Phosphorus Reduction in Wisconsin Water Bodies

An Economic Impact Analysis

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Approved:

Secretary

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Date

Executive Summary

The purpose of this report is to evaluate the costs and benefits of ch. NR 102.06 and ch. NR 217, Wis. Adm. Code on the state of Wisconsin. Changes to administrative rules aimed at cutting phosphorus coming from industrial and municipal wastewater dischargers were adopted by the state Natural Resources Board in June 2010, and went into effect Dec. 1, 2010. Chapter NR 102, Wis. Adm. Code comprises numerical standards for various bodies of water, and ch. NR 217, Wis. Adm. Code outlines how phosphorus limits will be calculated for those applying for point-source discharge permits.

Using a Monte Carlo simulation, we predict the net benefits of the DNR rules to Wisconsin to be $18,800,000 (with a standard deviation of $97,100,000). We recognize that this is a large variance; it is driven by uncertainties on the cost variables. By dividing the total net benefits of the regulations, $18,800,000, by the pounds of phosphorus reduced, 800,000, we obtain the shadow price of phosphorus, $23.56 per pound. This means that each pound of phosphorus reduced by the regulations brings $23.56 in benefits to Wisconsin residents over and above the cost of reducing it. Many benefits are excluded from these monetized values either because we determined them to be small in magnitude or because not enough information was available for us to make a reliable estimate. Because these benefits are real, yet impossible to monetize, this report likely underestimates of the monetary benefits of the new rules.

The DNR has identified four primary categories of dischargers that may be impacted by the new rules: municipal waste water treatment facilities, cheese makers, paper mills, and food processors. The analysis considers two cost categories including (1) capital costs and operating and maintenance costs and (2) the implementation costs and the transaction and administration costs of Watershed Adaptive Management (WAM).

This report also includes a quantification of benefits. Wisconsin derives many benefits from its clean water. Some benefits could be quantified and monetized but many others could not. Monetized benefits include:

- Increased property values
- Improved recreational opportunities
- Avoided lake cleanup/management costs

Benefits that could not be quantified or monetized include:

- Wildlife health and biodiversity
- Tourism
- Scenic beauty/quality of life
- Human and pet health
- Health of commercial fisheries
- Reduction in other pollutants that will be removed concurrently along with phosphorus by new technologies

Contents

1 Introduction

1.1 Background and Purpose

The purpose of this report is to evaluate the costs and benefits of ch. NR 102.06 and ch. NR 217, Wis. Adm. Code for affected parties in the state of Wisconsin. Phosphorus pollution has been identified as the controlling factor in excessive plant and algae growth in Wisconsin bodies of water. Changes to administrative rules aimed at cutting phosphorus coming from industrial and municipal wastewater dischargers were adopted by the state Natural Resources Board in June 2010, and went into effect Dec. 1, 2010. Ch. NR 102, Wis. Adm. Code comprises numerical standards for various bodies of water, ch. NR 217, Wis. Adm. Code outlines how phosphorus limits will be calculated for those applying for point-source discharge permits, and ch NR 151 addresses non-point source phosphorus discharge.

While the DNR had been working on these rules for some time, pressure from the U.S. Environmental Protection Agency (EPA) accelerated their adoption. After the DNR's adoption of the rules in December 2010, the EPA approved ch. NR 102.06, Wis. Adm. Code as consistent with the Clean Water Act and it became effective under federal law. For a more detailed explanation of s. NR 102.06 and ch. NR 217, Wis. Adm. Code, please see the plain-language analysis of the rule in Appendix P.

The DNR is required under Section 9135 (3f) of 2011 Wisconsin Act 32 to prepare an "economic impact analysis (EIA)" of s. NR 102.06 and ch. NR 217,Wis. Adm. Code that includes all the information specified in s. 227.137 (3), Wis. Stats. The purpose of this document is to comply with the requirements set forth in Section 9135 (3f) of 2011 Wisconsin Act 32.

1.2 Design of the Analysis

The DNR has identified four primary categories of dischargers that may be impacted by the new rules: municipal waste water treatment facilities, cheese makers, paper mills, and food processors. Costs to these facilities could potentially include updating current facilities with additional filtration or other wastewater treatments, an increase in fees for those sending their wastewater to outside treatment facilities, and an increase in operation and maintenance costs. These potential costs will be explained more completely in the Costs section below, along with a discussion of how the Watershed Adaptive Management (WAM) option may mitigate costs to industry.

This report also includes a quantification of benefits. Wisconsin derives many economic benefits from its clean water. This report includes increased benefits for recreation, property values, and avoided costs of future lake management that can be monetized. There are many other benefits to improved water quality that could not be monetized. As such, the monetary benefits of the rules are likely underestimated by our report.

1.3 Review Process

The report was prepared at the staff level. Upon completion, it was then reviewed at the Bureau level, Division level, and Secretary's Office.

1.4 Report Organization

The remainder of the report will be organized as follows: Section 2 will summarize the report findings. Section 3 outlines the economic questions considered in the analysis, and Section 4 explains the costs and benefits considered. Section 5 outlines the methodology of the report, and Section 6 includes a discussion of the results.

2 Summary

The analysis of the economic impact of chapters NR 102 and NR 217, Wis. Adm. Code considers two cost categories and three benefit categories that could be monetized. The two cost categories are (1) capital costs and operating and maintenance costs and, (2) the implementation costs and the transaction and administration costs of Watershed Adaptive Management (WAM). The benefit categories include (1) the avoided costs of future lake management, (2) improved recreation, and (3) increased property values. Other types of benefits were considered but could not be monetized because not enough information was available for us to make a reliable estimate. As such, this report likely underestimates the monetary benefits of the new rules.

Based on our Monte Carlo simulation, we predict the net benefits of the DNR rules to Wisconsin to be $18,800,000, with a standard deviation of $97,100,000. We recognize that this is a large variance; it is driven by uncertainties on the cost side. (For more detail, see section 5.4).

By dividing the total net benefits of the regulations, $18,800,000, by the pounds of phosphorus reduced, 800,000, we obtain the shadow price of phosphorus, $23.56 per pound. This means that each pound of phosphorus reduced by the regulations brings $23.56 in benefits to Wisconsin residents over and above the cost of reducing it.

Table 1. Summary of assessed costs

	Capital Costs	O&M Costs	Total Costs
Fixed point sources (No chance of using WAM)	$345,500,000	$736,700,000	$1,082,200,000
Variable point sources (May or may not use WAM)	$312,400,000	$640,100,000	$952,500,000
Total Costs (minimum estimate)	$345,500,000	$736,700,000	$1,082,200,000
Total Costs (maximum estimate)	$657,900,000	$1,376,800,000	$2,034,700,000

Source: Authors

Table 2. Summary of all assessed benefits

Benefits	**Effect can be Quantified?**	**Effect can be monetized?**	**More information**
Increased property values	Y	$1,094,300,000	Appendix H and J
Improved recreational opportunities	Y	$596,700,000	Appendix K and L
Avoided lake cleanup/management costs	Y	$4,800,000 – 11,400,000	Appendix M
Human and pet health	N	N	Appendix N
Wildlife health and biodiversity	N	N	Section 4.5.3
Health of commercial fisheries	N	N	Section 4.5.3
Reduction in other pollutants that will be removed concurrently along with P	N	N	Section 4.5.3
Tourism	N	N	Section 4.5.3
Scenic beauty/quality of life	N	N	Section 4.5.3
Total Monetized Benefit (minimum estimate)		1,695,800,000	
Total Monetized Benefit (maximum estimate)		1,702,400,000	

Source: Authors

3 Economic Questions Considered

Our assessment of the phosphorus policy takes the form of a benefit-cost analysis, which identifies each area of cost and benefit resulting from the policy and attempts to quantify the magnitude of the cost or benefit in dollar terms. Costs and benefits that are not directly valued in markets, such as the ability to fish on a lake, are valued using a technique called shadow pricing. Shadow prices can be derived by studies measuring a person's willingness to pay for the enjoyment of a benefit (or avoidance of a cost), either as revealed through another market transaction or as measured in a survey question. Our analysis uses many shadow prices to measure benefits and costs. Some effects of the rule cannot be measured through these methods, but are still believed to be of importance. We discuss those areas qualitatively. We also limit our analysis to primary markets, ignoring impacts on secondary industries (i.e. fishing supply stores) to avoid any double-counting issues (explained in more detail in section 4.5.1).

4 Specification of Baseline and Rule

NR 102 establishes a set of phosphorus water quality standards criteria for rivers, streams, various types of lakes, reservoirs, and Great Lakes. Chapter NR 217, Wis. Adm. Code establishes procedures for determining and incorporating phosphorus water quality based effluent limitations (WQBEL) into Wisconsin Discharge Pollutant Elimination System (WPDES) permits, which limit phosphorus outputs.

This analysis compares the costs and benefits of affected parties under the new regulations (water-quality based standards) to the original rules (technology based standards). While in most reports this would result in a comparison of proposed rules against the status quo, our analysis is complicated by two facts: first, that the rules have already been promulgated; and second, that federal oversight makes the repeal process uncertain.

The rules were adopted on a federal level under 303(c) of the federal Clean Water Act, which requires states to establish their own water quality criteria. The EPA approval of each state's water quality criteria is required, and EPA may step in and promulgate standards when the state fails to do so. While it is impossible to know for certain how the EPA would respond to any attempts to repeal the new rules, EPA intervention/enforcement is likely.

Therefore, while we are comparing the economic outcome of the new rules to the economic outcome of the old, we do not assume that repealing the rule is a viable alternative. Additionally, because the rule has already been adopted on the federal level, we are not analyzing any additional alternative policy options.

4.3 Time Horizon

We calculated the costs and benefits for a 20-year time period, beginning in 2012, as that is when we expect permits to be reissued under the new phosphorus rules. A 20-year time horizon is the standard for planning and management at municipal wastewater treatment plants, which are some of the main dischargers affected by the new phosphorus rules. We selected the time period to ease the cost calculations, but as we discuss later, we found that many of the costs are accrued more immediately than the benefits. We acknowledge that limiting the time horizon to 20 years may underestimate the net benefits; however, the nature of economic analysis limits the possibility of valuing benefits far into the future. Therefore it is worth noting that future benefits may be underestimated in our analysis, and there is significant value in having clean bodies of water in fifty years that we were unable to monetize.

4.4 Discount Rate

The costs and benefits are listed at their 20-year present values. To determine these values, we used a real discount rate of 3.5 percent, as generally recommended by Boardman et al. (2011). We find it important to note that a lower discount rate would yield greater net benefits because of the mechanics of discounting and the fact that many of the costs would be realized almost immediately while many of the benefits would be realized in the more distant future.

4.5 Benefits and Costs Considered

This report focuses primarily on lake quality, despite the fact that most point-source dischargers discharge to rivers. There are two primary reasons we focus on lakes: First, phosphorus moves through water systems and ends up in lakes. Because of the nature of water systems, the effects of phosphorus pollution are not limited to where the phosphorus was discharged. Thus, lakes are affected by excessive phosphorus discharge coming from any upstream sources. Second, the DNR primarily measures phosphorus levels on lakes; there is very little information available on phosphorus levels in Wisconsin rivers. Therefore, we were limited to examining the effects of the rule on lakes. 4.5.1 Costs

The DNR has identified four primary industries/municipalities that will be affected by the new regulations: municipal waste water treatment facilities, cheese makers, paper mills, and food processors facilities. We have met with representatives from each of these industries to discuss costs and concerns (See Appendix A for additional details.)

The costs of the new phosphorus regulations primarily consist of equipment upgrade and increased operating and maintenance costs borne by industries and municipalities who must comply with stricter discharge limits. Watershed Adaptive Management (WAM) practices have the potential to lower total compliance costs by providing less expensive alternatives to equipment upgrades to reduce phosphorus loads. In our analysis, we calculate municipal and industry costs of compliance with estimated new permit limits, and we examine the effects on these compliance costs of different WAM scenarios.

4.5.2 Benefits

The phosphorus rules are intended to improve the quality of Wisconsin's bodies of water by mitigating eutrophication. While phosphorus occurs naturally in the environment, excess amounts resulting from runoff and pollution cause algae blooms that pollute bodies of water. Excess amounts of algae are unsightly, smell bad, and can negatively affect fish and wildlife populations. Some algae can also sicken people or animals who ingest the water. As a result, many of our waters are not swimmable or fishable, and property values surrounding them are depressed. A 2009 study by Dodds et al. found that the largest costs of eutrophication were to property values ($0.3-$2.8 billion per year for the United States) and to recreational uses of water ($0.37-$1.16 billion per year). Our analysis estimates the increased property values and increased recreational values derived from cleaner water as a result of the regulations. We also examine the avoided future costs of cleaning phosphorus-polluted lakes.

4.5.3 Benefits not included in analysis

There were many other types of benefits we considered but ultimately excluded from the analysis, as not enough information was available to make a reliable estimate of their monetary value. Despite their exclusion from this economic analysis, these benefits are no less valuable than the benefits we were able to monetize and ought to be considered when weighing the merits of the rules. These categories include benefits to human and pet health, tourism, commercial fishing, biodiversity, scenic beauty, avoided costs of treating drinking water, and reduction in other pollutants that would result from increased treatment. Those using the numbers in this report should consider these merits as well as the ones we were able to quantify.

