Extension lawn care publications, newsletter articles
- Dane County Public Works sponsors a compost bin sale, and supports Environmental Action teams, which include a lawn care/water quality component

Kussow

A summary of what is being done in the Lake Mendota Priority Watershed Project can be obtained from the DNR.

Stier

Some encouragement, possibly regulations through NR151 to use vegetative buffer strips around cropped areas.

T4. What difference will a 0% P in lawn fertilizer restriction ordinance make in runoff and lake water quality (potential lbs P reduction; and resulting benefit in algae growth)?

Armstrong

The reduction lawn fertilization would reduce the amount of phosphorus in urban runoff, but I can not provide specifics on the amounts.

Bannerman

Removing the phosphorus from lawn fertilizers will probably result in a small reduction in the annual phosphorus loadings to our lakes and streams. Lake Wingra watershed is a good example. About ½ of the homeowners apply fertilizer. Their lawns represent about 10% of the annual phosphorus load to lake Wingra (50% of lawns x All lawns contribute 20 of annual load). If they add no more phosphorus to their lawns the concentrations might drop in half. Therefore the annual reduction from a P ban would be about 5%. I am ignoring the fact a lot of the stormwater for lake Wingra is treated by wet detention ponds. The same calculation for lake Mendota produces a reduction of less than 1% in the annual phosphorus load.

These reduction values are low because lawns are only one source of phosphorus and lawns that have not been fertilized still produce high phosphorus concentrations. All lawns produce high phosphorus concentrations compared to other source areas. Usually, about half of the lawn phosphorus is in the dissolved form. If the phosphorus added in the fertilizer is tightly bound to the soil particles, this dissolved phosphorus must be coming from other sources, such as decaying vegetative material. The phosphorus bound to the particles moving off the lawn is another whole issue.

The particle phosphorus washed off the lawn might carry some of the phosphorus applied with the fertilizer. A long term benefit of removing phosphorus from fertilizer might be to reduce the amount of particulate phosphorus washed off the lawns.

Bennett

Restricting P in lawn fertilizer will eventually lead to reductions in soil P concentrations in lawns. Since P runoff is partly dependant on concentrations of P in soils, this would clearly lead to a reduction in P loads.

Dr. Steve Carpenter has provided an answer to address the resulting benefit in terms of reduced P load and algae growth.

Carpenter

A policy of zero-P fertilizers will certainly reduce P runoff and algae blooms. The amount of the load reduction will be less than the total loading from urban sources, i.e. less than 19% under median conditions (see answer to Question #2).

According to our analyses (published in Lathrop et al. 1998), the current risk of algae bloom in Lake Mendota during summer is around 65%. In other words, if a citizen goes

to the lake every day for a month, she or he will encounter an algae bloom on about 20 days of that month, and will encounter low-algae conditions on about 10 days of that month.

Some background on this calculation: Our model for bloom-days in Lake Mendota says that we have 10 low-algae days per summer month at present (in an average-load year, with average weather). If we carried out the 50% P load reduction envisioned under the Priority Watershed Project we would have about 24 low-algae days per month, an increase of 14 days per month.

The increase from controlling the urban P load is less, because it is a small percentage of the total P load. If we could cut the urban load to zero, we would get 6.5 additional low-algae days per month. But, the lawn fertilizer contribution is only part of the urban load, and there is uncertainty about the magnitude of the lawn fertilizer contribution. This leads to the range of 1 to 5 additional low-algae days per month.

The change in low-algae days can seem out of proportion to the P load changes because the curve that relates them is nonlinear. You can view the curve in the Lathrop et al. 1998 paper.

Using the same data and models, I calculated that the zero-P fertilizer policy for lawns will produce 1 to 5 additional low-algae days per month, under median weather conditions.

Combs

According to some research I recall that Steve Carpenters group did several years ago, practices implemented to reduce loss of P from farm fields were made ineffective because of 1 or 2 intense rainfall events WI usually experiences in late winter. If indeed the majority of P loss is due to the early intense rains coupled with the lack of active vegetative cover, then restricting application time may have more impact than P2O5 content of the material. I also recall Dr Wayne Kussow referring to the inadvertent application of P2O5 on sidewalk/street surfaces as being a major contributor to the runoff P problem. Emphasizing appropriate application timing and fertilizer 'hygiene' may as or more effective than regulating P2O5 formulations.

Kussow

Based on my research and that of many others, 0% P in lawn fertilizer will have very minimal impact on the P loss from lawns per se, but may have some significance regarding fertilizer falling on impervious surfaces and not being cleaned up. The impact on algae growth can only be determined by modeling the lakes, taking into account all existing P sources and amounts in them, knowing what level of reduction is required to get algae on a P starvation diet, knowing all of the sources and amounts of annual P loadings, and the rates at which the lakes flush. Then and only then can the impact of a single act such as restricting P use on lawns be assessed. A good general reference on this is the article by G. Fred Lee published in the journal Stormwater 3(1): 10-24 in Jan.

2002.

Potter

Restrictions on P in fertilizer will likely reduce P runoff to lakes. But stored P in lakes and stream sediment will delay any benefit regarding lake water quality. Primary benefits of restrictions are symbolic, as the restrictions will call attention role of individual citizens.

Stier

Little to none. Only 5% of fertilizer sold in Wisconsin is used for lawn and garden; 95% is used on conventional agriculture (Source: Mike Koran at WDATCP). Most turf fertilizers have low amounts of P relative to the main nutrient used for turf fertilization (Nitrogen); organic fertilizers have higher amounts of P relative to N.

Swingle

None. In fact, an ordinance to restrict P in lawn fertilizers could actually harm water quality rather than protect it.

Numerous university studies that measure both the quantity as well as the quality of the runoff from a lawn without artificially disturbing the turf-thatch-soil interface zone have demonstrated that lawn fertilizers are not likely to be a direct source of P in runoff.

USGS

Addressing only one of the sources noted in our response to Question 2 may not affect the eutrophication problems of a given lake if that source is not a dominant one. Most of the phosphorus loading to the larger lakes in Dane County is from sources other than lawn fertilizers; therefore, limiting the use of fertilizers containing phosphorus is expected to have minimal impact on the larger lakes.

Specifically regarding the impact of a lawn fertilizer phosphorous ban, the primary question is: How are phosphorous runoff loads affected by the use of phosphorous free lawn fertilizers? The answer to that question is not clear cut. Loading values are determined by two factors: the concentration in the runoff and the amount of runoff. Therefore, studies examining either of these factors and studies examining overall phosphorous runoff are important.

See our response to Question 8 for summaries of relevant research conducted by USGS in Wisconsin.

T5. The Commission currently is considering a draft ordinance that would exempt vegetable and flower gardens. How much phosphorus control would be lost by exempting these sources?

Bannerman

Exempting flower and vegetable gardens should not have much effect on the benefits of the ordinance. These gardens probably represent a small acreage and their locations near the building or in the back yard make the delivery of the runoff pollutants less likely.

Combs

Of most concern is the difficulty homeowners have in obtaining fertilizer materials appropriate to their soils need in manageable quantities and in correctly applying recommended rates. Neither of these is easy. About 15 years ago, the recommendations given to homeowners identified a blend that was close to the N-P-K need as determined by a soil test. Problems surfaced because not all outlets stocked all blends and most homeowners (as well as many seasonal L+G personnel) do not understand the traditional fertilizer nomenclature. The UW Labs revised the urban recommendations to identify 'straight' materials. Historically, 'straight' materials (i.e. triple super phosphate, urea) are packaged in 66-pound bags and available mainly at farm cooperatives/fertilizer dealerships. Again problems surfaced because homeowners were having to buy relatively huge amounts of material for application on small areas. In many cases, the leftover fertilizer was applied/disposed inappropriately.