Human Health (Harmful Algae Blooms)

Chapters. NR 102 and NR 217, Wis. Adm. Code, create positive benefits to human health by reducing the overall emission of phosphorus pollution. Although we made an effort to gather economic data as comprehensively as possible, both the type and amount of available data were limited. Most states neither conducted economic studies of the effects of harmful algae blooms (HABs) nor collected data that can be used to generate reliable quantitative estimates of such effects (Hoagland and Scatasta, 2006). In many cases, it is difficult to determine whether an algal bloom is the immediate and relevant cause of certain illnesses because of the complex physical and ecological characteristics of the environment (Hoagland and Scatasta, 2006). In addition, opinions from local experts about the magnitude of economic effects from HABs tend to differ substantially.

Wisconsin had a total of 62 cases reported as potential algae-related illnesses in 2009-2010. According to the Wisconsin Department of Health Services (DHS), 14.5 percent of these cases were associated with dermal rashes, 8.1 percent were associated with respiratory irritation, 51.6 percent were associated with gastrointestinal distress, and 29.0 percent associated with cold/flu-like illness symptoms. Many cases included a combination of symptoms such as a rash and gastrointestinal distress. This explains why there are more symptoms than there are cases.

Many of the public health costs of HABs are realized in U.S. coastal states. Wisconsin's symptoms are rather minor and quantifying the avoided health care costs would be nearly impossible because of the lack of quantitative data available for these minor symptoms. Therefore, we estimate that chs. NR 102 and NR 217 results in a marginal decrease in potential cases reported and thus a marginal increase in benefits to human health. For details on potential algae-related illnesses reported in Wisconsin, see Appendix N.

Tourism

Tourism is one of Wisconsin's most important industries, ranking third after agriculture and manufacturing (Wisconsin Department of Tourism n.d.). Eutrophication from phosphorus is commonly cited as a threat to tourism because of its effect on water recreation. Decreases in water quality that reduce numbers of tourists negatively affect resorts, restaurants, equipment stores, and other businesses. However, we omit benefits to tourism from our analysis because of the risk of double-counting with the recreational benefits category. In addition, it would be very difficult to estimate accurately the effects on tourism from eutrophication. Even if algal blooms deter tourists from visiting a particular lake and patronizing the businesses on that lake, they may choose another form of recreation and visit other businesses; thus the loss to the tourism industry in one area of the state may be offset by a benefit in another part of the state. It is also difficult to accurately quantify how many tourists do not come to Wisconsin as a result of eutrophic lakes.

However, it is likely that phosphorus regulations would bring benefits to the tourism industry by increasing lake quality.

Commercial Fishing

Wisconsin is home to a commercial fishing industry with fisheries in the Mississippi River and the Great Lakes. Jeffrey Malison, a member of the Wisconsin Aquaculture Industry Advisory Council, stated in an email on Dec. 2, 2011, that the phosphorus regulations are unlikely to affect commercial fisheries; the Mississippi River fishery concentrates on rough fish that can tolerate eutrophic conditions, and in his opinion the water quality in the Great Lakes is unlikely to be greatly affected by the regulations.

Commercial fishing should be distinguished from aquaculture (fish farming). Some large fish farms may be negatively affected by the new regulations because they must obtain permits to discharge phosphorus. Effects to aquaculture are included in the costs section of this report.

Biodiversity

Eutrophication of bodies of water has the potential to alter fish populations, killing fish that require cold water and high levels of dissolved oxygen, and leading to the prevalence of rough fish (Heiskary and Wilson, 2005). Aside from the importance of coldwater fish on anglers and the fishing industry, fish species have an existence value (Loomis and White 1996). This means that research has found that many people have a positive willingness to pay for the existence of certain animal species, even if they do not benefit in other obvious ways from the species. The phosphorus regulations would benefit Wisconsinites who value the existence of the state's fish and aquatic species by protecting them from the harmful effects of continued eutrophication. However, it is prohibitively difficult to project the changes in fish populations in each body of water without the regulations; therefore, we could not monetize the benefits associated with biodiversity.

Reduction in other pollutants

The treatments to reduce phosphorus discharge will likely reduce other pollutants (such as nitrogen) concurrently. There will be some future benefit associated with reduction in other pollutants; however, it was beyond the scope of this project to quantify and monetize the benefits associated with reductions in each pollutant.

5 Methodology

5.1 Nature of the Economic Approach

Estimating the costs to industries and municipalities was challenging. Discharge limits are calculated on a permit-by-permit basis based on the quality of the receiving water. Because the five-year permits are issued on a rolling basis, we do not yet know which dischargers will be impacted by the new rule. We are also unsure of which technologies they will select to meet new requirements, as well as how many will engage in Watershed Adaptive Management (WAM). We will discuss in greater detail how we calculated costs below.

On the benefits side, we needed to estimate how much phosphorus would be removed from bodies of water and the impact that would have on water clarity and eutrophication rates; then estimate how changes in water quality would affect property values, recreation, and lake management costs.

After calculating and monetizing all the effects we were able to accurately measure, we summed the costs and summed the benefits.

5.2 Calculation of Costs

We indirectly modeled eutrophication levels by approximating current phosphorus concentrations in Wisconsin watersheds. We then calculated reductions in phosphorus loads caused by the implementation of the regulations (see Appendix B). We used a model of current phosphorus concentrations in Wisconsin lakes developed by Bernthal et al. (2011). We used Pollutant Load Ratio Estimation Tool (PRESTO), a Wisconsin GIS-based tool that compares the average annual phosphorus loads originating from point and nonpoint sources, to determine the total amount of phosphorus inputs into the Wisconsin watersheds. We assumed that statewide phosphorus inputs roughly equaled phosphorus outputs – that is, that the phosphorus entering Wisconsin waterways will move through the water system and leave Wisconsin waters with no accumulation in the state. In reality, some phosphorus accumulation (known as loading) occurs, but it was not possible for us to calculate how much. This input = output assumption allows us to estimate that a percentage change in phosphorus inputs would equal the same fractional change in average phosphorus concentrations. We do not believe the amount of loading that occurs would change the the numbers significantly. To approximate how the regulation would be enforced, we split the state into three areas based on the ratio of point and non-point sources. We then estimated the reduction of point phosphorus loading into the Wisconsin watersheds based on each point source's current reported loads and average concentration. This allowed us to calculate the estimated change in phosphorus loading, based on PRESTO data regarding point and non-point phosphorus loading in each Wisconsin watershed; thus allowing calculation of change in phosphorus concentration in each of the three state areas.

For purposes of our model, the phosphorus change in the Low point source/non-point source ratio area is assumed to be zero. While there will likely be a very minor change in phosphorus loads, it is not expected to have any effect on eutrophication as the receiving waters have additional capacity for phosphorus without change to the environment.

5.2.1 Description and Calculation of Costs

Capital and Operating & Maintenance Costs

Some point source dischargers will have to reduce their phosphorus loads to comply with the new regulations; this will require installation of additional equipment and treatment processes. We have cost estimates on upgrade costs for installing metal salt chemical and filter equipment from an EPA report (EPA 2008). This equipment model was chosen as it is the easiest to integrate into all types of existing equipment and has a very minimal land footprint; further, it is the most widely applicable model to the potential technology that will actually be installed.

It is impossible to predict or model the diverse and specific technologies that will be used by each point source, which is why a single, widely-applicable model equipment was chosen. This model will err on the side of being very conservative for two primary reasons: first, plants with significant land on which they can expand or build can have substantially reduced costs, both immediate capital and long term operating costs; and second, phosphorus removal technology is a quickly evolving field, and costs and effectiveness of equipment could likely be reduced substantially by the time some or all of these companies have to install their equipment.

Capital costs, as well as operating and maintenance costs, are calculated using the three-year average daily flow rate for each discharger.

Capital costs are determined using the dollars per million gallons per day values provided for the equipment, utilizing the average flow capacity as the flow rate for each point source. A 30 percent contingency cost increase was added to this value based on DNR information, as unique projects tend to have unexpected costs, and average flow capacity may not completely represent the full equipment needed. Capital costs of the equipment are assumed to be borne entirely on the year they are installed.

Operating and Maintenance (O&M) costs are determined using dollars per million gallons of total flow values provided in the EPA report for the equipment. Total yearly flow was determined by multiplying the daily average flow rate by 365, to determine the yearly O&M cost. O&M costs are assumed to be borne every year after the equipment is installed.

Using estimates prepared by the DNR describing which point sources, watersheds, and areas of Wisconsin would likely have their permitted phosphorus concentrations reduced by the new rule, we estimated which point sources would have to install the equipment; not including those expected to utilize adaptive management (discussed later). Point sources in areas with excess assimilative capacity (phosphorus is not causing any significant eutrophication), and point sources for which it would be cost prohibitive were excluded from this cost analysis, as it is expected they will receive a variance by the DNR.

Permits are issued on a rolling basis every five years, but when permits will actually be issued to a given facility is unknown; therefore, when the equipment would have to be installed is also unknown. We assumed that 20 percent of permits will be issued each year starting in 2012 through 2016, and the corresponding equipment will be installed at the end of that permit period.

Therefore, 20 percent of the point sources having to install equipment are modeled to have it installed at the end of 2017, and 20 percent more each year thereafter, until 100 percent of the point sources determined to have to install equipment are assumed to have installed it at the end of 2021.

As the Capital Costs are spread out over time, the Capital Cost for each point source is discounted back to the present day based on the year it is installed. The Net Present Value of the yearly O&M costs for each point source are then calculated, accounting for each year after the equipment is installed until reaching the end of the 20 year time horizon.

Based on the analysis in the Watershed Adaptive Management section, immediately following this section, the point sources known to be using adaptive management have been excluded from this section of the cost analysis, accounting for approximately 4 percent of the total phosphorus reduction by mass. As well, the point sources that may potentially use WAM are also calculated separately, splitting the point sources into two categories, Fixed and Variable point sources. Fixed point sources are assumed to always use equipment to address their phosphorus load in the analysis, while variable point sources are varied as to using equipment or WAM to manage their phosphorus load in the analysis.

The costs are laid out in the figure below. (See Appendix C.)

	Capital Costs	O&M Costs	Total Costs
Fixed point sources (No chance of using WAM)	$345,500,000	$736,700,000	$1,082,200,000
Variable point sources (May or may not use WAM)	$312,400,000	$640,100,000	$952,500,000
Total Costs (minimum estimate)	$345,500,000	$736,700,000	$1,082,200,000
Total Costs (maximum estimate)	$657,900,000	$1,376,800,000	$2,034,700,000

Source: Authors.

5.2.2 Costs for Watershed Adaptive Management

The new phosphorus rules are designed to bring about better water quality in Wisconsin by imposing more stringent phosphorus limits on point and nonpoint sources. In urban areas, discharges from point sources (such as wastewater treatment plants) often generate the majority of the phosphorus load in local water bodies. In agricultural areas, runoff from nonpoint sources, such as farm fields, often contributes the majority of the phosphorus. Load reductions are achieved in different ways at the various sources. Point sources often require advanced technology and equipment to reduce the phosphorus concentrations of their effluent while nonpoint sources adjust and improve their nutrient management practices to reduce the phosphorus loads in their runoff.

The new limits within ch. NR 217, Wis. Adm. Code, would require some point sources to make significant and expensive upgrades to their facilities. In watersheds dominated by nonpoint source pollution, these expensive upgrades would have a small impact on water quality while equal or smaller expenditures at nonpoint sources would have a large impact. To address this incongruence, the phosphorus rules include a Watershed Adaptive Management (WAM) option, which allows point sources to partner with other point sources and nonpoint sources in their watersheds to meet the water quality standards in s. NR 102.06, Wis. Adm. Code.

This option is a cost-effective solution to water quality problems: point sources with high compliance costs would be allowed to delay these expenditures by compensating nearby nonpoint sources to implement best management practices (BMPs) or take other actions that would reduce their phosphorus loads and improve overall water quality. The option depends on partnerships among point sources and nonpoint sources in a watershed. The point sources support the nonpoint sources, which initially make the major management changes, and measure the quality of waters across the watershed in order to guarantee that all partners are in compliance with the permit and that the strategy is effective.

Because the WAM option is designed to be a low-cost alternative to traditional compliance practices, the costs associated with the phosphorus rules would be reduced in the watersheds that select this option. Across the state, the net benefits associated with the phosphorus rules, therefore, depend on the number of watersheds that select the option and the resulting costs in those watersheds.

The costs break down into two categories: (1) implementation costs and (2) transaction and administration costs. Before applying for a permit, a point source would estimate its expected upgrade costs and assess the feasibility of WAM. To pursue WAM, the point source would engage with point and nonpoint sources within the watershed to determine the reduction needs, the possible courses of action, the project implementation costs, and the ongoing monitoring costs. The program assessment and initiation would take time and resources. If the assessment and application were successful, then farmers or other nonpoint source partners would implement the BMPs, potentially requiring education and training, equipment purchases, payroll changes, and production losses due to lost acreage or reduced efficiency. In addition, the point sources would eventually make upgrades to their facilities. Finally, enforcement of compliance would be completed by the DNR (see Appendix D and E for further explanation). The costs of Water Quality Trading are omitted from the analysis because the program framework is new and the trading option is a very close substitute for the WAM option (see Appendix F).