The interpretation/recommendation system was again revised about 3 years ago. It now has updated data base information and identifies fertilizer to apply in terms of readily available turf blends. These blends have been promoted by the industry as 'regular' or maintenance (high N), 'starter' (high P₂O₅) and 'winterizer' (high K) relating to their simplistic method of advising specific nutrient needs based on seasonality, not soil test results. Because these blends are packaged in bags more suitable to urban use and are available wherever lawn/garden supplies are sold, they made sense to use in the recommendation program. However, which blend(s) is recommended is based on soil test results as mentioned in question 6. Using these blends has meant that homeowners could use the spreader setting listed for their specific brand of spreader to get the applied rate spread correctly--both the industry and Dr Kussows/other research agree that 1 lb N/1000 sq ft applied 3 or 4 times per season results in optimum turf quality. All crops related to urban landscapes are, if possible, fit to the turf blend system. The difficulty in calibrating a home spreader and converting from nutrient (i.e. P) to material (i.e. P₂O₅) or from one blend to another is probably as much a contributor to overuse as is application without good identification of need. Using the soil test recommendation system with the recent changes should help homeowners make appropriate applications more easily. Emphasizing informed use for all areas fertilized makes sense--exemptions do not.

Kussow

Early evidence from research going on in Florida indicates that exempting vegetable and flower beds from the ordinance would be a mistake. They're finding P losses from these sources that are considerably larger than those from the adjacent turf. Through the years I've had students bring in soil samples from home gardens for analysis. These soils, without exception, have always tested excessive in P.

Potter

Most gardens probably do not produce runoff, so not much control would be lost.

Stier

Not much if any for reasons given in #4. However, most vegetable and flower garden fertilizers have 1:1 ratios of N to P, much higher than the typical 7:1 ratio of turf fertilizer.

Swingle

We are not aware of any data on flower beds and gardens at this time. Also, most urban flowerbeds and gardens are surrounded by turf that filters out the nutrients and significantly reduces runoff. One must consider that most university extension programs recommend a grass border strip to protect reduce agricultural runoff. A lawn works in the same fashion. There is no reason to suggest that lawns and flowerbeds are major contributors to urban P loading.

***T6. What are the base levels of P in Dane County soils (both urban and rural)?
What are UW-Extension's P application recommendations for lawns, gardens and
crops given a certain level of P in the soil?***

Bannerman

I can provide levels of available P in urban soils. We have tested over 35 lawns. All the values exceed the recommended levels of phosphorus.

Bennett

Recent sampling in Dane County (236 lawn samples taken) shows that the average available soil P concentration in lawns is 54 parts per million (same as 54 mg/kg). The range for lawns is 5 mg/kg to 438 mg/kg (Bennett, In press). Average available soil P concentrations, separated by location of lawn:

Urban: 50 mg/kg

Suburban: 40 mg/kg

Suburban Fringe (new suburban homes built in the last 5-10 years): 50 mg/kg

Rural lawns: 65 mg/kg

This research also shows a good correlation between samples for available soil P concentrations and total P concentrations in Dane County. A graph can be found in Bennett (In press).

The researchers at UW-Extension would be far better prepared to answer the question about recommended soil P for lawns, gardens, and crops. For recommended soil tests, see their report: Kelling et al. 1991.

Combs

A recent summary of urban soil tests is not currently available. Based on information summarized about 20+ years ago, the average level of soil test P for urban soils was approximately 100 ppm. These were soils tested by the UW-Madison Lab, but information as to number of samples and extent of sample origin is not available. The last summary available for farm soils in WI completed for years 95-99 show that the statewide average soil test P level is approximately 50 ppm. This average includes all samples tested by FSA-certified WI soil testing labs. The urban soil recommendation program was recently revised because of new research information. The optimum soil test P and K levels and nutrient recommendations are crop-specific. Optimum soil test P for turf at planting is 31-45 ppm if seeded or 21-30 ppm if sodded. After establishment, the optimum soil test P level is 11-15ppm. At optimum soil test P and K levels, a 'regular' or maintenance turf fertilizer (i.e. 27-3-3) would be recommended to homeowners at a rate of 1 lb N per 1000 sq ft applied 3 or 4 times per season. Dr Wayne Kussows', Dept Soil Sci, research has shown that the amount of P₂O₅ in a 'regular' turf fertilizer applied at the recommended rate is below what is used by turf and a gradual draw-down of soil reserves is expected. If soil test P levels are below optimum, a 'starter' or high P turf blend is recommended as one or more of the annual applications. If soil test P levels are above optimum, a caution is given about applying only what is recommended.

Jones follow-up question: why, if soil P levels are already optimum for turf, would a "maintenance" fertilizer (with 3% phosphate) be needed? Couldn't the N alone be applied if needed?

The only easily available granular nitrogen source for homeowners is urea, generally sold in 66 lb bags. This form of nitrogen can easily burn foliage if topdressed. It also will excessively stimulate top growth in turf. The nitrogen contained in turf blends is a slow release form (i.e. sulfur-coated). This form of nitrogen tends to promote more desirable growth. The amount of P₂O₅ in a 'regular' turf blend applied at the recommended amount of 1 lb N per 1000 sq ft, is less than turf takes from the soil--therefore drawdown of soil P reserves should occur with long-term use. It is not that turf 'requires' the P but that the material is easily available to homeowners, packaged in 20 lb bags and spreader settings recommended by the industry are appropriate for getting the 1 lb N spread--all essential for getting the recommended amount spread. That is the biggest challenge to the P issue--the amount actually applied. If the system to work through is complex (recommending nutrient and forcing homeowners to calculate material or spending time calibrating a fertilizer spreader to deliver a specific rate) or has the potential to fail (urea = foliage burn) there will be 'shortcuts' taken. These 'shortcuts' may include over application because we have made it too difficult to do the right thing. Using the system that Kussow has developed and working with what the industry has promoted for materials meets the homeowners needs of easy and understandable--they are more likely to do 'the right thing' and avoiding overapplication.

Good

I'm not sure what is meant by "base level" of P? The UW-Extension recommendations for crops are too numerous to repeat here and are given in Extension Publication A2809, available on line at <http://cecommerce.uwex.edu/showcat.asp?id=11>.

Kussow

The UW Soil and Plant Analysis Lab can give you data on baseline P levels in Dane Co. soils. The only numbers they have for urban areas are for lawns and gardens combined. They do not keep separate records on lawns. Some data sent to me by Charles Silver out of some urban NY areas indicate high to excessive soil P levels in 79 - 95 % of home lawns. Three years ago my students sampled soil from 39 turf areas on the UW campus and found that only 3 (7.7%) would potentially benefit from P fertilization. I am the person that developed the current UW-Extension interpretations for lawn soil analyses. I did this in 1994 and based the values on whatever relevant literature I could find which, quite frankly, was very limited. I'm currently conducting research that will lead to more realistic and reliable interpretations for all types of turf. The changes I made in 1994 not only reduced the soil test levels where no P is recommended from 75 ppm to 20 ppm, but I also devised a new format for the recommendations that homeowners could actually follow. The sad thing is that 9 years later, in 2003, the UW lab has not fully implemented my recommendations.

Stier

Varies tremendously across and even within fields, lawns, parks, etc.

Potter

Most tested soils are at or well above recommended levels.

USGS

Findings from Ongoing Studies

- Soil core data in the Lake Wingra watershed have relatively high phosphorus concentrations in the upper 4 inches of soil, in excess of what established lawns need. Phosphorus concentrations are highest in the upper one inch of soil. (T. Stuntebeck, ongoing study).
- Soil cores from a lawn known not to have had fertilizer applied for 28 years still contain soil phosphorous above suggested lawn growth levels (T. Stuntebeck, ongoing study).

T7. Are there any specific situations (e.g. new lawn establishment, restoration of damaged turf) that require use of phosphorus fertilizer, even when soil phosphorus tests already show high levels?

Armstrong

Off hand, I can't think of reasons to apply P when the soil test shows high levels already.

Bannerman

This is a question for our turf experts. I know they recommend some P for new lawns to help stimulate root growth.

Combs

Fast growing annuals and row crops benefit from application of P₂O₅ at time of planting or transplanting. These crops either are subjected to cool, wet conditions in early spring or stress from changing growing environments that limits root growth and subsequent uptake of P from soil solution. Placing P₂O₅ in a band near the seed or transplant ensures a ready supply to meet plant needs when root growth is physiologically limited. Areas of home or commercial landscapes that test high in soil test P require additional P₂O₅ applications for optimum growth, however these quantities are less than when soil tests are at lower levels. When very high or excessively high soil test P levels are reached, then either no additional P₂O₅ is recommended for professionally managed turf (golf courses, athletic fields etc) or only 'regular' or high N turf blend for homeowners.