There are benefits stemming from WAM, but this analysis assesses only the costs. Implementing BMPs to reduce phosphorus runoff has the effect of reducing erosion and nitrogen runoff, thereby improving soil and water quality, but we omitted these benefits because of the challenges of finding and analyzing the appropriate data.

To monetize the costs of WAM, we used information from the DNR on the likely point source reduction requirements—our phosphorus reduction model projected that statewide point source phosphorus reductions would reach 800,000 pounds per year. We considered calculating our implementation costs by using BMP implementation costs, but BMPs vary in type and cost both within and across watersheds. Furthermore, BMP costs do not fully capture the costs of WAM implementation. The Madison Metropolitan Sewerage District (MMSD) has worked extensively with stakeholders and experts across the Yahara Watershed to predict its implementation costs for WAM. The District estimated that its WAM plan would result in a phosphorus removal cost of $29/lb phosphorus removed (20-year present value). Although there would likely be variation in the costs across watersheds in the state, we considered the MMSD value to be the best estimate of the removal costs in the state and we used it in our calculations. We assumed a 1:1 trading ratio between point reductions and nonpoint reductions. (It should be noted that while the 1:1 ratio is a reasonable assumption, the trade ratio has not yet been formalized. A higher ratio would increase costs.) Using the discount rate of 3.5 percent, we found the 20-year present-value of the implementation costs when all phosphorus reductions are made through WAM. These implementation costs would be $344,500,000 (see Appendix D).

Our implementation costs did not account for the transaction and administration costs associated with program implementation. Instead of making estimates about staffing, planning, and permitting costs, we let the transaction and administration costs equal 35 percent of the implementation costs (see Appendix E). The transaction and administration costs were $120,587,704, making the total costs of WAM equal to $465,100,000.

These total costs are the costs that would be realized across Wisconsin over 20 years if all of the phosphorus load reductions were achieved through WAM. We know, however, that all dischargers will not opt for WAM. It is likely that only the larger watersheds will have the resources to launch WAM. The Yahara Watershed in the Lower Rock River Basin is actively pursuing WAM (Taylor, personal communication, November 14, 2011) and stakeholders in the Rock, Milwaukee, and Fox River basins have expressed interest in the option (Shafer, personal communication, November 22, 2011.) For this analysis, we assumed that WAM will at least involve dischargers in the Yahara Watershed and may be implemented in some or all of the watersheds in the Rock, Milwaukee River, and Lower Fox basins (See Appendix G). Therefore, we estimate a range of 4 to 48 percent of the state's phosphorus reductions would be achieved through Watershed Adaptive Management. In other words, Watershed Adaptive Management would cost at least $18,600,000 and at most $223,300,000. This range was used in our Monte Carlo analysis of net benefits (discussed below).

5.3 Description and calculation of benefits

As discussed in Section 4.5, our analysis estimates the increased property values and increased recreational values derived from cleaner water as a result of the regulations, as well as the avoided future costs of cleaning phosphorus-polluted lakes. There are additional benefits described in 4.5, but these three were the only benefits we could accurately quantify and monetize as a result of the new rules.

Benefits to Property Values

High levels of phosphorus effluence from activities such as agriculture, paper manufacturing, municipal discharge, food processing, and dairy industries are one of the major factors that cause turbidity and undesirable odor problems in Wisconsin's bodies of water. This poor water quality lowers the demand for housing and land adjacent to water bodies such as lakes, rivers, and streams. As a result of the decrease in housing and land demand, property values drop and property owners lose benefits from holding their properties.

Limiting the levels of phosphorus in effluence cannot only reduce the loss but increase the gain in benefits to property values. According to Dodds et al. (2009), one meter gain (or loss) in Secchi depth (a method of water clarity measurement) results in a 15.6 percent increase (or decrease) in property value. Using this value, Dodds et al. convert a loss in Secchi depth into a loss in the property values of housing and land adjacent to U.S. water bodies. As their method seems reasonable, we modified their equation and use it in estimating the benefits gained from increased property values (see Appendix H, for our modified version of the Dodds et al. equation).

We calculate the one-time change in benefits to property values using a 3.5 percent discount rate during the 20 years of the project lifetime. As we assign different rates of phosphorus reduction to high and medium point-source regions, we calculate the benefits of the project by region (see Appendix B). We make several assumptions for the calculation as described in Table H-1, Appendix H.

Among those are five major assumptions that highly affect our calculation. The first assumption is that benefits to property values include the recreational benefits of those who own properties adjacent to bodies of water. We make this assumption to avoid the double counting the overlap between property value benefits and recreational benefits.

The second assumption is property owners of land lots adjacent to lakes are representative of all properties owners of land lots adjacent to Wisconsin waterbodies. We decided not to include the benefit to those owners whose properties are adjacent to rivers, streams, and other water bodies into our analysis, due to the fact that we have very limited data on the length of shoreline for those Wisconsin water bodies, which is necessary for calculating the numbers of properties that will benefit from phosphorus regulation. By excluding numbers of property owners of land lots adjacent to other water bodies, it is likely that the real benefits are higher than our estimated benefits.

The third assumption is that only property owners of land lots adjacent to a body of water will benefit from the phosphorus regulation. This assumption can underestimate the real benefits because water quality can affect property values to land lots located up to 4,000 feet away from the water's edge (Dornbusch, Barrager, and Abel, 1973). This underestimation of benefit can be fixed by including benefits to those owners of the land lots located 4,000 feet away. We think that benefits to those land lot owners should be smaller when their land lots are further from the shoreline. Unfortunately, Dodds' factor in the equation (see the definition in Appendix H) is the specific value for calculating benefits to the waterfront property owners and we do not have any data on the rate of benefit reduction for the owners whose properties are located further from the lake. To avoid the wrong estimation, we decide not to include benefits to those owners of the land lots located 4,000 feet away. This likely underestimates the benefit of the rule to all property values.

The fourth assumption is that phosphorus concentrations of bodies of water in the high and medium point-source regions are identical at 31.94 µg/L(see Appendix I). This assumption can overestimate the real benefits to property values, if the actual phosphorus concentration is higher in the high point-source region than in the medium point-source region.

The last major assumption is that land and housing values will be treated as constant during the 20 years of the project lifetime. Considering the long-term upward trend of Wisconsin's housing prices during the 60-year period of 1940-2000 (2.03 percent growth rate, Table H-2, Appendix H), this assumption might underestimate the actual benefits. On the other hand, this assumption could overestimate the actual benefits when we consider the short-term downward trend during the past three years (-1.81 percent growth rate, Table H-3, Appendix H). According to the uncertain and unpredictable trend of housing value growth, as well as the fact that the growth of housing value can affect benefits to property value for only the first five years of the project, we decided not to include it in our calculation.

According to our findings, the project will give $952,900,000 of benefits to property values in the high point-source and $141,400,000 in the medium point-source region (see Appendix J for benefits by year). Summing the two numbers up, the total benefits to property values is $1,094,300,000. However, this number likely underestimates benefits because of the assumptions we described above.

Recreational Benefits

Wisconsin's bodies of water provide varied opportunities for recreation, both for residents and nonresidents. Recreational activities associated with water are major drivers of Wisconsin's tourism industry, and bring direct economic benefits to the state in the form of expenditures from out-of-state visitors. Activities enjoyed by Wisconsin residents also have value, but are more difficult to quantify. Phosphorus pollution has rendered some of Wisconsin's waters unfit for swimming and fishing, and threatens the quality of others. A large part of the benefits of the new regulations will be the value of cleaner water to those who use it for recreation.

This analysis focuses on the benefits that Wisconsin residents would derive from improved water quality. Over one million Wisconsinites fish for recreation; even larger numbers swim and boat (Wisconsin DNR, 2011). The value that these activities hold for users is difficult to quantify because they are often free or available for the price of a permit, rather than purchased in a market where flexible prices adjust to reflect demand. We make use of studies that estimate "shadow prices" for these activities. Shadow prices are a method of valuing items or activities that do not have observable prices; they represent people's willingness to pay for activities that are not bought and sold on markets. Shadow prices are estimated using a variety of methods, such as calculating the cost of traveling to enjoy an activity, or through interviews with users about their preferences.

We also estimated the economic benefits that the phosphorus rule would bring in the form of increased numbers of anglers coming to Wisconsin from out-of-state. In 2006, Wisconsin attracted 381,000 nonresident anglers, who brought over $580 million to the state in trip-related and other expenditures (U.S. Department of the Interior 2008). The phosphorus regulations would most likely increase this source of revenue.

Effect of the phosphorus regulations

It is clear that recreational benefits of water would increase with an improvement in water quality. Bad water quality can result in a less enjoyable experience for swimmers, boaters, and fishers, and even deter some people from taking part in these activities. In addition, eutrophication due to phosphorus can affect fish communities; highly eutrophic waters may experience die-offs in fish species prized by anglers and become populated mainly by rough fish that anglers do not value catching (Heiskary and Wilson, 2005). This would lead not only to a decrease in the benefits of recreation for Wisconsin residents, but a decrease in the revenue coming to the state from nonresident visitors.

It is difficult, however, to predict the increase in benefits that would result from the new phosphorus regulations. Both the improvement in water quality, resulting from the regulations, and the effect of that improvement on Wisconsin residents and out-of-state visitors, must be estimated with some uncertainty.

In order to estimate the improvement in water quality, we use the value for the current statewide average phosphorus concentration developed by Bernthal et al. (2011). We then use the model of phosphorus reduction described earlier and in Appendix B to predict the lower levels of phosphorus concentration that would result from the rule. For each region, we convert the current and projected levels of phosphorus concentration to Secchi depth meters, using equations developed for Wisconsin lakes by Lillie, Graham, and Rasmussen (1993) (see Appendix I for more details).

To quantify the value to Wisconsin residents of improved water clarity, we use a Finnish study that predicts the increased usage of water resulting from water clarity changes (Vesterinen, Pouta, Huhtala, and Neuvonen, 2010). Although many studies have been performed in the United States to value water quality improvements, Vesterinen et al. appear to be the most applicable to Wisconsin's phosphorus situation. The study's findings, along with data on current demand for swimming and fishing by Wisconsin residents, allows us to predict the additional number of anglers and the additional swimming and fishing trips that would result from the predicted improvement in water clarity. We then use a meta-analysis by Kaval and Loomis (2003) to monetize the value of the increased water usage for the 20-year period we are considering, based on average shadow prices from a large number of U.S studies.

To estimate the gain in revenues from out-of-state anglers due to the regulations, we use the Vesterinen et al. study to predict the increased numbers of anglers and fishing trips that would result from improved water clarity, and calculate the increased expenditures from those additional trips. We perform the calculations for Wisconsin residents and for nonresidents separately for the medium and high point-source regions, which differ in their degrees of improvement and in the population that would benefit. (See Appendices K and L for more details on the strategy and data used.)

This method most likely produces an underestimate of the true benefits to recreation due to improved water quality. It does not include recreational benefits to boaters and to others who may value clean water but do not use it for swimming or fishing. Also, we do not consider the potential negative effects of continued phosphorus pollution on the health of fisheries; protecting the existence of fisheries has a benefit apart from the aesthetic enjoyment fishers hold for cleaner water.

Our final total value for the recreational benefits of the phosphorus regulations is $596,700,000. Because of the uncertainty of estimated shadow prices for recreational activities, the range of the recreational benefits of the regulations would equal $650,600,000 using upper-range shadow prices, and would equal $542,800,000 using lower-range shadow prices.

Reduced costs of cleaning lakes

Highly eutrophic lakes require treatment beyond reducing phosphorus inputs. Examples of such treatments include precipitating out the phosphorus with alum treatments, agitating the water to increase aeration, harvesting and disposing of excessive surface weeds, or draining and dredging the sediment from the bottom of lakes or reservoirs. While generally successful at reducing eutrophication, these management techniques are also expensive and time consuming. Therefore, by reducing phosphorus inputs to water, the new regulations would yield avoided costs of cleaning eutrophic bodies of water.

While the new rules would not completely eliminate algal blooms and other eutrophication problems, they would reduce them drastically. There may be a delay in improvement as phosphorus tends to recycle throughout the system, but the rules would both reduce the problems and prevent lakes from getting to the point where they need to be expensively treated and managed. The EPA notes that "preventing lake and reservoir problems would seem preferable to in-lake management wherever possible. Very few techniques provide lasting relief at a consistently low cost" (Holdren et al, 2001, p. 314). In the long run, it is usually less expensive to prevent algal blooms rather than treat them after they occur.

Based on the number of impaired bodies of water in Wisconsin, we predicted there are approximately 50,000 acres of lakes/reservoirs in need of treatment. According to the DNR, treatments range from $344 to $861 per acre (Wisconsin DNR, 2003). Appendix M describes in detail the calculations used to calculate the avoided costs. The avoided costs, taken out to twenty years and discounted at 3.5 percent, range from $4,800,000 to $11,400,000.