Kussow

Rapid establishment of a healthy, dense lawn that minimizes runoff does require a one-time starter fertilizer (a high P fertilizer) application at the time of establishment unless the soil test is 3 times higher than that required once the turfgrass is established.

Stier

Any time the plant root system does not exist or when it is severely injured, damaged, or otherwise compromised, even if the surface vegetation does not show it. Examples include new establishments, root rot damage, or environmental stresses such as hot temps that kill roots or cold temps that decrease root functioning.

Swingle

Many researchers have demonstrated or reported that fertilizers that provide adequate phosphorus during the establishment of turf grass can enhance the fill-in of turf and/or improve root development of developing seedlings (Beard, 1973; Hull, 1983; Kussow, 2003a; McVey, 1971; Turner and Hummel, 1992; Westfall and Simmons, 1971). A mature turf with an extensive root system is very efficient in exploring the soil and obtaining P (Christians, 1998). However, because the much smaller root system of a germinating seeding lacks the same efficiency, young turf will generally respond favorably to higher levels of soil P during establishment than are needed by a mature stand of grass. Rapid establishment of turf is important as a dense turf helps reduce soil erosion and runoff. Once the turf has become firmly established and the small, undeveloped root system of young grass plants has been replaced by the extensive root system of a mature sod, high rates of phosphorus are no longer needed nor beneficial and the applications of phosphorus should be reduced to meet the maintenance requirements of the lawn.

T8. Does P applied to lawns run off grass surfaces? Can P in lakes be traced to lawn fertilizer?

Armstrong

Grass cover is beneficial in reducing runoff, but P can be transported off of grass surfaces by runoff. The phosphorus in lakes partly comes from lawn fertilizer. I do not have further information on the amounts from this source.

Bannerman

The phosphorus applied to lawns can runoff with the particulate matter. Work we have done does not distinguish fertilizer P from other sources of the P. It would be interesting to do a lawn study that includes a way to trace the fertilizer P. We will be studying lawn runoff again next summer. This could be an interesting addition to that work.

Bennett

Yes, P applied to lawns can runoff from grass surfaces. This can happen through particulate phosphorus movement, dissolved phosphorus movement (in surface or groundwater), or movement of lawn clippings into storm sewers.

Carpenter

Yes, P from lawns runs off to lakes. It can run off in the form of eroded soil particles, or plant material (e.g. grass clippings or leaves). Once in the water, P can dissolve from soil particles or dead plant matter, and contribute to growth of algae or other aquatic plants.

Combs

Inorganic fertilizers are soluble and therefore if an intense rainfall occurs that causes runoff, P₂O₅ will likely be included. Soil moisture and other precipitation such as dew will dissolve topdressed fertilizer P₂O₅ and move it to soil surfaces where adsorption will occur. Generally, less than 30% of applied fertilizer P₂O₅ can be recovered because soil sorption processes. The only chemical method that I can think may be able to definitively establish origin is the use of radioactive P³³--a very expensive and impractical field approach. To date, computer models have been used to predict the portion of soil P that may be leaving edge-of-field. These models attempt to take on all relevant field information such as slope, soil texture, soil test P and many other characteristics that might impact P loss. Examples are the P-index being developed for use in NRCS 590 and PALMS being implemented on Discovery Farms and other field research areas by Dr John Norman, Dept Soil Sci..

Good

P applied to grass surfaces can run off. If it is still in particulate (undissolved) form when there is rainfall that produces runoff, it can move in particulate form. But all the lawn fertilizers I ever came across required a watering after application. This watering should wash the fertilizer into contact with the soil, and for soluble organic fertilizers, it should dissolve the fertilizer. The dissolved phosphate is then in solution in contact with the soil and can be sorbed onto the soil. How much of the phosphate remains in solution

depends on the ability of the soil to sorb P. Generally, the soil's ability to sorb additional P decreases with increasing soil P concentration. Conversely, the soil's ability to release P to water increases with increasing soil P concentration. Although concentrations can be very low, I can not remember seeing any runoff data for Wisconsin where there was no measurable phosphate in the water. If land is fertilized with a phosphate-containing fertilizer, then some of the phosphate in runoff will originate with the fertilizer but it will be indistinguishable from the phosphate that was sorbed to the soil prior to the fertilizer application. Phosphate is phosphate.

Kussow

The P in fertilizer is 100% water soluble and, with a minimal amount of rain or watering, quickly moves into the soil where it is adsorbed on soil particle surfaces. Loss in runoff water is therefore largely by way of erosion of the soil per se in the form of sediment. Proper maintenance of lawns results in sediment losses that range from zero to a few pounds per acre, which is a far cry from the tons per acre of sediment coming from farm land and construction sites. A significant amount of P in runoff from urban landscapes come from the vegetation itself and, I suppose this could somehow be allocated at least partially to fertilizer. The bottom line is that there is no reliable way to directly trace lake P to fertilizer P. Based on a lot of literature and my own 6-year study of P in lawn runoff water, I'm estimating that no more than 50% of the runoff water P can be attributed to fertilizer. Based on my research, this amounts to some thing like 0.2 to a maximum of 0.4 lb P/acre/year. Note, I said year, which is a 12 month period and not just the growing season of April to November.

Potter

I am certain that P applied to lawns ends up in our lakes. I don't know that anyone has a good estimate of the amount.

Stier

Scientifically peer-reviewed research shows properly applied fertilizer does not runoff from turf. A recent paper published in J. Envir. Quality showed P could runoff when it was applied to saturated soil and application was followed by high levels of simulated rainfall. The majority of evidence, though, in studies conducted in Wisconsin, New York, Pennsylvania, Florida, and elsewhere do not indicate that P applied correctly to lawns runs off.

Thus, P in lakes cannot be directly traced to lawn fertilizer. This could be tested, though, by applying radiolabelled P to lawns then tracking it. Would be cost prohibitive, environmentally and politically unfriendly, and logistics of tracking it would be enormous.

Swingle

No. Numerous university studies that measure both the quantity as well as the quality of the runoff from a lawn without artificially disturbing the turf-thatch-soil interface zone have demonstrated that lawn fertilizers are not likely to be a direct source of P in runoff. Rapid fixation of phosphorus by the soil, the overall general lack of runoff and the nearly total elimination of soil erosion by a dense healthy lawn all function to prevent P from

lawn fertilizers from leaving the site of application. Where P losses in runoff from fertilizers have been observed, extremely harsh downpour conditions immediately following the application of unusually high rates of P have been required before any significant movement of this nutrient from established turf has been measured in university studies.

USGS

The results of studies conducted by the USGS in Wisconsin may provide helpful information for making the phosphorus-free fertilizer policy decision. These include:

Phosphorus Concentration Studies:

- Phosphorus concentrations were higher in lawn runoff than in runoff from other urban sources (streets, driveways, roofs and parking lots) in Madison (Waschbusch, Selbig, and Bannerman, 1999) and other areas of the state (Steuer, Selbig, and Hornewer, 1997).
- One study showed that concentrations of dissolved phosphorus in lawn runoff from phosphorus-free fertilized lawns was about half of that from phosphorus fertilized lawns (Garn, 2002).
- Runoff from lawn sites with phosphorus-free fertilizers had phosphorus concentrations that were similar to that from unfertilized sites (Garn, 2002).
- Phosphorus concentrations in runoff from fertilized lawns (with phosphorus) were not significantly different from runoff of nonfertilized lawns in Madison (T. Stuntebeck, ongoing study).
- Total and dissolved phosphorus are mobile and easily transported in high concentrations off site by runoff (Garn, 2002; Waschbusch, Selbig, and Bannerman, 1999; and other studies).

Lawn Runoff Studies

- Runoff from lawns can occur frequently. More than 50 percent of storms resulted in runoff from many lawns, especially on slopes greater than 5 percent. Runoff from phosphorus-free fertilized lawns was not different from that with phosphorus fertilized lawns (Garn, 2002). Another study showed that runoff from fertilized lawns occurred much less frequently than 50 percent of the storms (T. Stuntebeck, ongoing study).
- Well established healthy lawns and other lawn best management practices reduce runoff (Legg, Bannerman, and Panuska, 1995)

Studies examining Phosphorus Runoff from Lawns

- Urban runoff modeling (with the urban model SLAMM) indicate that lawns are a major contributor to phosphorous runoff loads (Waschbusch, Selbig, and Bannerman, 1999)

- Quantity of phosphorous loading from lawns is being addressed in an ongoing study with the WDNR (T. Stuntebeck)

Finding from Ongoing Studies

- Fertilizer overspreading to sidewalks and streets provides a rapid and direct source of phosphorous to storm sewers (T. Stuntebeck, ongoing study)

References:

Garn, H. S., 2002, Effects of lawn fertilizer on nutrient concentration in runoff from lakeshore lawns, Lauderdale Lakes, Wisconsin: U.S. Geological Survey Water-Resources Investigation Report 02-4130, 6 p.

Legg, A.D., Bannerman, R.T., and Panuska, J. 1995, Variation in the relation of rainfall to runoff from residential lawns in Madison, Wisconsin, U.S. Geological Survey Water-Resources Investigations Report 96-4194, 11 p.

Steuer, J.J., Selbig, W.R., Hornewer, N.J., 1997, Sources of Contamination in an Urban Basin in Marquette, Michigan and an Analysis of Concentration, Loads, and Data Quality: U.S. Geological Survey Water-Resources Investigation Report 97-4242.

Waschbusch, R.W., Selbig, W.R., Bannerman, R.T., 1999, Sources of Phosphorus in Stormwater and Street Dirt from Two Urban Residential Basins in Madison, Wisconsin, 1994-1995: U.S. Geological Survey Water-Resources Investigation Report 99-4021.

T9. What does a soil test actually measure? Does it measure P available to plant from the soil? If so, how does this support or undermine the claim that P is too tightly bound to the soil to be available for plant growth?

Armstrong

The soil test measures the phosphorus status of the soil - whether the soil is phosphorus deficient with respect to the phosphorus needs of plants growing on the soil. Phosphorus does bind to soil, but becomes less tightly bound as the soil becomes more saturated or enriched in phosphorus.

Bennett

There are several different kinds of soil tests. A test can be done for total P, which measures all of the P in the soil. A test can also be done for what is called 'available' or 'plant available P'. In Wisconsin, the most common test for measuring P available to plants is called "Bray-1 phosphorus". In Dane County, there is a reasonably good correlation between total P and available P (Bennett, in press). P bound to soil can behave differently once it is in water. That is, P that appears unavailable in soil may become available in water due to chemical transformations.

Carpenter

It is important to note that soil test P is not directly relevant to the behavior of P once it enters the aquatic environment. Once the soil particles enter the lakes or streams, they are in a different chemical context. P which appears to be “non-available” in soil can become available to cause eutrophication in lakes or streams.

Combs

Soil tests measure a portion of a nutrient source that potentially can be available to a plant during the growing season. Not all of the nutrient contained in soil is in a chemical form available for plants to use--some of the total nutrient is structural, some may be 'fixed' to reactive surfaces that vary with soil pH, some may be a component of organic matter requiring microbial decay. The unique mix of chemicals used in WI to evaluate this portion of potentially available P and K supply is called the 'Bray P-1' test. The amount of P and K extracted by the Bray P-1 solution is only an index of the potential supply and only useful when compared to a reference database. The reference database preferably contains local research-based information on crop yield (if applicable) and/or quality (disease resistance, rooting characteristics, resistance to use damage, resistance to weed competition etc.). By this comparison, specific for each type of crop, an interpretation can be made as to the potential for a response to added nutrient (i.e. the likelihood of a deficiency). Soil test values are interpreted in terms of low (likely to be deficient, P₂O₅ and/or K₂O needed > amount removed by crop), optimum (crop yield/quality optimized with P₂O₅ and/or K₂O added = amount removed), high (deficiency not likely but some P₂O₅ and/or K₂O needed) and excessively high (no need for additional P₂O₅ and/or K₂O).

The interpretations/recommendations are specific to crop (turf vs vegetables), use (home turf vs golf course greens) and soil texture/type. Considering soil characteristics when making recommendations takes into account factors such as 'fixation'--that is why recommendations may be different for different locations and/or soil texture. Frequently 'starter' , a fertilizer high in P, is banded in spring when growing short-season annuals or transplants. Root growth, therefore nutrient uptake, is restricted in cool, wet soils of early spring. Phosphorus is most important because of its' central role in energy transfers. Adding a small amount of high P₂O₅ fertilizer at planting will offset poor growth and temporary P deficiency.

Good

The phosphorus soil test used in Wisconsin is called the Bray P1. It measures how much inorganic phosphate will be released from soil when it is shaken with a solution of 0.025 M HCl in 0.03 M NH₄F. This test measures only a small fraction of the total P in the soil. To create the soil fertilizer recommendations for various crops, numerous field experiments were done to relate Bray P values to crop growth in response to fertilizer. A particular crop was grown on soil with a range of Bray 1 P values and a range of P fertilizer rate was added for each soil test value; plant growth and yield were measured, and it was determined whether the added fertilizer at each rate caused an increase in yields. After repeating this kind of experiment over a number of years at a number of

sites, soil P fertilizer recommendations were put together based on the probability that adding the recommended amount of P to a soil with a particular Bray-1 P would increase yield sufficiently to be of economic benefit for the grower.

I'm not sure I understand the question about P in the soil being too tightly bound to be available for plant growth. Obviously, plants are growing in soil and they absolutely cannot grow without P. The dissolved P concentration in soil solution is much smaller than the total P in soil, but a relatively small concentration is adequate for plant growth (0.2 mg P L⁻¹ is the concentration given in textbooks).

Kussow

Soil tests provide an index of plant available P. The extractants used are designed to remove only that portion of the P bound to soil particle surfaces that, through research, has been found to actually be available to plants.

Stier

I'll let Wayne or Sherri Combs answer most of this. There are different methods to analyze P which use different procedures and reagents, they don't necessarily give same results. I don't think the confidence level is great in determining what is actually available to plants.

Swingle

A soil test is used to predict the availability of a nutrient to a crop during the growing season. The results of a soil test that are reported in lbs/acre or ppm P are not to be confused with the levels of P in lakes that will cause algal blooms that are in ppb. There are no studies that measure both the quantity as well as the quality of the runoff from a lawn without artificially disturbing the turf-thatch-soil interface that have demonstrated that what little P that can be measured in turf runoff is related soil test levels.

T10. Can we get the UW soil and plant analysis lab to summarize soil tests done for Dane County lawns (they do it routinely for ag soils, but not urban)? It would be good to know what the P level was for these. There are several projects completed over the years (among them are Roger Bannerman research, and soil tests done for the Commission's Better Lawns and Gutters tour) where all soil tests completed for these urban lawns showed that no P application was necessary. It would be good to have this summarized on a broader scale.

Bannerman

I think this is a good idea.

Bennett

I have provided a summary of the soil tests that I took in Dane County lawns (urban and rural) for question #6.

Combs

Soil testing labs offering routine fertility soil tests to WI farmers must be certified by DATCP (formerly FSA). Certification requirements are many and include the release of

all farm soil test results to the UW Soil and Plant Analysis Lab for periodic summary. These summaries have been prepared since 1968 when recommendations became computerized and can be viewed on at <http://uwlab.soils.wisc.edu/>. These summaries are used to help guide educational programs by Dept of Soil Sci and UWEX county faculty. More recently they have become the focus of regulatory programs. Summaries are prepared every 4-6 years to minimize seasonal fluctuations and include approximately 400,000 to 500,000 samples. Data for available P, available K, pH and organic matter is summarized for all soils tested, by texture and by name for the state and by county. It is time consuming and expensive to prepare a summary, but is required by the university lab to fulfill obligations to the certifying agency and is useful to campus and county faculty. Until recently, the UW Soil and Plant Analysis Lab had its urban soil test recommendation program operating on an outdated computer system that prevented retrieval of urban soil test information. The Madison and Marshfield Labs test approximately 4000 - 6000 urban samples per year within the state and now has about 3 years of data available. A summary after the 04 spring season is possible, but is time consuming and expensive. A requirement of the DATCP certification program is payment from private soil testing labs to the public lab in order to offset expenses incurred from QA/QC oversight, educational support and data summarization.