There were several assumptions made in these estimates: First, the estimates assume that Wisconsin's impaired bodies of water will be treated. In reality, not all these bodies of water will be improved, but there are many other lakes not designated as impaired that nevertheless receive some treatment. We also assume that in the absence of the rule, no additional lakes or rivers will become impaired, which is unlikely. Despite these assumptions, we are confident that the impaired water acreage is an appropriate, if conservative, sample of the acreage of lakes managed annually to use as a basis for calculating lake management costs.

Our second assumption is that lakes would be restricted to an alum treatment. In reality, the type of treatment depends on the geography and chemistry of the lake, as well as the preferences of those treating the lake. Alum treatments are a moderately priced treatment; aeration is more common and less expensive while dredging is extremely expensive and is thus less common. Alum treatments are an appropriate middle ground.

The final assumption concerns how many lake treatments would be avoided by the new regulations. One alum treatment effectively controls eutrophication for eight years. Because phosphorus tends to accumulate (or load) into and recycle through water systems, the benefits of reducing phosphorus discharge would not be immediately apparent. Even if all phosphorus inputs were completely eliminated, the phosphorus that has already accumulated over the years would continue to cause eutrophication in highly polluted lakes (Strumbord et al., 2001). As a result, we assume two rounds (16 years) of alum treatments with the new regulations versus indefinite rounds (capped at 20 years because of our time horizon) of treatments that would occur with no regulations. Because of the reduced acreage and exclusion of dredging costs, these cost estimates are likely conservative.

5.4 Assessment of Variability

We assessed the variability of our results using a Monte Carlo analysis. A Monte Carlo analysis is designed to provide useful numbers and conclusions when there is a known range of uncertainty in some or all of the estimates being considered in an analysis. It works by establishing the known range and a distribution for each variable, and repeating a number of trials in which a random draw for each uncertain variable is taken and used to calculate a final value. Analyzing the results of a large number of trials, one establishes an expected value for net benefits, as well as a plausible range for net benefits.

The fixed values in this analysis were equipment costs for fixed point source polluters, WAM costs for sources definitively going to use WAM, and the property value benefit from the expected phosphorous reduction due to regulations. The variables in this analysis were the WAM costs for variable point sources, the equipment costs for variable point sources, the year at which each participating point source receives their permit and thus must address their phosphorous loading, the shadow price range for recreational benefits, and range for lake cleanup cost reduction benefits.

WAM variable point source costs and equipment variable point source costs are directly related: each point source that uses WAM would increase the WAM costs while simultaneously decreasing the equipment costs. Therefore, in each trial, the same random distribution is used to calculate the WAM costs and variable point source equipment costs: the inverse of the proportion of point sources assumed to use WAM in a trial is used to determine the proportion of point sources assumed to use conventional equipment.

Based on this Monte Carlo analysis of the variables conducted over 10,000 trials, we conclude the monetized net benefits of the DNR regulations for the phosphorus rule to Wisconsin to be $18,800,000, with a standard deviation of $97,100,000 (see Appendix O for further detail).

6 Results and Discussion

6.1 Benefit/Cost Summary and Shadow Prices

In this cost-benefit analysis, we predict that implementing chs. NR 102 and NR 207, Wis. Adm. Code, would have total net benefits of $18.8 million dollars to the state of WI over the 20 year time period.

By dividing the total net benefits of the regulations, $18,800,000, by the pounds of phosphorus reduced, 800,000, we obtain the shadow price of phosphorus, $23.56 per pound. This means that each pound of phosphorus reduced by the regulations brings $23.56 in benefits to Wisconsin residents over and above the cost of reducing it.

6.2 Impacts and Distribution

Accurately predicting impact on each industry was not feasible for two reasons. First, much of the cost depends on the method of treatment selected. As discussed previously, point source dischargers in watersheds dominated by nonpoint source phosphorus sources will have more opportunities to engage in cost-reducing WAM. Therefore, the variability introduced by WAM would make any predictions based on industry highly variable.

Secondly, it was not possible to calculate the effected economic impact on specific business sectors without introducing double-counting errors. Double counting occurs when a value is erroneously counted more than once, and leads to an inaccurate and inflated result. In cost-benefit analysis, this is usually handled by restricting analysis to the primary affected market, and ignoring the effects on secondary markets. Primary markets would be considered the parties bearing the initial costs, such as the WWTF or food processing factory investing in new technology; secondary markets would be those who experience a rate or price increase resulting from the WWTF or factory's attempts to offset their increased costs. If a WWTF offsets their costs by raising rates on their customers, counting both the raised rates and construction costs would be incorrect.

In this case, we can ignore the secondary market of rate-payers – their increased rates are simply another iteration of the construction and O&M costs initially borne by WWTF. It becomes more complicated when attempting to calculate the individual costs to cheese makers, food processors, and paper mills as some of these facilities treat their own waste water, while others send their water to WWTF. To avoid double counting, we must exclude costs to firms that have increased rates (as the increased rates are merely another expression of costs already accounted to WWTF.)

Thus, we found it more useful to group costs not by industry, but by the ratio of point source to non-point source phosphorus discharge in the watershed. Because WAM has the potential to significantly lower costs, dischargers in watersheds with a high percentage of non-point phosphorus sources will have more opportunities for trading and will thus bear fewer costs.

6.3 Uncertainty

6.3.1 Limitations of CBA analysis

We believe it appropriate to include an assessment of the appropriateness of cost-benefit analysis with regard to our specific topic, using the concepts described in *Cost Benefit Analysis: Concepts and Practice* (Boardman et al., 2011). While cost-benefit is a useful tool for assessing the efficacy of a project, it also has two potentially problematic limitations. First, the quality of the analysis can be compromised when necessary information is not available. CBA depends upon accurate monetization of all costs and benefits, but limitations in data make it impossible to accurately measure and value the impacts of a project. Second, CBA is designed to measure economic efficacy; however, many policies have other relevant goals. In these cases, CBA can be a useful source of some information, but it should not be the primary tool used in the evaluation of said policies. It is our conclusion that this report falls into both these categories, limiting the applicability of cost-benefit analysis as a tool for evaluating chs. NR 102 and NR 217.

First, while the costs to industry are immediate and concrete, the benefits of improving water quality are more long-term and difficult to quantify accurately. We were not able to assess the impact of algae-free water on tourism, for example, because the DNR has no information on how many tourists Wisconsin loses annually due to algal blooms. We know that fishing, tourism, and water-based recreation play a significant role in Wisconsin's economy; however, there is insufficient information to isolate the effects of the particular rules on these particular sectors of the economy. There are many benefits to improving water quality that we were simply unable to monetize.

Additionally, while few would argue that there is no value to having a clean lake fifty years in the future, discounting ignores any values (or costs) past twenty years. Unfortunately for this project, the costs are up-front and the benefits only begin to manifest significantly after twenty years. There is obviously value in having clean water in the future; however, this analysis fails to capture it, making the costs seem much higher and the benefits much lower. Meanwhile, it is almost always more expensive to treat lakes after they becoming loaded with phosphorus. Preventing currently clean lakes from becoming eutrophic is less expensive, but the avoided costs are far enough into the future that we were not able to include them in our report.

The second problem is ignoring goals besides economic efficacy. While the DNR obviously is concerned with an appropriate use of resources, its primary directive is to manage the state's resources. The primary goal of this policy was to maintain the quality of Wisconsin water, and that goal must also be taken into account when evaluating this policy.

6.3.2 Watershed Adaptive Management

The cost-benefit analysis resulted in net benefits, but there was a wide range of results in the Monte Carlo analysis and in the sensitivity analysis. Indeed there is considerable uncertainty about the impact of the phosphorus rules because WAM is a new option with unrealized, incompletely-understood costs and hard-to-anticipate popularity among dischargers and because environmental benefits are difficult to quantify and monetize.

6.3.3 Sensitivity

This analysis is by far the most sensitive to the variation in percentage of WI point sources choosing to use WAM. This is due primarily due to the very significant cost savings of WAM for phosphorous loading reductions compared to equipment phosphorous reductions; it is also important to note that this variance and sensitivity would significantly lower as equipment and O&M costs come down as better technologies become available (see Appendix O for more specific details).

The maximum and minimum ranges for WAM variance are from $-354,000,000 to $393,900,000 in net benefits, although the minimum number is an extremely conservative estimate of the point sources that will use WAM. This highlights the importance of WAM utilization to reduce and control costs related to these regulations.

Holding WAM variance constant in the analysis, the standard deviation of our conclusions drops to $22,100,000 dollars, with that variance driven significantly by the variation in recreational shadow prices. While still relevant, shadow price variance has relatively little impact of the sensitivity of the analysis while compared to the WAM utilization variance.

We recognize that the variance of our cost predictions is very high; however, there are three factors that make it difficult to reduce variability. First, because permits have not been issued or calculated, dischargers do not yet know if they even have to make adjustments, let alone which technologies they would pick.

6.4 Conclusion

In this cost-benefit analysis, we predict that implementing chs. NR 102 and NR 207, Wis. Adm. Code, would have total net benefits of $18.8 million dollars to the state of WI over the 20 year time period. Through a sensitivity analysis, we find that the analysis is very sensitive to changes in WAM utilization, placing significant weight on the implementation and scope of WAM utilization by point source phosphorous emitters.

We believe that our analysis presents a very conservative estimate of the impacts of the policy and our predicted net benefits attempt to take into account the extreme uncertainty in our estimates of impacts and their monetization, almost exclusively erring on the side of a more conservative, higher cost and lower benefit model.

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Appendix A – List of Meetings with Affected Parties

1. Midwest Environmental Advocates/Wisconsin Wildlife Federation/Clean WI (July 22, 2011):

The environmental groups were primarily concerned that the difficult-to-monetize benefits will be understated. They came with handouts listing studies and resources to help estimate the price tag of WI natural resources.

2. Paul Kent (representing MEG) and Madison Metropolitan Sewerage District (August 02, 2011):

We discussed the role of adaptive management and trading for both small and large dischargers.

With Paul Kent, we discussed the difference between the Strand estimates and Jim Baumann's estimates for costs to waste water treatment facilities.

3. Builders' Association (August 02, 2011):

The BA did not have any comments on the phosphorus rules. The discussion focused on shoreland zoning.

4. Paper Council (August 18, 2011):

The Paper Council expressed concern about high costs. However, many of their facilities are in areas where TMDLs are in place. Thus, the majority of paper mills will be subject to the less-stringent TMDL phosphorus standards.

He did express concern that companies with narrow profit margins are especially at risk with these regulations. He was concerned about Wisconsin mills' ability to compete with mills in other states.

5. WI Realtors Association (August 19, 2011):

The WI Realtors Association did not have any comments on the phosphorus rules. The discussion focused on shoreland zoning.

6. WI Cheese Makers Association (September 8, 2011):

Most of the P comes from flushing out the lines with milk (for cleaning purposes).

They were concerned about how the regulations would affect their ability to compete with states like California and New York. They referred us to the Probst report commissioned by their organization in 2010, which estimated industry costs.

7. Wisconsin Lakes: Due to an illness, I was not able to attend this meeting. However, Tim and Jamie met with the group. Their primary concerns were that the benefits of clean water were not understated. They had a handout with many resources for establishing the value of clean water.

8. Midwest Food Processor's Association (October 18, 2011):

MFPA was concerned about industry competitiveness. Members have not expressed interest in trading. Nick's impression was that half of the members handle their own waste, the other half send it along to a WWTP.

9. Farm Bureau (November 15, 2011):

Farmers have not thought much about engaging in WAM. Farm Bureau was concerned about agricultural land being taken out of production.

Appendix B: Eutrophication

To calculate the costs and benefits of the regulations, we first needed to approximate the effect these regulations would have on Wisconsin waterways, specifically the change in eutrophication and phosphorous concentrations. Discussions with limnologists and knowledgeable members of the DNR on the subject led to the determination that a direct modeling of the change in phosphorous concentrations would be not feasible because of the sheer number of lakes and rivers, their complex interconnections, and the unique and differing nature of phosphorous interactions within many of the lakes and rivers, as well as the diffuse and complex nature of phosphorous loading.

Further analysis based on available data determined that the most feasible way to indirectly model eutrophication would be to model phosphorous concentration changes in the Wisconsin watershed. This is modeled by taking current phosphorous concentrations in Wisconsin watersheds, and reducing them by the estimated fractional reduction in phosphorous loads to each watershed affected by the regulations.

The model of current phosphorous concentrations was created by Bernthal et al. (2011). We slightly adjusted this model to provide three different average concentrations, corresponding to our three different areas of Wisconsin, as discussed below.

We first had to assess how to model phosphorous concentration changes, as phosphorous concentrations in watersheds depend on a large number of factors. Based on discussions with knowledgeable DNR personnel, we determined that it was reasonable to assume, for modeling purposes, that phosphorous inputs equaled phosphorous outflows over a long enough timescale. Stated differently, we assume no phosphorous accumulates in the watersheds over time, and thus phosphorous concentrations in the water at any given time are directly and solely related to phosphorous input loads.