My computer specialist estimates at least 2 weeks to prepare a summary of the lab's soil test results for urban Dane County residents. It is not something that outside assistance can be used because of the unique in-house code used. The Lab is planning to move in early Jan to a new facility at the UW West Madison Experiment Station. My computer specialist will be extremely busy re-establishing Lab instrumentation and in-house networking. I only have data from May 2001 on our new system and ideally would be most comfortable with at least a 3, preferably 4, year data base to summarize. It is not a problem with 'getting' a number, but how this number will relate to all subsequent summary information.

Kussow

Summaries by the UWEX lab do not and are not set up to separate lawns from gardens.

T11. Do shoreline buffers reduce the amount of P that can run off to lakes and streams? Does it make a difference what type of vegetation (native plants etc) comprises the buffer?

Armstrong

Shore line buffers help to reduce P transport, partly by filtering out soil particles carried in the runoff. The type of vegetation does make a difference and buffer zones are more effective during the growing season than after frost in the fall. They help but do not eliminate transport of phosphorus into lakes and streams.

Bannerman

Shoreline buffers can reduce phosphorus loads to lakes and streams. This is especially true for the particulate phosphorus. In the agricultural setting a properly designed buffer and associated upland practices can reduce the annual sediment load by 50%. Depending on the soil types it is possible to estimate a reduction for P. Unfortunately,

these buffers will usually be short-circuited over time. A better long-term solution is to limit the amount of phosphorus applied to the fields and to maintain good upland practices. Good barnyard BMPs are also important.

Except for the riparian landowner, it is not a good idea to depend on buffers to control phosphorus for an urban area. It is not practical to control all the runoff with a vegetative strip along a stream or lake. We have to do something before the water reaches the end of a pipe. Buffers do have many other benefits in an urban area and they should be established along all our urban waterways.

I think we should limit the use of just woody plants in a buffer. Woody plants tend to shade out the grasses, which have a better chance of reducing the pollutant transport. The most effective type of buffer for a riparian landowner is a rain garden. There is less chance it will be short-circuited over time and we can quantify the benefits.

Bennett

Yes, shoreline buffers do reduce the amount of P runoff. There are several current research and synthesis programs to determine what type of buffers are best. Size, shape, location, and vegetation seem to be important aspects of buffers that may impact their ability to reduce nutrient runoff.

However, buffers are not a permanent solution to the problem. The only permanent solution to the problem of reducing P load to lakes is to reduce the inputs of P to the watershed – that is, to reduce P in fertilizers or reduce fertilizer use. Buffers work by trapping P as water and soil move through them. But the laws of physics imply that buffers do not have infinite capacity for soil or nutrient storage. Therefore, the only permanent solution is to reduce P inputs to the watershed.

Carpenter

Yes, buffers matter. Having a vegetated buffer is better than having no buffer at all. Also, it is important to have a continuous, un-interrupted buffer. There is currently debate about which types of vegetation are most effective. The WDNR is currently funding a statewide study of buffers to determine the effectiveness of the different types of buffers. The following calculations published by Reed et al. (2000) show that stream buffers around all streams draining to Lake Mendota would substantially decrease P concentrations in the lake. However, reductions of fertilizer would decrease P concentrations even more.

Conditions for the calculation	Percentage of present P concentration in Lake Mendota
Present conditions	100%
Riparian buffers (continuous, uninterrupted) on all streams draining to Lake Mendota	72%
P fertilizer use in all croplands reduced to the recommended level for corn	64%

Zero-P fertilizer for all croplands, lawns and gardens in the Lake Mendota watershed	23%
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In response to a follow-up question on interpretation of the above table, Carpenter said:

If we took all the cropland fertilizer applications down to the recommended level for corn, Mendota total P concentration would drop to 64% of the current average AT STEADY STATE. It takes ~90 years to reach steady state, because it takes a long time to draw down the excess P accumulated in the soil. On the bright side, the curve is exponential so we would get most of the benefit in the first few years.

Combs

Information related to width and effective crops for buffer strips can be found in the NRCS 590 Technical Guidelines.

Good

Shoreline buffers can reduce the amount of P that can runoff to lakes and streams by slowing down runoff, resulting in sediment deposition and sometimes in increased infiltration. If there are any breaks in the buffer or runoff travels through the buffer in channels, then it will not be effective. There is a huge body of literature on buffers and filter strips and I am not well-versed in it. In the Phosphorus Roundtable Archives, there is a presentation by Gary Bubenzer on buffers from October 30, 2002. I am not aware of any studies that say that native vegetation is better or worse than non-native vegetation. The important thing seems to be avoiding channels.

There was a study that measured P in runoff from native prairie in Minnesota and found it to be very low (< 0.1 lb/acre/yr; Timmons, D.R. and R.F. Holt. 1977. Nutrient losses in surface runoff from a native prairie. Journal of Environmental Quality, 6: pp 369-373). A note of caution about interpreting these findings — the Bray P for this was site was very low (3.8). As the purpose of a buffer is to catch sediment and P, P concentrations will build up within the buffer area. Runoff DP concentrations from a prairie area used as a buffer are likely to be much higher than this.

Kussow

Buffer strips can be effective in trapping soil sediment, but do very little in terms of soluble P. You always have to keep in mind that the vegetation in buffer strips are sources of P.

Potter

I am confident that shoreline buffers reduce the amount of runoff and P that reaches water bodies. Native vegetation with deep roots would trap more runoff and P than turf.

Stier

They should up to a point. Anything that reduces runoff flow quantity and sediment loss will help. However, nutrients such as P do leach out of leaf tissue, so there will always be a certain background level of P removal in runoff from ANY vegetation. We suspect,

and are doing 3 studies now (2 in Madison, 1 in Stevens Point) to help answer what the background levels of P leaching out of prairie and turfgrass vegetation may be.

Various research projects indicate P runoff in cool season turf (type we have in Wisconsin) is low, at or less than 0.3 lb P/acre/yr. Ag land can be 40X or more this amount. Prairie vegetation studies conducted in Oklahoma/Texas area (couldn't find any from upper Midwest) show about 0.3 lb P/acre/yr on average, similar to turf (though no direct studies were done). Talking with USDA forestry researchers, and scant amount of information published, suggests best buffer strip around a lake would be undisturbed forest with a thick duff layer. Even so, some pollen will still enter lake through pollen and leaching from leaves.

Swingle

The USDA and most university extension program recommend the use of a grassy border strip to filter out agricultural runoff and nutrients before they can reach streams and lakes. This is a BMP tool that has received general acceptance across the country.

As for the second question, more research is needed in this area. Research has shown that much P in urban runoff is found in the early spring during snowmelt and tree flowering and also in the fall. Many native species of plants do not form a dense thatch (sod) that a grassy border strip can develop that impedes water movement and reduces runoff. In addition, these native species may not provide much resistance to water movement until later in the spring or summer when their vegetative growth rates are at a maximum. Cool season grasses start regrowth earlier in the spring than many warm season natives. Finally, native species are allowed to flower and shed pollen whereas a mowed turf generally mowed before pollen shedding can occur. Pollen is relatively high in P.

T12. What does the research say about turf where no P has been applied, and general turf health, and its relationship to runoff of water and nutrients? For the research done for the turf industry, was it done on soils that needed P? Is there research on application of P to soils that were already high in P, and what happened?

Bannerman

The better the quality of lawn the less runoff. Lawns in poor condition (lots of bare spots) produce more runoff than lawns with thick grass. What is poorly identified is the role of P in maintaining the healthy lawn. A lot of the turf studies compare using fertilizer to not using fertilizer. This type of study does not isolate the importance of the P. The results might be the same without the P. I hope our turf experts will provide more information on this question.

Carpenter

To be relevant, research on lawns or turf must meet several requirements. (a) It must be conducted on watersheds similar in size, topography, soils, land use and land cover to those encountered lake management. At a minimum, whole subwatersheds must be studied. Methods for measuring hydrology and P loading must pass peer review in

reputable scientific journal. (b) The test watersheds must contain lawns managed by a diversity of practices resembling those used in actual neighborhoods by citizens of the region. (c) The experimental watersheds must include treatments of P-containing fertilizer (with other nutrients such as N and K) and treatments of zero-P fertilizer (other nutrients such as N and K, but no P). (d) The experiments must include pre-treatment and post-treatment monitoring at the full subwatershed scale following publishable practices of ecosystem science. I am not aware of any lawn or turf research that meets these minimal scientific standards.

There are, however, many measurements of P runoff from urban and suburban watersheds that show elevated discharge of P to streams or lakes.

Combs

Dr. Wayne Kussow's research at the O.J. Noor Turfgrass Center and other locations has shown that turf quality is best when 1 lb of N as a 'regular' or maintenance turf fertilizer blend (i.e. 27-3-3) is applied 3 or 4 times per season when soils tested in the optimum and above range for P and K. Weed competition was minimized and disease resistance maximized by following this recommendation. Demonstration plots are established and are a part of summer field days held at the Turfgrass Center. If 'no P2O5' fertilizer becomes 'no fertilizer' from the homeowner's perspective, the increased weed burden may prompt increased use of herbicides and/or greater amounts of exposed soil susceptible to runoff--both undesired consequences of a 'no-P2O5' fertilizer regulation.

Good

Wayne Kussow has a study showing fertilized turf reduced annual DP loads compared to unfertilized turf by reducing runoff volumes. The DP concentrations were greater in the fertilized plots, but runoff volumes were so much lower that DP loads were lower. The fertilizers used were complete fertilizers - they contained nitrogen and potassium in addition to phosphorus. I am not sure what the soil test P values were. He has more information about this study in his slide presentation in the Phosphorus Roundtable Archives from September 10, 2002 on "P Losses from Turf".

Kussow

In my 6 years of research I was applying fertilizers to a soil testing excessive in P. My data show no relationship between the amounts of fertilizer P applied and the quantities of P in the runoff water. When I failed to apply any fertilizer for two years, the turfgrass thinned out so much that the amount of runoff increased 134% and the runoff water from the unfertilized turfgrass contained nearly two times as much P as in the runoff water from the fertilized turfgrass. Furthermore, Mr. Barten's research in the Twin Cities shows that there is no significant relationship between soil test levels of P and the concentrations of P in lawn runoff water.

Stier

Depends on type of turf, management inputs, expectations, soil type, etc. If established turf stops being fertilized with P, and plenty of P exists in soil, and nothing occurs to

inhibit root uptake of P or P solubilization in soil, then it could be several years (3-5 or more) before turf starts thinning out and runoff losses and sediment and P losses actually increase.

Swingle

Research has demonstrated that a thin turf will allow more runoff and in some cases more P in runoff than a well fertilized turf. A turf that is P deficient or becomes P deficient over time will be less effective in reducing runoff. Applications of a P free fertilizer will not result in efficient use of the nitrogen and may cause consumers to apply more N than the turf can effectively use. All the benefits that turf provides in the way of reducing runoff and nutrient movement may be lost.

T13. Does vegetation accumulate more P when P-containing fertilizer is added to soil where that vegetation is growing (therefore making more P available for runoff if vegetation clippings are left on impervious surfaces)? Does P build up in soil with P-containing fertilizer application, so that the P is more easily leached out when grass is not growing?

Armstrong

The build up of soil phosphorus as a result of phosphorus fertilization does tend to increase the amount of phosphorus leached from the soil by runoff.

Bannerman

I do not know if plants take-up more P if more P is available. I assume the plant available P criteria established by the university is based on the maximum amount of P the plants will up-take to maintain their health. Plants do not need P levels higher than the criteria. All of our lawns exceed that level. Phosphorus not used by the plants does build-up in the soil. This extra P can be washed-off the lawns with the particulate matter.

Bennett

Yes, P builds up in soils as fertilizer is applied. Many studies have shown this to be true even in agricultural areas where crops are presumably also taking up some of the P applied in fertilizers (Sharpley and Menzel 1987; Heckrath et al. 1995).

Carpenter

Excess fertilizer P can go into vegetation or into soil. Excess P fertilization in agricultural regions of the world, including Dane County, has caused P buildup in soils.

Combs

Phosphorus is incorporated into complex compounds in the plant after uptake and is a major player in energy transfer systems, cell membrane integrity, cell division and flower/fruit formation and maturity. Killing frost can disrupt cell walls and lead to 'leakage' of contents that is susceptible to runoff as mentioned in question 1.

Decomposition of fresh plant materials by soil microorganisms results in conversion of organic P into inorganic forms available for plants to take up or soil surfaces to adsorb. Phosphorus can build up in soil whenever applications of any material containing P

(fertilizer, manure, other organics, etc) are applied at rates greater than plant removal. However, predicting what the increase in soil test P may be depends on soil texture. Sandy soils and med-fine textured soils have different P buffering capacity. It takes about 18 lbs P₂O₅/a to increase the soil test P level by 1 ppm for med/fine-textured soils but only 12 lbs P₂O₅/a for sandy soils--indicating that med/fine-textured soils have greater capacity to 'fix' P into forms not extractable by the Bray P1 soil test. Phosphorus is held by specific adsorption sites on soil surfaces by very strong coordinate-covalent bonding and is not susceptible to leaching out of the soil. The sites most likely to adsorb P are the smallest-sized aggregates. These aggregates are also most likely to erode if soils are exposed with no vegetative cover to intense rainfalls.

Good

A relationship between Bray P concentration in soil and dissolved P concentrations in runoff has been well-documented in agricultural soils in Wisconsin. In the Phosphorus Roundtable Archives on July 17, 2002, Wes Jarrell's slide #14 shows how soil water-soluble P is related to Bray P and Larry Bundy's slide 15 shows the relationship between soil test P (that's Bray P) and dissolved inorganic P in simulated rainfall runoff experiments.

Kussow

Vegetation P concentrations increase until the plant has all that it can utilize (tissue P concentrations are at their optimum levels). At this point, increasing soil test P levels has no impact on tissue P levels and losses of P from plants plateau.

Stier

P in soil is only slightly soluble in soil; amount able to solubilize in soil does not increase with the amount in soil past a certain point. Try putting a little sugar in water, it dissolves; put a whole lot of sugar in water and eventually it starts increasing, though the actual sugar content in water is same as when all sugar solubilized.

Turf vegetation maximizes its P content at less than or about 1%, usually its about 0.5% P. Actual amount may depend on factors unrelated to P in soil such as cultivar, species, soil porosity, etc.

T14. For turf/lawn research cited in response to these questions, we need to know if the soils were real or artificially constructed, and how this difference affects results that are suggested to be applied to existing lawns in Dane County.

Bannerman

Some of the information we need to use to understand the impacts of phosphorus is in the agricultural literature. Agricultural scientists have extensively studied phosphorus dynamics. For example, Tom Daniels has prepared papers describing the build-up of P in soils and the impact on the amount of P in the runoff. I need time to find some of these papers.

Bennett

The research that I have cited (Bennett, In press) is on real soils in real lawns in Madison and Dane County.

In my research efforts, I noticed that most lawn soils had at most 6 inches of topsoil under the turf, and more usually only 4 inches of topsoil. Relevant loading research would have to address these conditions as well as the spatial extent, topography, and infiltration conditions found in the actual landscape draining to the Madison lakes.

Kussow

In my research I went to great lengths to simulate a home lawn. The topsoil was stripped off, the subsoil compacted with a vibrating roller such as those used in road construction, and the top soil replaced. My research is criticized on the basis that the quality of the turf exceeded that of an average home lawn. My approach was to follow UWEX recommended maintenance practices to show what is possible when these practices are followed.

Swingle

Numerous studies that measure both the quantity as well as the quality of the runoff from a lawn without artificially disturbing the turf-thatch-soil interface zone have demonstrated that lawn fertilizers are not likely to be a direct source of P in runoff. The literature review attached to this answers does not reference a series of studies that were conducted in WI that use a section of ½ inch PVC pipe that is set into a groove that was installed in a fashion that artificially disturbed the turf-thatch-soil interface. University agronomists, the group of scientists most qualified to study runoff in turf, do not accept these studies as being valid for many reasons.

T15. What factors would support or undermine a policy of exempting compost and other organic sources of P (including products such as Milorganite) from ordinance requirements?

Bennett

I can't imagine people applying compost to their lawn unless they are planting a new lawn or putting it on a garden, so given that the ordinance exempts new lawns and gardens anyway, it seems silly to also exempt compost.