This assumption allowed us to use the DNR PRESTO model data to determine phosphorous concentrations via loading changes. The PRESTO model uses a regression analysis of several major factors to approximate non-point phosphorous loading to a given watershed, along with geo-located point source phosphorous emitters to determine the total phosphorous loading and point/non-point ratio in the given watershed. Point source emitters discharging to Lake Michigan, Lake Superior, and the Mississippi River were excluded from the PRESTO model as those waterways cannot to be properly modeled, as well as lie outside the scope of this cost-benefit analysis.

Using the point to non-point ratio provided in the PRESTO data, we divided up Wisconsin into three areas. The Low area was watersheds with less than 5 percent point source phosphorous contributions, and makes up 41.8 percent of Wisconsin by surface area. The Mid area was watersheds with between 5 percent and 10 percent point source phosphorous contributions, and makes up 26.0 percent of Wisconsin by surface area. The High area is watersheds with over 10 percent point source phosphorous contributions, and makes up 32.1 percent of Wisconsin by surface area.

We matched the point-source phosphorous emitters in the PRESTO model to their average effluent phosphorous concentrations reported to and recorded by the DNR; a three-year average of phosphorous concentrations for each point source was used (2007-2009), to correspond with the three-year average phosphorous loads used in the PRESTO model. The estimated average effluent phosphorous concentration after implementing the regulations was then used to calculate the change in phosphorous load for each point source. The aggregated phosphorus load change for the point sources in each watershed were then used to calculate the phosphorous load change for each watershed, comparing the phosphorous load change to the total phosphorous loading (point and non-point) of each watershed.

We then calculated the percent P change in each of the three areas, based on the total P loading for and the reduction in P loading each watershed in the area. This number, applied to the current P concentrations for each area, provides a model estimate for the phosphorous reduction for each area.

Calculating population of each region

In order to calculate the percent of Wisconsin population in each region, we assigned each of Wisconsin's major metropolitan areas to the high, medium, or low point source region, and subtracted their populations from the total state population and their surface areas from the total state surface area. Then, we divided the remaining population over the three regions according to each region's percent of total state surface area. We added back the populations of the major cities to their respective regions to obtain the total population for each region. We used population figures from the 2010 Census (U.S. Census Bureau n.d.).

Table B-1

Population per Phosphorus Reduction Model Region

Region	Population	Population (% total)	Major cities
Low	1,604,406	28	None
Medium	1,468,522	26	Green Bay, Manitowoc, Sheboygan, Racine, Kenosha, Eau Claire, La Crosse
High	2,614,058	46	Milwaukee and suburbs, Waukesha, Madison and suburbs, Beloit, Janesville, Fond du Lac, Appleton, Oshkosh, Wausau, Stevens Point

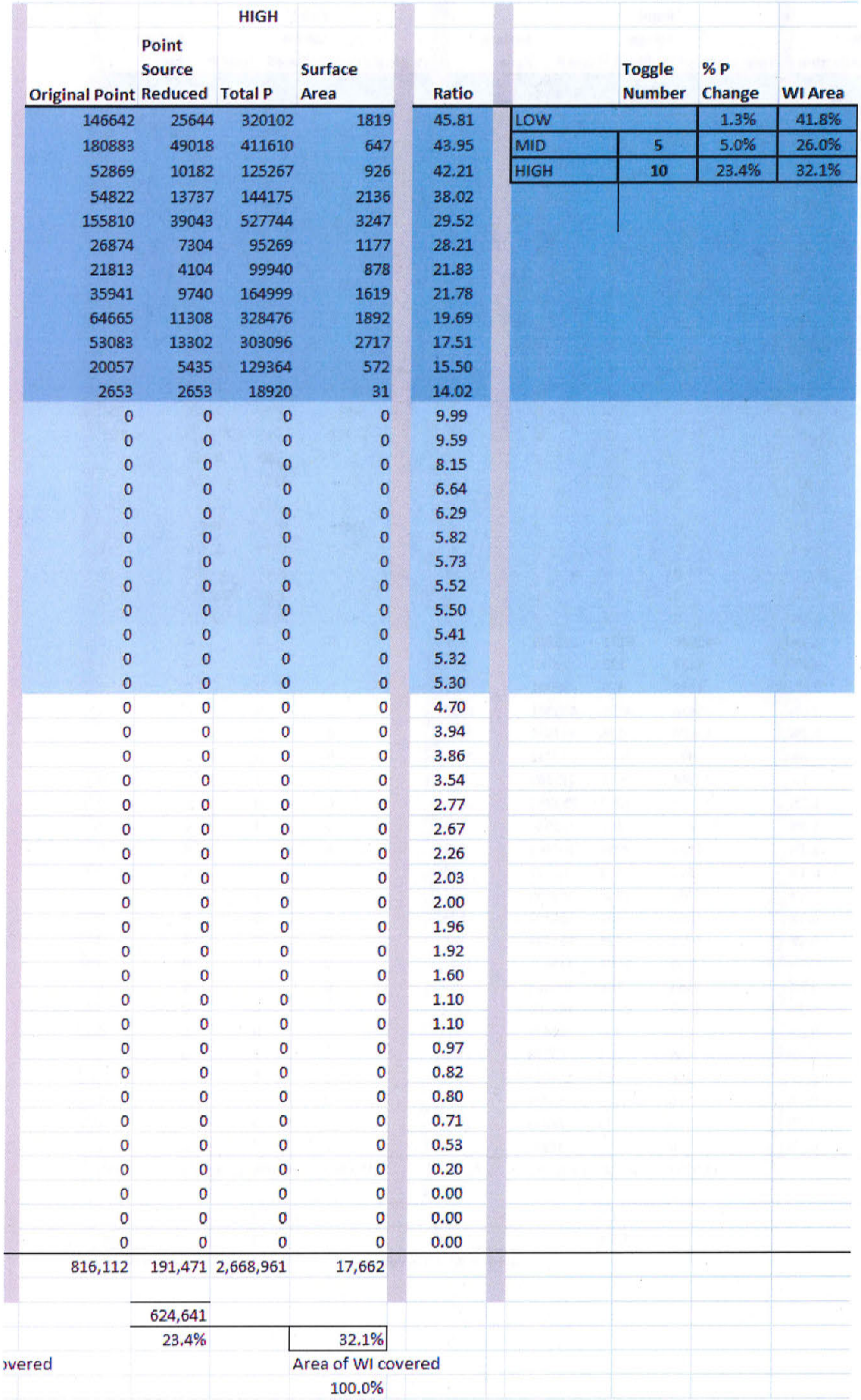
Source: Authors.

The spreadsheet below shows how we divided up each HUC8 basin into the three categories, as well as the point and non-point phosphorous loads for each basin, and the predicted changes in the phosphorous loading.

Major Basin	HUC08 Basin Name	Basin Area (sq. mi)	Basin Area in WI (sq. mi)	Basin Area in PRESTO (%)	Stream Density	30m Grass Buffer (%)
Rock	Lower Rock River	1830.26	1819.37	99	0.71	9.02
Wolf - Fox	Lower Fox River	647.93	647.34	100	1.20	18.93
Fox (IL)	Upper Fox River	1543.66	925.82	60	0.45	6.88
Wisconsin	Upper Wisconsin Rive	2178.15	2135.93	98	0.55	1.82
Wisconsin	Castle-Rock	3246.87	3246.85	100	0.82	7.98
Chippewa	Flambeau River	1176.94	1176.56	100	0.59	5.08
Milwaukee	Milwaukee River	878.78	878.40	100	0.71	7.64
Wolf - Fox	Upper Fox River	1619.08	1619.08	100	0.77	4.02
Rock	Upper Rock River	1891.97	1891.96	100	0.90	8.89
Wisconsin	Lake Dubay	2717.31	2717.30	100	0.96	1.48
Wolf - Fox	Lake Winnebago	572.07	572.07	100	1.02	10.77
Kishwaukee	Kishwaukee River	1254.21	31.41	3	0.01	7.24
Chippewa	Lower Chippewa River	2058.93	2058.93	100	0.91	7.82
Wolf - Fox	Wolf River	3723.64	3723.62	100	0.70	4.85
Green Bay	Oconto River	960.52	960.48	100	0.75	4.72
Wisconsin	Baraboo River	654.84	654.84	100	1.30	13.11
Root - Pike	Pike-Root Rivers	418.34	333.87	80	0.64	8.71
Bad Axe - La Crosse	Coon-Yellow Rivers	1423.35	674.46	47	0.70	11.36
Grant - Platte	Apple-Plum Rivers	1485.25	232.22	16	0.25	34.22
St. Croix	Lower St. Croix River	2620.08	1701.35	65	0.38	19.54
Chippewa	Rush-Vermillion River	1112.43	513.62	46	0.60	12.30
Green Bay	Peshtigo River	1219.11	1219.02	100	0.71	3.73
Manitowoc / Sheboygan	Manitowoc-Sheboyga	1629.90	1628.64	100	0.93	28.88
Bad Axe - La Crosse	La Crosse-Pine Rivers	694.63	600.03	86	0.87	13.59
Sugar - Pecatonica	Sugar River	759.98	691.19	91	1.10	23.01
Fox (IL)	Des Plaines River	1455.31	134.91	9	0.09	9.70
Chippewa	South Fork Flambeau	738.84	738.84	100	0.59	2.20
Chippewa	Red Cedar River	1890.35	1890.34	100	0.96	17.66
Black	Black River	2274.24	2274.23	100	1.07	8.45
Wisconsin	Lower Wisconsin Rive	2359.76	2359.54	100	1.18	15.93
Grant - Platte	Grant-Little Maquoket	1118.28	792.71	71	1.11	28.71
Sugar - Pecatonica	Pecatonica River	1878.69	1143.04	61	0.97	36.47
Chippewa	Jump River	853.82	853.82	100	0.81	3.72
Buffalo - Trempealeau	Trempealeau River	728.93	728.92	100	1.32	17.65
Lake Superior	St. Louis River	2941.40	75.57	3	0.04	6.83
Wisconsin	Kickapoo River	767.16	767.16	100	1.47	13.63
Chippewa	Eau Claire River	883.23	883.23	100	1.15	5.84
Twin - Door - Kewanee	Door-Kewaunee River	766.21	765.32	100	0.59	41.96
Lake Superior	Beartrap-Nemadji Rive	1927.68	1647.44	85	0.97	10.72
Buffalo - Trempealeau	Buffalo-Whitewater R	1391.98	736.70	53	0.74	15.84
Lake Superior	Bad-Montreal Rivers	1300.18	1202.32	92	1.02	5.46
Green Bay	Pensaukee River	332.69	332.59	100	1.18	11.55
St. Croix	Upper St. Croix River	2025.83	1482.01	73	0.37	8.60
Chippewa	Upper Chippewa River	1930.53	1930.52	100	0.67	3.86
Brule	Brule River	1051.48	184.81	18	0.15	1.91
Green Bay	Menominee River	2292.42	1346.34	59	0.43	2.82
Rock	Lower Rock-Piscasaw	2167.04	13.87	1	0.01	10.56
		71,394	54,939			

r	Upstream Point Source (lbs)	Basin extends beyond state boundary	MR1 Nonpoint P Load (lbs), Lower Interval	MR1 Nonpoint P Load (lbs), Upper Interval	MR1 Nonpoint P Load (lbs)	MR1 Total P Load (lbs)	MR1 Model (P), Point to Nonpoint Ratio
2	146642	Partly	87138	345297	173461	320102	46 : 54
3	180883	Partly	113812	467747	230728	411610	44 : 56
3	52869	Partly	36704	142808	72399	125267	42 : 58
2	54822	Partly	45200	176644	89354	144175	38 : 62
3	155810	No	186134	743205	371935	527744	30 : 70
3	26874	Partly	34527	135486	68396	95269	28 : 72
4	21813	Partly	39254	155503	78128	99940	22 : 78
2	35941	No	64775	257139	129059	164999	22 : 78
9	64665	No	131659	528613	263812	328476	20 : 80
3	53083	No	124799	500862	250014	303096	18 : 82
7	20057	No	54310	219999	109308	129364	16 : 84
4	2653	Partly	8365	31637	16268	18920	14 : 86
2	30595	No	137585	552447	275697	306291	10 : 90
5	29290	No	138908	549369	276246	305535	10 : 90
2	6955	Partly	39337	156082	78357	85311	8 : 92
1	15754	No	108948	449821	221375	237128	7 : 93
1	2273	Partly	17065	67315	33893	36165	6 : 94
5	9158	Partly	74439	295069	148205	157362	6 : 94
2	6379	Partly	53480	206301	105038	111416	6 : 94
4	10176	Partly	88435	343501	174292	184467	6 : 94
0	5661	Partly	49038	193134	97319	102979	5 : 95
3	4854	Partly	42714	168926	84944	89797	5 : 95
3	27256	Partly	241393	976551	485523	512778	5 : 95
9	6292	Partly	56127	225253	112440	118731	5 : 95
1	12940	Partly	129679	530166	262204	275143	5 : 95
0	1153	Partly	14418	54817	28113	29265	4 : 96
0	1389	No	17483	68527	34613	36001	4 : 96
5	15426	No	209182	845520	420556	435981	4 : 96
5	12100	No	211073	857048	425323	437422	3 : 97
3	19977	Partly	359420	1473562	727756	747732	3 : 97
1	10744	Partly	229776	941535	465126	475869	2 : 98
7	15271	Partly	365148	1483882	736095	751365	2 : 98
2	1481	No	36332	144609	72484	73964	2 : 98
5	5992	No	147687	611400	300492	306483	2 : 98
3	805	Partly	21109	79957	41083	41887	2 : 98
3	5580	No	168307	702602	343879	349458	2 : 98
4	1808	No	80541	328226	162590	164397	1 : 99
5	1771	Partly	80270	317984	159764	161534	1 : 99
2	3255	Partly	165444	667706	332367	335621	1 : 99
4	1563	Partly	94499	376091	188521	190083	1 : 99
5	1507	Partly	93321	377128	187600	189106	1 : 99
5	614	Partly	42439	173704	85859	86472	1 : 99
0	455	Partly	43259	167508	85124	85578	1 : 99
5	246	No	62363	245937	123844	124089	0 : 100
1	0	Partly	7545	28728	14722	14721	0 : 100
2	0	Partly	39004	151274	76813	76812	0 : 100
5	0	Partly	16963	64185	32996	32995	0 : 100
	1,084,832	0	4,609,407	18,580,803	9,254,117	10,338,902	

						LOW				MID	
Model (P), Load By Area	% Change Point Load	Point Source Reduced	%P Reduction	Original Point	Point Source Reduced	Total P	Surface Area	Original Point	Point Source Reduced	Total P	Surface Area
176	17.5%	25644	37.8%	0	0	0	0	0	0	0	0
636	27.1%	49018	32.0%	0	0	0	0	0	0	0	0
135	19.3%	10182	34.1%	0	0	0	0	0	0	0	0
68	25.1%	13737	28.5%	0	0	0	0	0	0	0	0
163	25.1%	39043	22.1%	0	0	0	0	0	0	0	0
81	27.2%	7304	20.5%	0	0	0	0	0	0	0	0
114	18.8%	4104	17.7%	0	0	0	0	0	0	0	0
102	27.1%	9740	15.9%	0	0	0	0	0	0	0	0
174	17.5%	11308	16.2%	0	0	0	0	0	0	0	0
112	25.1%	13302	13.1%	0	0	0	0	0	0	0	0
226	27.1%	5435	11.3%	0	0	0	0	0	0	0	0
602	100.0%	2653	0.0%	0	0	0	0	0	0	0	0
149	27.2%	8315	7.3%	0	0	0	0	30595	8315	306291	2059
82	27.1%	7937	7.0%	0	0	0	0	29290	7937	305535	3724
89	52.8%	3673	3.8%	0	0	0	0	6955	3673	85311	960
362	25.1%	3948	5.0%	0	0	0	0	15754	3948	237128	655
108	17.5%	398	5.2%	0	0	0	0	2273	398	36165	334
233	32.6%	2987	3.9%	0	0	0	0	9158	2987	157362	674
480	5.7%	363	5.4%	0	0	0	0	6379	363	111416	232
108	49.3%	5013	2.8%	0	0	0	0	10176	5013	184467	1701
200	27.2%	1539	4.0%	0	0	0	0	5661	1539	102979	514
74	52.8%	2563	2.6%	0	0	0	0	4854	2563	89797	1219
315	10.7%	2907	4.7%	0	0	0	0	27256	2907	512778	1629
198	32.6%	2052	3.6%	0	0	0	0	6292	2052	118731	600
398	47.7%	6171	2.5%	12940	6171	275143	691	0	0	0	0
217	19.3%	222	3.2%	1153	222	29265	135	0	0	0	0
49	27.2%	378	2.8%	1389	378	36001	739	0	0	0	0
231	27.2%	4193	2.6%	15426	4193	435981	1890	0	0	0	0
192	76.3%	9236	0.7%	12100	9236	437422	2274	0	0	0	0
317	25.1%	5006	2.0%	19977	5006	747732	2360	0	0	0	0
600	5.7%	612	2.1%	10744	612	475869	793	0	0	0	0
657	47.7%	7282	1.1%	15271	7282	751365	1143	0	0	0	0
87	27.2%	403	1.5%	1481	403	73964	854	0	0	0	0
420	34.3%	2056	1.3%	5992	2056	306483	729	0	0	0	0
554	76.8%	619	0.4%	805	619	41887	76	0	0	0	0
456	25.1%	1398	1.2%	5580	1398	349458	767	0	0	0	0
186	27.2%	491	0.8%	1808	491	164397	883	0	0	0	0
211	63.7%	1128	0.4%	1771	1128	161534	765	0	0	0	0
204	76.8%	2501	0.2%	3255	2501	335621	1647	0	0	0	0
258	34.3%	536	0.5%	1563	536	190083	737	0	0	0	0
157	76.8%	1158	0.2%	1507	1158	189106	1202	0	0	0	0
260	52.8%	324	0.3%	614	324	86472	333	0	0	0	0
58	49.3%	224	0.3%	455	224	85578	1482	0	0	0	0
64	27.2%	67	0.1%	246	67	124089	1931	0	0	0	0
80	100.0%	0	0.0%	0	0	14721	185	0	0	0	0
57	52.8%	0	0.0%	0	0	76812	1346	0	0	0	0
2379	17.5%	0	0.0%	0	0	32995	14	0	0	0	0
		277,171		114,077	44,005	5,421,981	22,975	154,643	41,694	2,247,960	14,301
	Difference	807,661			70,072				112,949		
	P Change	7.8%			1.3%		41.8%		5.0%		26.0%
							Area of WI covered				Area of WI cov



		HIGH		
Original Point	Point Source Reduced	Total P	Surface Area	Ratio
146642	25644	320102	1819	45.81
180883	49018	411610	647	43.95
52869	10182	125267	926	42.21
54822	13737	144175	2136	38.02
155810	39043	527744	3247	29.52
26874	7304	95269	1177	28.21
21813	4104	99940	878	21.83
35941	9740	164999	1619	21.78
64665	11308	328476	1892	19.69
53083	13302	303096	2717	17.51
20057	5435	129364	572	15.50
2653	2653	18920	31	14.02
0	0	0	0	9.99
0	0	0	0	9.59
0	0	0	0	8.15
0	0	0	0	6.64
0	0	0	0	6.29
0	0	0	0	5.82
0	0	0	0	5.73
0	0	0	0	5.52
0	0	0	0	5.50
0	0	0	0	5.41
0	0	0	0	5.32
0	0	0	0	5.30
0	0	0	0	4.70
0	0	0	0	3.94
0	0	0	0	3.86
0	0	0	0	3.54
0	0	0	0	2.77
0	0	0	0	2.67
0	0	0	0	2.26
0	0	0	0	2.03
0	0	0	0	2.00
0	0	0	0	1.96
0	0	0	0	1.92
0	0	0	0	1.60
0	0	0	0	1.10
0	0	0	0	1.10
0	0	0	0	0.97
0	0	0	0	0.82
0	0	0	0	0.80
0	0	0	0	0.71
0	0	0	0	0.53
0	0	0	0	0.20
0	0	0	0	0.00
0	0	0	0	0.00
0	0	0	0	0.00
816,112	191,471	2,668,961	17,662	
	624,641			
	23.4%		32.1%	
vered			Area of WI covered	
			100.0%	

	Toggle Number	% P Change	WI Area
LOW		1.3%	41.8%
MID	5	5.0%	26.0%
HIGH	10	23.4%	32.1%

Source: Presto output.

Appendix C: Capital and O&M costs

Cost estimates are based off of the EPA model of an Alum Addition and Filter equipment modification and expansion costs. This model was found to be most appropriate under recommendation and use by the DNR, as well as having some stand-alone value so not to misrepresent the small amount of permitted point-load emitters that do not currently have phosphorous removal equipment. It also has one of the smallest footprints of the equipment available, which is of particular importance to some emitters as land and space is at a premium. This does, however, over-estimate costs for emitters who have plentiful land, where they could build alternative equipment with very significantly lower operating and maintenance (O&M) and similar capital costs.

Attempts to quantify a range of plants that would potentially have the land available, or the costs of the differing equipment that could theoretically be installed failed: no practical way was found to know, or predict, which of the 500 point source emitters has sufficient land available on hand, or for purchase, for the necessary equipment, much less whether that entity would actually be willing to use that land. As well, specific footprint information for the larger-footprint equipment was unavailable.

This also overestimates the cost of the variety of likely equipment to be installed at the places. Attempts were made to contact and get cost information from companies currently in the business, but none were successful. This EPA report is what is used by the DNR for cost predictions, but the report itself is 3 years old, and the equipment was finished and installed roughly 5 years ago. Technological advances have been made, and the field is rapidly evolving. While it is likely that the equipment being modeled will be used at many of the point sources in Wisconsin, it is also likely that many new and potentially innovative solutions will be used as well. Costs for this equipment would be impossible to predict, but is likely to be lower as the industry gains more development and experience with manufacture and installation.

Not all emitters will be required to reduce their phosphorous loads. The two main reasons why this would be the case is financial hardship, and unnecessary as that point source's watershed has not reached critical phosphorous levels and thus phosphorous discharges have no significant effect on the relevant watershed. Based on spreadsheets provided by the DNR as well as modeling zones, dischargers likely to have to reduce their phosphorous loads under these criteria are included in the cost calculation; this includes all dischargers with a total load of greater than 1200 pounds per year.

As well, any discharger we believe likely to participate in Watershed Adaptive Management (WAM) is also not going to be included in these capital costs. They will be able to reduce their phosphorous loads per regulations utilizing WAM instead of directly via equipment. As which point sources will participate in the WAM program is impossible to specifically determine, but a range has been established based on discussions with DNR personnel and major point source potential participants (primarily Madison, Milwaukee, and Green Bay). Roughly 4% of the state phosphorous emissions (by weight) are sure to participate in a WAM, with an estimated conservative upper bound of 48%.

Using the cost curves from the EPA report, included below, capital costs and O&M costs figures can be calculated; figures not on the chart are linearly interpolated or extrapolated. For capital costs, all equipment in excess of 10million gallons per day (MGD) are assumed to be at $0.30 per gallon capacity; equipment under 0.5MGD has its cost doubled on top of any other costs to account for issues of scale. A 30 percent contingency cost was added to the capital costs to account for various costs associated with the issues complex projects tend to experience.

Capital costs are determined using the dollars per million gallons per day values provided in the EPA report for the equipment, utilizing the average flow capacity as the flow rate for each point source. A 30% contingency cost increase was added to this value based on DNR information, as unique projects tend to have unexpected costs, and average flow capacity may not completely represent the full equipment needed. Capital costs of the equipment are assumed to be borne entirely on the year they are installed.

Operating and Maintenance (O&M) costs are determined using dollars per million gallons of total flow values provided in the EPA report for the equipment. Total yearly flow was determined by multiplying the daily average flow rate by 365, to determine the yearly O&M cost. O&M costs are assumed to be borne every year after the equipment is installed.

The figures used to determine these values can be found below. These numbers were adjusted to present day (as they are in 2007 dollars in the EPA report) using the consumer price index. Table C extrapolates cost curves from the following EPA cost tables.

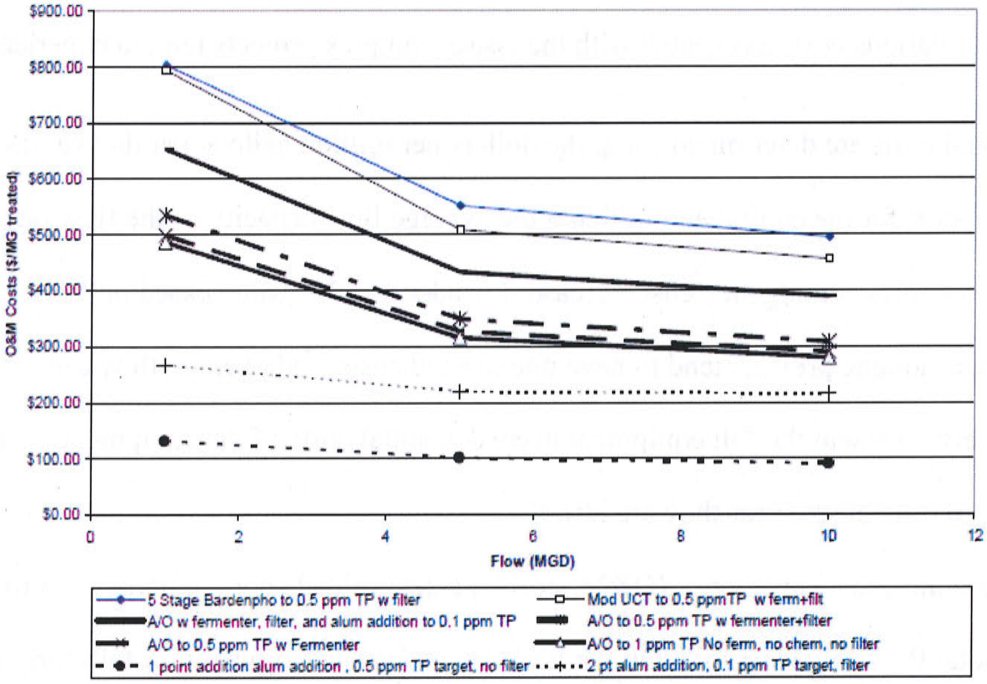


Figure 4-10. O&M costs for expansion phosphorus removal technologies ($/MG treated).