Combs

Any material containing a relatively high P₂O₅ content, whether inorganic or organic, can result in accumulation of soil test P. The P₂O₅ formulation of high N "regular" turf fertilizers if applied to meet the recommended N need of turf, will result in draw-down of soil test P levels. Milorganite falls into this category. However, fresh manure does not because of its relatively high available nutrient level (4-4-8 N-P₂O₅-K₂O). Manure applied to meet the N need of crops generally results in P accumulation because the equivalent proportion of N to P₂O₅. Compost from yard waste has little nutrient value and excellent value when incorporated for improving soil structure too often destroyed by construction. Good soil structure=better crop growth=minimal soil erosion=less P loss. The 'one-size-fits-all' of bad guys inorganic fertilizers vs good guys organic

fertilizers perpetuates a myth and it not the issue. The issue is overapplication when not needed and application to areas that are impervious--not the formulation used.

Connors

These sources are already in the environment. The compost and organic sources are 'not imported' versus the commercially available sources of P. In particular, Dave Taylor from MMSD is concerned about the possible restriction on their dried sludge(Milwaukee's' Milorganite). They are going thru their plant upgrade to make available dried sludge to the urban folks.

Cooperband

I can't give citations for literature, but in general phosphorus in composts or pelletized biosolids (e.g. Millorganite) will be less bioavailable than from commercial fertilizers. Composts applied to urban soils have the benefit of improving soil water holding capacity and infiltration, thereby reducing amounts of runoff water and the P dissolved (or in suspended particles) in that runoff water. I would not ban the use of composts or pelletized biosolids products for use on lawns because the benefits of improved soil physical properties far outweigh their potential contribution to runoff P.

Kussow

The key consideration here is the fact that turfgrass takes up N and P₂O₅ in the ratio of 4:1. In a product such as Milorganite and most natural organic products, this ratio is 3:1 or less. What this means (I have research that verifies this with Milorganite) is that repetitive application of these products will build up soil test levels of P. This is contradictory to what the P ordinance is attempting to achieve. It has to be understood that for the most part, lawn P restrictions are a de facto banning of all natural organic fertilizers.

Milles

Composting should be encouraged if that person has a use for that material. I believe most homeowners are not willing to take the time or have a significant need for compost materials. Homeowners should be encouraged to use lawn mowers with mulching blades, and leave grass clippings and leaves on the turf. When a homeowner removes grass clippings and leaves from his/her yard, nutrients are being removed and this yard will require one more application of fertilizer per year compared to a yard that did not remove grass clippings or leaves.

Homeowners should also not be allowed to deposit leaves along streets or discharge grass clippings onto hard surfaces that will eventually enter the storm water. This can be a significant source of phosphorus.

Potter

I believe that an exemption for compost is essential, as compost will likely be a major tool in dealing with compacted soil. Also, I doubt whether leaf compost, the most abundant source, contains much mobile P. (There are plenty of experts around who can answer that question.)

As for Milorganite, there is the issue of balancing the benefits of putting sewage treatment residuals to good use.

Stier

If indeed fertilizer is an effective source of P in surface waters, then exempting organic fertilizers/composts from a P ban will not help reduce P in surface waters. Most synthetic turf fertilizers, with the obvious exception of starter fertilizers (1:2:1 N:P:K ratio) have a low ratio of P to N, e.g., 1:7. Organic fertilizers have about a 3:1 ratio. Since turf is fertilized primarily for N purposes, use of an organic fertilizer requires the addition of about twice as much P compared to a synthetic fertilizer. However, peer-reviewed scientific data do not support the contention that turf properly fertilized with P-containing fertilizer contributes to P runoff anyway (see abstract from manuscript below), in which case exempting organic P fertilizer really won't matter much.

Gross, C. M.; Angle, J. S.; Welterlen, M. S.
Dep. of Agronomy, Univ. of Maryland, College Park, MD
Nutrient and sediment losses from turfgrass
Journal of Environmental Quality. Vol. 19, No. 4, October-December 1990, p. 663-668.

Abstract "The contribution of turfgrass fertilizer to surface and groundwater pollution is not well documented. Two studies, at separate locations, were therefore initiated to examine losses of nutrients and sediment via leaching and runoff from turfgrass. Treatment included fertilizer applied in a liquid and granular form and an unfertilized control. Sodded tall fescue (*Festuca arundinacea* Schreb.)/Kentucky bluegrass (*Poa pratensis* L.) plots were fertilized at a rate of 220 kg N ha⁻¹ yr⁻¹ in metered applications of urea. Runoff was collected and analyzed for volume, suspended and soluble solids, NH₄-N, NO₃-N, total N, PO₄-P, total soluble P, and total P. Runoff losses of total N were significantly ($P \leq 0.05$) higher when comparing the liquid and granular treatments to the control, although there was no difference between fertilizer treatments. Losses for all forms of P and sediment did not significantly differ with regard to treatment. Soil percolate (0.75 m depth) was collected monthly from the various treatments. Percolate NO₃-N concentrations from the liquid and granular treatments did not differ significantly, although both were significantly higher than the untreated control. Soil cores (2.1 m depth) were collected every spring and fall in 0.30-m increments. Nitrate-N concentrations generally decreased with depth; however, the granular treatment exhibited a higher soil NO₃-N concentration than either the liquid or control treatments. These results indicate that when compared with agronomic row crops, nutrient and sediment losses from turf via runoff, and leaching are very low."

Gross, C. M.; Angle, J. S.; Hill, R. L.; Welterlen, M. S.
Dep. of Agronomy, H.J. Patterson Hall, Univ. of Maryland, College Park, MD 20742
Runoff and sediment losses from tall fescue under simulated rainfall
Journal of Environmental Quality. Vol. 20, No. 3 July-September 1991, p. 604-607.

Abstract "A study was initiated to examine runoff volume and sediment loss from various density tall fescue (*Festuca arundinacea* Schreb.) turf stands. Plots were established with seeding rates of 0, 98, 244, 390 and 488 kg/ha and allowed to mature for 9 months. Three different rainfall intensities (76, 94, and 120 mm/h) were applied to the plots using

a variable intensity rainfall simulator. Results indicate that there were significant differences in runoff volume and sediment load as affected by rainfall intensity. The runoff initiation time for the 0 kg/ha seeding rate was the only seeding rate that was significantly different from all others. Mean runoff rates over time were significantly different for the first 5-min time interval of the 30-min storm for all three intensities. There was a significant difference in total sediment load for all three intensities. There was a significant difference in total sediment load for all three rainfall intensities. At the high (120 mm/h) rainfall intensity, there was over a sixfold reduction in sediment loss when comparing the 0 kg/ha seeding rate to the 98 kg/ha seeding rate. Greater sediment loss reductions were observed at the lower rainfall intensities when comparing the same seeding rates. Sediment loss rates did not differ for the 98, 244, 390 and 488 kg/ha seeding rates at the low (76 mm/h) and medium (94 mm/ha) rainfall intensities. At the high (120 mm/ha) rainfall intensity, significant differences were detected between the 0 kg/ha and the 488 kg/ha seeding rate. The 98, 244, and 390 kg/ha seeding rates were not statistically different at this intensity. These results indicate that even low density turfgrass stands significantly reduce sediment loss."

Swingle

Factors that Support: Using "waste" products which have plant nutrient value is a benefit to society by recycling materials and preventing these materials, such as animal and human waste, from being disposed of without any benefit gained. As we already have the city of Madison and the City of Milwaukee utilizing the nutrient value as plant fertilizer, thereby reducing waste disposal costs or the unnecessary placement of these potentially beneficial by-products in landfills. The County must be cognizant of the fact that ordinances banning phosphorus in lawn fertilizer, which almost all natural organic sources contain, could disrupt and possibly end the possibilities for these waste products and by-products to be used beneficially, economically and sensibly for fertilizer. It could also eliminate innovative and cost conscious possibilities for local governments and their waste treatment and sanitary districts in reclaiming, reusing, repackaging and marketing waste by-products products as commercial fertilizer, costing taxpayers more money.

Organic sources of P are just as beneficial to turfgrass plant health as are inorganic sources. The chemistry is the same for the elemental P to be bound in soils.

Factors that Undermine Support: Phosphorus(P) applied as fertilizer does not run-off turf according to numerous University peer-reviewed research studies throughout the U.S. The migration of phosphorus from fertilizer granules is typically measured in millimeters, not in inches. Phosphorus is a natural occurring mineral. Regardless of its source, mined phosphate or organic sources, the phosphorus is tied up by clay particles in the soil by the strong charge of the elemental P. It remains relatively insoluble and unavailable to the plant. Very little is available for plant growth at any one time. Because phosphorus is bound so tightly to soil particles, the amount of P that exists in soil solution (soil water) rarely exceeds 1.0 ppm (Black, 1968). As a consequence of this well-known property, P neither leaches nor runs off in solution. The only way for phosphorus to "run-off" lawns is when soil particles erode and the nutrient P is carried on the soil particle to which it is attached.

However, it must be noted that organic particles of P take longer to decompose or "breakdown" into the form that is readily tied up by the soil particle, so if the theory that fertilizer particles run-off of lawns was true, organic fertilizer particles last longer in the particle form on the turf surface and would thereby be subject to runoff for a longer period of time than a fertilizer particle from an inorganic source of phosphorus.

Organic fertilizers have a lower ratio of nitrogen to phosphorus (e.g. Milorganite 6-2-2) versus other commonly sold commercial fertilizer e.g. 32-6-10. Because of this fact, the recommended fertilizer application rate is higher for organic sources to equal the amount of nitrogen recommended per application. For example, the typical recommended rate of nitrogen for a single lawn application is one (1) pound nitrogen per 1,000 sq. feet for proper plant growth based on a four to six week interval between applications during the growing season. For a 5,000 sq. foot lawn it would take 84 pounds of Milorganite (6-2-2) versus 15.6 pounds of the 32-6-10 fertilizer to make the application. At the same time the Milorganite(6-2-2) applied 1.68 pounds of phosphorus to the lawn, whereby the 32-6-10 product applied only 0.936 pounds of phosphorus. To achieve the same nitrogen application rate of 1 pound per 1,000 sq. ft., you must apply the organic 6-2-2 products at a rate 5.3 times higher than the 32-6-10. This means a much larger amount of fertilizer (and phosphorus applied to lawns, and to impervious surfaces).

If the facts supported the idea that phosphorus run-off from lawns, and they do not, then exempting organic products would be contradictory to the purpose of the ordinance which is reducing phosphorus run-off into the watershed. As written this ordinance would (NOTE: comment ended there)

Compost should not be applied to lawns. It should be used in flowers and gardens to recycle waste and benefit from the beneficial plant nutritional value. Compost would not breakdown into its elemental form in a relatively short period of time and would remain on the surface subject to runoff in a heavy rain due to the relatively large particle size in relation to its light weight. Additionally, compost would be more difficult to completely remove from impervious surfaces by sweeping. And if the homeowner attempted to wash the staining compost from the sidewalk or driveway, they would be potentially washing the phosphorus into the street. Due to the porosity of asphalt, compost could not be completely removed or recovered by sweeping, unless a vacuum was used. Spills of commercial lawn fertilizer are more easily recovered from these surfaces by sweeping with a broom or using a leaf blower. Compost cannot be applied to a lawn in a uniform manner.

It is an unfair advantage for producers or providers of organic fertilizer products or services, that cannot be justified with a goal of less phosphorus runoff.

If organic sources of phosphorus fertilizer use increases substantially there theoretically could be additional runoff into the watershed of Phosphorus. With an exemption for unadulterated organic sources of P fertilizers to be used, one could spread liquid cow

manure over their lawn at any desired rate of application. If runoff occurred, there would be no violation of the ordinance.

Miscellaneous remarks

Bannerman

Provided copies of the following references in support of his responses to questions:

Bannerman, Roger. in press. Source area and regional storm water treatment practices: options for achieving phase II retrofit requirements in Wisconsin. Conference proceedings of the North American Surface Water Quality Conference and Exposition, August 12-15, 2002, Marco Island, Florida, 21 p.

Bannerman, Roger T.; Legg, Andrew D.; and Greb, Steven R. 1996. Quality of Wisconsin stormwater, 1989-94. U.S. Geological Survey Open File Report 96-458. 26 p.

Caraco, Deb and Brown, Ted. 2001. Crafting an accurate phosphorus budget for your lake. In Watershed Protection Techniques special issue on Urban Lake Management. Center for Watershed Protection. Vol. 3, No 4.

Center for Watershed Protection. 1998. Nutrient loading from conventional and innovative site development. Prepared for Chesapeake Research Consortium.

Corsi, Steven R.; Graczyk, David J.; Owens, David W.; and Bannerman, Roger T. 1997. Unit area loads of suspended sediment, suspended solids, and total phosphorus from small watersheds in Wisconsin. U.S. Geological Survey Fact Sheet FS-195-97. 4 p.

Garn, Herbert S. 2002. Effects of lawn fertilizer on nutrient concentrations in runoff from lakeshore lawns, Lauderdale Lakes, Wisconsin. U.S. Geological Survey Water Resources Investigations Report 02-4130. 6 p.

Kroupa, Gene & Associates. Westmorland lawn care survey. Prepared for City of Madison Department of Public Works. 100 p.

Schuler, Tom. 2001. Managing phosphorus inputs into lakes – introduction. In Watershed Protection Techniques special issue on Urban Lake Management. Center for Watershed Protection. Vol. 3, No 4.

Steuer, Jeffrey; Selbig, William; Hornewer, Nancy and Jeff Prey. 1997. Sources of contamination in an urban basin in Marquette, Michigan and an analysis of concentrations, loads and data quality. Water Resources Investigations Report 97-4242. Middleton, WI: U.S. Geological Survey. 25 p.

Waschbusch, R.J., Selbig, W.R., and R.T. Bannerman. 1999. Sources of phosphorus in stormwater and street dirt from two urban residential basins in Madison, Wisconsin, 1994-95. Water Resources Investigations Report 99-4021. Middleton, WI: U.S. Geological Survey. 47 p.

Wierl, Judy; Giddings, Elise; and Roger Bannerman. 1998. Evaluation of a method for comparing Phosphorus Loads from Barnyards and Croplands in Otter Creek Watershed, Wisconsin. Fact Sheet FS-168-98. Middleton, WI: U.S. Geological Survey. 4 p.

Wisconsin Department of Natural Resources. 1993. Evaluation of urban nonpoint source pollution management in Milwaukee County, Wisconsin. Volume 1: urban stormwater characteristics, sources and pollutant management by street sweeping.

Wisconsin Department of Natural Resources. 1997. Nonpoint source control plan for the Lake Mendota priority watershed – project summary. Publication WT-481-97. Madison, WI. 16 p.

Wisconsin Department of Natural Resources. 2000. Nonpoint source control plan for the Lake Mendota priority watershed. Publication WT-536-00 REV. Madison, WI.

Good

The Phosphorus Roundtable Archives mentioned in my response to question #T1 include a September 5, 2001 presentation by Richard Lathrop on “Phosphorus Dynamics in Lake Mendota” that may be useful in responding to other questions.

Bennett

Bennett, E. M. In press. Soil phosphorus concentrations in Dane County, Wisconsin, USA: An evaluation of the urban-rural gradient paradigm. Environmental Management. Heckrath, G., P. C. Brookes, P. R. Poulton, and K. W. T. Goulding. 1995. Phosphorus leaching from soils containing different phosphorus concentrations in the Broadbalk experiment. Journal of Environmental Quality 24:904-910.

Kelling, K. A., E. E. Schulte, L. G. Bundy, S. M. Combs, and J. B. Peters. 1991. Soil test recommendations for field, vegetable, and fruit crops. A2809 University of Wisconsin-Extension, Madison.

Sharpley, A.N. and R.G. Menzel 1987. The Impact of Soil and Fertilizer Phosphorus on the Environment. Advances in Agronomy 41:297-324.

Carpenter

Lathrop, R.C., S.R. Carpenter, C.A. Stow, P.A. Soranno and J.C. Panuska. 1998. Phosphorus loading reductions needed to control blue-green algal blooms in Lake Mendota. Canadian Journal of Fisheries and Aquatic Sciences 55: 1169-1178.

Reed-Anderson, T., S.R. Carpenter and R.C. Lathrop. 2000. Phosphorus flow in a watershed lake ecosystem. Ecosystems 3: 561-573.

Soranno, P.A., S.L. Hubler, S.R. Carpenter and R.C. Lathrop. 1996. Phosphorus loads to surface waters: A simple model to account for spatial patterns of land use. Ecological Applications 6: 865-878.