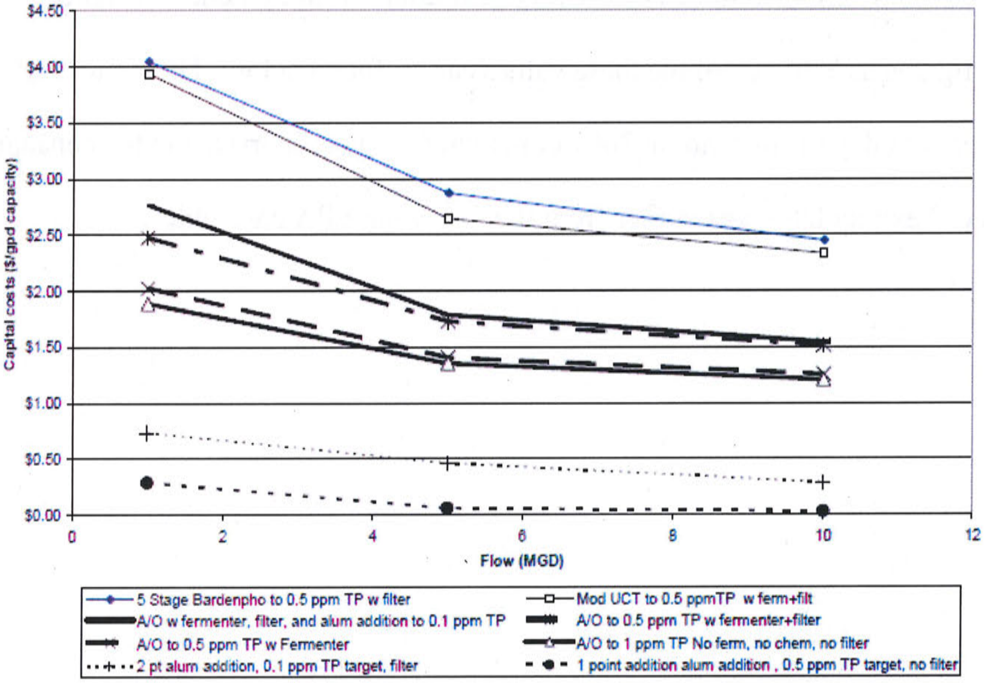


Figure 4-11. Capital costs for expansion phosphorus removal technologies.

Source: (EPA, 2008).

Table C-1. Cost Table

Average Daily Flow Rate	**Maximum Daily Flow Rate**	**Total Equipment Cost**	**Operations and Maintenance Cost**	**Operations and Maintenance Cost**
(Million gallons/day)	(Million gallons/day)	(Installed)	(Per year, present dollars)	(NPV Over Years of Operation)
(MGD)	(MGD)	(Present $)	(Present $)	(Present $)
0.1	0.25	566,000	11,400	156,000
0.25	0.25	566,000	28,300	388,000
0.1	0.5	555,000	11,400	156,000
0.5	0.5	555,000	56,000	768,000
1	1	1,066,000	109,700	1,507,000
1	2	1,954,000	109,700	1,507,000
2	2	1,954,000	210,600	2,893,000
2	5	3,552,000	210,600	2,893,000
5	5	3,552,000	438,800	6,026,000
5	10	4,263,000	438,800	6,026,000
10	10	4,263,000	877,700	12,052,000

Variables For Whole Sheet

Inflation-Adjusted Discount Rate	0.035
Years of Operation	20
Current Date CPI index (Jan 2012)	226.625

Equipment Cost Contingency	0.3

Formulas Re-create or Extrapolate cost curves from EPA cost tables

Source: Authors

Appendix D: Implementation Costs

Watershed Adaptive Management (WAM) involves best management practice (BMP) implementation costs, which vary considerably within and across watersheds. Nonpoint sources employ farm- and site-specific BMPs, such as manure storage and cultivation of cover crops. The costs of BMP implementation are wide-ranging. Furthermore, the cost-effectiveness of the BMPs depends on the management practice, the topography, and the weather, among other things. The USDA suggests that transport BMPs, including terracing, contour cropping, and manure management, demand $0.80 to $4.70 per pound of phosphorus removed; meanwhile, source BMPs like barnyard runoff control and milk house waste treatment cost about $10 per pound of phosphorus removed and a waste storage facility costs nearly $1000 per pound of phosphorus removed on average (Sharpley et al., 2006).

Selecting an appropriate suite of BMPs for the relevant Wisconsin watersheds and estimating their implementation costs would be a significant chore. The work would not even capture all implementation costs: WAM is a strategy that allows point sources to delay, rather than eliminate, their upgrade costs. It also requires point sources to make incremental improvements to their effluent quality over the course of the permit cycle. The Madison Metropolitan Sewerage District was instrumental in allowing us to reach our cost estimate. The District has worked extensively with stakeholders and experts across the Yahara Watershed to predict the implementation costs at both the nonpoint and point sources. The District estimated that its Watershed Adaptive Management plan would result in a phosphorus removal cost of $29/lb phosphorus removed (20-year present value). We used its result in our calculations. We considered scaling the cost by a number between 1 and 1.5 to reflect the possibility that the

Madison Metropolitan Sewerage District's proactive approach to WAM might imply that their costs would be lower than a statewide average. In the end, we decided to use $29/lb phosphorus removed because it is watersheds with these low costs that would be most likely to select this management option.

To calculate the implementation costs, we first estimated the costs of making all the reductions in the state through Watershed Adaptive Management. The annual and total costs for this very unlikely scenario are included in Table C-1.To generate the more likely statewide costs of Watershed Adaptive Management, we then scaled the total cost by 4 to 48 percent, the estimated percent of the state's phosphorus reduction that we expect to occur through Watershed Adaptive Management. The resulting range of costs was utilized in the Monte Carlo analysis.

Table D-1

Implementation Costs

Statewide Phosphorus Removal	807,661 lb P
Removal Rate	$ 29/lb P removed
Annual Cost	$ 23,422,169/year

Year	**Discounted Annual Costs**
0	$23,422,169
1	$22,630,115
2	$21,864,845
3	$21,125,454
4	$20,411,067
5	$19,720,838
6	$19,053,950
7	$18,409,613
8	$17,787,066
9	$17,185,571
10	$16,604,416
11	$16,042,914
12	$15,500,400
13	$14,976,232
14	$14,469,789
15	$13,980,473
16	$13,507,703
17	$13,050,921
18	$12,609,586
19	$12,183,174
20	$-
20-year Total of Annual Costs	$344,536,298

Appendix E: Transaction and Administration Costs

Watershed Adaptive Management (WAM) introduces a variety of costs that fall under the heading of transaction and administration costs. Administration of a WAM program can be accomplished locally or remotely and to varying degrees by people and computers. Large wastewater treatment plants may conduct in-house assessments of their phosphorus reduction needs and their potential project partners. Small wastewater treatment plants may hire consultants to complete the assessments. Additionally, various programs and websites like Nutrient Net may be utilized to compute nonpoint source load reductions under various best management practices and to organize nutrient load exchanges. After this assessment takes place, nonpoint source partners must be engaged and educated and the permit application must be completed and approved. Once the program is in place, water quality monitoring must be completed by the partners.

We explored the possibility of computing administration costs from point source staffing costs, consulting firm costs, phosphorus runoff modeling software, and government administration costs. For example, in the start-up years of water quality trading programs in the Chesapeake Bay region, states demanded about one half-time person to engage and educate point and nonpoint source participants and monitor water quality. In subsequent years, the states devoted less than a half-time person to work on monitoring and ongoing administration costs (M. Selman, personal communication, November 9, 2011). The programs in the Chesapeake Bay have significant differences from the WAM option. We, therefore, sought another means of estimating transaction and administration costs.

The transaction and administration costs are calculated as 35 percent of the implementation costs. This method allows the costs to vary with the size of the project. It depends on the findings of Fang, Easter &Brezonik (2005), who studied water quality trading in Minnesota and found transaction costs to fall mostly to the regulator during the permitting and enforcement periods and to equal at least 35 percent of the implementation costs. Because the cost estimate from the Madison Metropolitan Sewerage District does not include all of their staffing costs or government staffing costs, we added 35 percent of the implementation costs to the implementation costs in order to reach our total estimate.

Table D-1
Total Costs

Implementation Costs	$344,536,298
Transaction Costs	$120,587,704
Total	**$465,124,002**

Appendix F: Omission of Cost Savings from Water Quality Trading

The Watershed Adaptive Management (WAM) option provides point sources with a new cost-effective means of complying with the phosphorus rules. Water Quality Trading is another cost-effective means of compliance that uses a market-based, rather than a partnership-based, framework. The DNR developed the framework and, in 2011, published *A Water Quality Trading Framework for Wisconsin*. Thus, WAM is not the only cost-saving option for point sources.

There is much uncertainty about the potential success of Water Quality Trading in Wisconsin. Water Quality Trading between point and nonpoint sources has been attempted in the United States since the mid-1980s, but trading programs have been mostly small and unsustainable due, in part, to legal restrictions and high transaction costs (Fang, Easter, and Brezonik, 2005). In 1997, Wisconsin's own Water Quality Trading pilot project engaged stakeholders in three study areas, but resulted in only one trade in one watershed (DNR, 2011). The new framework for Wisconsin addresses some of the past challenges, but leaves other questions unanswered.

In view of the lingering uncertainty regarding Water Quality Trading and the very close substitutability of Water Quality Trading and WAM, we omitted Water Quality Trading costs from this analysis and assumed that all cost-saving compliance measures would take the form of WAM.

Appendix G: Potential for Adoption of Watershed Adaptive Management

The Watershed Adaptive Management (WAM) Option is inherently attractive to point sources that would otherwise have to make unanticipated and expensive upgrades in order to comply with the new rules. Yet these point sources must organize themselves in order to successfully implement the program (Table G-1).

Table G-1

Key Components for Adoption of the WAM Option

A problem	Total phosphorus concentrations equal or exceed the water quality criteria for the local surface waters.
An organizer	A major point source exists to drive the process and fund the initial assessment, based on its belief that WAM would yield significant savings.
A critical mass	Multiple point sources are not in compliance, face high upgrade costs, and express interest in collaborating on the project.

Source: Authors.

In northern Wisconsin, the high quality of most waters makes it unlikely that upgrades, let alone WAM, would be necessary. In rural areas and in watersheds with phosphorus loads dominated by nonpoint source pollution, it is unlikely that point sources would have the time and resources or the initiative and incentive to implement WAM. Rather the WAM option is likely to be used in the watersheds with high phosphorus loads and high point source phosphorus loads.

Indeed, the Madison Metropolitan Sewerage District has thoroughly assessed the WAM option and indicated its interest in pursuing the option in the Yahara River watershed (Taylor, personal communication, November 14, 2011). The Milwaukee Metropolitan Sewerage District has discussed the option with other dischargers in the Milwaukee River watershed, although it has yet to complete an assessment or develop cost estimates (Shafer, personal communication, November 22, 2011). Because of the lingering uncertainty about nutrient trading and WAM, most point sources are not currently pursuing a program of either sort. Because their point source phosphorus loads and total phosphorus loads are high, the Lower Rock, Milwaukee, Upper Rock, and Lower Fox River basins are the basins most likely to use WAM. It is important to note that watersheds within the basins may pursue WAM without the participation of all the watersheds in the basins. To maintain what we considered a reasonable upper limit of participation, we considered cases in which all or part of the Rock, Milwaukee, and Lower Fox River basins were engaged in WAM. This breakdown resulted in 4 to 48 percent of the phosphorus reductions occurring through WAM.

Appendix H: Equation and Assumptions for Calculating Benefits to Property Value

Dodds et al. (2009) proposed an equation for calculating the loss of property value as a result of a decrease of Secchi depth. They used this equation to calculate the loss of benefits from the eutrophication of US watersheds.

Since Secchi depth is a measurement of water turbidity and water turbidity is one of the signs of high level of phosphorus in a water body, Secchi depth is an effective measurement of phosphorus concentration in the lake. According to Dodds et al., one meter loss in Secchi depth results in a 15.6 percent decreases in property value. In our calculation, we interpret this relationship in the opposite direction and name it Dodds factor. In other words, Dodds factor is 15.6 percent increase in property value when one meter of Secchi depth is gained.

Equation

As our project analyzes the benefits gained from phosphorus regulations and is applied to Wisconsin watersheds, we decided to modify some parts of Dodds et al.'s equation before using it. Below is the modified version of equation.

$$gain\ in\ prop(\$) = Increase\ in\ SD(m) \times Dodds\ factor(\%) \times Med\ prop(\$) \times Lot \times private\ prop(\%) \times basin\ area(\%)$$

Definition of variables and assumptions

All definitions of each variable are explained in the following table.

Table H-1

Definitions of Variables in the Modified Version of Dodds' Equation

Variables	definitions	Values	Calculation methods and cited sources
Gain in prop	Value gain in property value	See Table I-1 for the results	
Increased in SD	Estimated increase in secchi depth (m)	See Table H-1 and I-1	Estimate secchi depth from phosphorus concentration for each year and then, find the difference between each year and the previous year level.
Dodds factor	% increase in property value per 1 m gain in secchi depth	15.6	Use value estimated by Dodds et al. (2009)
Med prop	Median WI property value	$141,722	Average the property value from the data collected from Vilas, Winnebago, and Sawyer county(Wisconsin Department of Revenue 2011)
Lot	Available lake lots	863077	See the "Available lake lots" subtopic
Private prop	% of land assumed to be private property	85	U.S. Fish and Wildlife Service (2011)
Basin area	% of basin area	32.1 for high point-source region 26 for medium point-source region	See appendix A

Source: Authors.

Available lake lots

We calculate numbers of available lake lots in Wisconsin by dividing total length of Wisconsin shoreline by average lot length. According to data provided by Wisconsin Lakes (2011), total length of Wisconsin shoreline is equal to 154730710 feet. We use 179.278 feet, which is the average lot length of Vilas County's lakeshore parcels (Spalatro and Provencer

2001), as the number of average lake lot length. After the division, we get 863,077 as our number of available lake lots.

Housing value growth rate

We study the growth of Wisconsin's land and housing value from housing and equalized value data provided by U.S. Census Bureau (2011) and Wisconsin Department of Revenue (2011). Growth rates are calculated by using the following equation, which is derived from present value and discount rate concepts.

$$housing\ price_{last\ year} = housing\ price_{beginning\ year} \times (1 + growth\ rate)^{time\ period}$$

The long-term trend (1940-2000) of Wisconsin's housing prices was upward with the growth rate of 2.03 percent (Table H-2) where as the short-term trend (2008-2011) of Wisconsin property price is downward with the growth rate of -1.81 (Table H-3).

Table H-2

The Long-term Trend of Wisconsin Housing Price

Year	**Housing Price (2000$)**
1940	33,600
1950	48,000
1960	62,100
1970	66,400
1980	96,200
1990	79,900
2000	112,200
Growth rate (%)	**+2.03**

Source: adapted from U.S. Census Bureau website (2011)

Table H-3

The Short-term Trend of Wisconsin equalized Values

Year	**Equalized Value ($)**
2008	514,393,963,700
2009	511,911,983,100
2010	495,946,529,900
2010	486,864,232,800
Growth rate (%)	**-1.81**

Source: adapted from Wisconsin Department of Revenue website (2011)

Appendix I: Calculating Increases in Water Clarity (Secchi Depth)

Calculating yearly levels of phosphorus concentrations

Our phosphorus reduction model predicts total decreases in phosphorus concentrations of 23.4 percent in the high point source region and 5.0 percent in the medium point source region, with no changes in the low point source region. We assume that the decrease takes place progressively over five years and that the concentrations remain the same thereafter. We use the current average statewide phosphorus concentration of 31.94 µg/L estimated by Bernthal et al. (2011), and calculate the total decrease for each region. We apply one-fifth of the decrease each year for the first five years, and subtract the decreased amount from the current levels to obtain yearly phosphorus concentrations.

Converting total phosphorus concentrations to Secchi depth

We convert total phosphorus concentrations, measured in µg/L, to Secchi depth, measured in meters, using equations developed for Wisconsin by Lillie, Graham, and Rasmussen (1993). They offer separate equations for natural lakes and impoundments, and for thermally stratified and for mixed bodies of water. Lillie et al. based their equations on analysis of a sample taken in 1979 of 25 percent of lakes in each county.12.6 percent of the lakes studied were impoundments and 87.4 percent were natural lakes; 58 percent of natural lakes were stratified and 42 percent were mixed. Although Lillie et al. did not specify the percentages of impoundments that were stratified and mixed, we assume that 58 percent of impoundments are stratified and 42 percent are mixed. We use Lillie et al.'s four equations for stratified natural lakes, mixed natural lakes, stratified impoundments, and mixed impoundments, weighting the results by 50.7 percent, 36.7 percent, 7.3 percent, and 5.3 percent, respectively.

For stratified natural lakes: $\ln(SD) = 2.10 - 0.44 \ln(TP)$

For mixed natural lakes: $\ln(SD) = 2.15 - 0.57 \ln(TP)$

For stratified impoundments: $\ln(SD) = 2.08 - 0.51 \ln(TP)$

For mixed impoundments: $\ln(SD) = 1.14 - 0.30 \ln(TP)$

We use these equations to convert the current statewide average phosphorus concentration (TP), 31.94 μg/L, to 1.50m Secchi depth (SD), and to convert future reduced levels of phosphorus to Secchi depth.

Table I-1
Levels of total phosphorus and Secchi depth (SD) by year

Year		High Point-source Region		Medium Point-source Region	
		Total P (μg /L)	SD (m)	Total P (μg /L)	SD (m)
0	2012 (beginning)	31.94	1.50	31.94	1.50
1	2012 (end)	30.44	1.53	31.56	1.51
2	2013	28.95	1.57	31.17	1.51
3	2014	27.46	1.61	30.79	1.52
4	2015	25.96	1.65	30.41	1.53
5	2016	24.47	1.70	30.02	1.54
6-20	2017-2031	24.47	1.70	30.02	1.54

Source: Authors.

Appendix J: Benefits Gain to Property Value

From data on the increase of Secchi depth per year, we calculate the benefits gain to property values for each year by region by using the modified version of Dodds et al.'s equation. We sum all numbers in Table J-1 and find total benefits to property values equal to $1,094,270,756.

Table J-1

Benefits Gain to Property Value for Each Year by Region

Year		High point-source region		Medium point-source region		Total benefits to property value ($)
		Increased in SD (m)	Benefits ($)	Increased in SD (m)	Benefits ($)	
0	Beginning of 2012	0.000	0	0.000	0	0
1	End of 2012	0.035	174,633,854	0.007	29,377,039	204,010,892
2	2013	0.037	181,518,465	0.007	28,813,165	210,331,630
3	2014	0.040	189,390,956	0.007	28,264,460	217,655,416
4	2015	0.044	198,437,470	0.008	27,730,555	226,168,025
5	2016	0.048	208,893,698	0.008	27,211,095	236,104,792
6-20	2017-2031	0.000	0	0.000	0	0
0-20	**2012-2031**	**0.211**	**952,874,442**	**0.046**	**141,396,314**	**1,094,270,756**

All benefit numbers are discounted back to the beginning of the project (year 2012)

Source: Authors.

Appendix K: Calculating Recreational Benefits

Use of Vesterinen et al study to predict changes in recreation demand

In order to calculate the recreational benefits to Wisconsin residents of improved water quality, we first must predict the changes in demand for recreational activities induced by cleaner water. To do this we use a study by Vesterinen et al. (2010), which examines the responsiveness of people in Finland to changes in water clarity close to their homes. The authors use a logit model to predict changes in participation rates for swimming, boating, and fishing, and a negative binomial model to calculate changes in the number of trips per person who engages in recreation. They find significant results for the negative binomial swimming model (meaning that the number of swimming trips per person who swims increases) and for the logit and negative binomial fishing models (meaning that both the percentage of angers and the number of fishing trips per angler increases). The results for boaters were insignificant.

To use their results to calculate the increased benefits to Wisconsin resident recreationists, we multiply our predicted increases in Secchi depth by the study's logit and negative binomial water clarity coefficients, and raise the natural base e to that product to obtain the odds ratio (for the logit model) and the incident rate ratios (for the negative binomial models.) We multiply the odds ratio by the current Wisconsin fishing odds (the percentage of anglers divided by the percentage of non-anglers) to obtain the new odds after a change in water clarity. Similarly we multiply the incident rate ratios for swimming and fishing by the current number of trips per swimmer and fisher to obtain the new numbers of trips. We perform the process twice, using the predicted Secchi depth increases for the high point source and medium point source regions of our model, to obtain predicted trip numbers for each region. We assume that fishing participation rates and the number of fishing and swimming trips per recreational user remains the same under the status quo. These results allow us to use shadow prices to calculate increased recreational benefits.

We also use Vesterinen et al.'s results to predict the increased number of out-of-state anglers that would follow an improvement in water clarity. Rather than using shadow prices, we multiply the increases relative the status quo by the average expenditures per angler and per trip to obtain the economic gain to Wisconsin from out-of-state visitors.

Applicability of Vesterinen et al. study to Wisconsin

With all else equal, it would be preferable to use a study from Wisconsin or from the United States to predict effects of water clarity improvements, because using studies from other countries increases the risk that results may not be applicable to Wisconsin residents because of underlying differences in the populations. However, we did not find US studies that were applicable to the changes we expect from the phosphorus regulations. Many studies that value recreational benefits of changes in water quality are based on measures of dissolved oxygen; it is difficult to predict changes in dissolved oxygen resulting from changes in phosphorus concentrations, whereas limnologists have developed models describing the relationship between phosphorus concentrations and water clarity as measured by Secchi depth. Many US studies also value changes in water quality by eliciting people's willingness to pay to move water to a different use, for example, to change water that is only clean enough for boating to water that is clean enough for fishing or swimming. This kind of measure fails to capture benefits of incremental changes in water quality.

Finland and Wisconsin have similar population sizes and similar median household income (U.S. Census Bureau n.d., Statistics Finland, 2011), and both face problems of eutrophication of water from high levels of nutrients. Significant differences exist as well. Finland has lower population density, and its participation rates for fishing, boating and swimming, as reported in Vesterinen et al. are greater than those in Wisconsin. It is difficult to predict how these differences affect Finns' and Wisconsinites' relative responsiveness to changes in water clarity.

Vesterinen et al.'s study measures changes in behavior resulting from close-to-home changes in water clarity. Therefore, the study may be less applicable to the response of nonresident anglers to increased water clarity in Wisconsin than it is to the response of Wisconsin residents. However, no other more relevant studies exist. It seems very likely that nonresidents would also be more likely to come to Wisconsin to fish if water clarity improved. Nonresidents may be more responsive to changes in water clarity because of the greater planning and expenditure required to make a trip,

We believe that using Vesterinen et al.'s study is more likely to result in an underestimate than an overestimate of recreational benefits in Wisconsin for two reasons. First, Finland's current level of water quality appears to be higher than that of Wisconsin. According to the Finnish Environment Institute, a government-sponsored research institute, the majority of Finnish waters "are classified as having an excellent or good ecological status" (2011). Vesterinen et al. report that the average water clarity in the home municipalities of their study subjects is 2.01 m, whereas our estimated statewide average Secchi depth level is 1.50m.Models of pollution abatement generally assume decreasing marginal benefits to pollution cleanup, meaning that an improvement in water clarity in an area with impaired water will have larger benefits than the same improvement in an area with higher water quality. Second, Vesterinen et al. did not detect significant effects on water quality for boaters. This means that their data did not allow them to rule out the possibility of no effect for boaters. However, it is likely that boaters as well as fishers and swimmers are affected by eutrophication and derive benefits from cleaner water that are not captured by the study.

Current and increased numbers of swimming and fishing trips

The current percentages of Wisconsin residents who fish and swim were taken from the Wisconsin Outdoor Recreation Demand report (Wisconsin DNR, 2011), which contains results from the 2005-2009 National Survey on Recreation and the Environment (NSRE). We used numbers and percentages reported for "Freshwater fishing" and for "Swimming in lakes, streams, etc." We used the number of fishing days per Wisconsin resident angler reported in the U.S. Department of the Interior (2008) Fish and Wildlife Service's 2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation (Fish and Wildlife Service Survey). Both the NSRE and the Fish and Wildlife Service Survey only reported information on Wisconsin residents aged 16 and over, so only their benefits are considered. We did not find any source reporting the average number of swimming trips per Wisconsin resident swimmer. A study by Helm, Parsons and Bondelid (2004) reported data obtained from the 1994 NSRE indicating that in their research area in the northeastern United States, people who swam took an average of 10.05 swimming trips per year. In order to avoid overestimating the number of Wisconsin swimming trips, we halve the Helm et al. number and assume that each Wisconsinite who went swimming at least once took five swimming trips. This would mean that swimmers took less than two swimming trips per summer month.

The current number of nonresident anglers who visit Wisconsin and the average number of trips per angler were taken from the Fish and Wildlife Service Survey. To calculate the percentage of nonresidents who come to Wisconsin to fish, we assumed that all nonresident anglers come from Michigan, Indiana, Illinois, Iowa, or Minnesota, and calculated percentages based on their 2006 populations as reported by the US Census Bureau (2011). It is likely that some nonresident anglers come from other states, but the five states bordering Wisconsin are probably home to the large majority of nonresident anglers.

The DNR's 2007 Recreational Boating in Wisconsin Survey lends some support to this assumption. Although the survey itself was administered only to a sample of Wisconsin registered boats and some Illinois registered boats, the survey introduction states that boats registered in Illinois, Iowa, and Minnesota make up a significant proportion of boats registered for use in Wisconsin. There is some overlap between the boating and fishing populations, as 42.7% of the boating survey respondents stated that they fished from their boats (Peterson and Nelson 2008).

We estimated the population of Wisconsin during each of the next 20 years based on projections from the Wisconsin Department of Administration (Egan-Robertson, Harrier, and Wells 2008). The authors projected Wisconsin's population in five-year increments from 2010-2035.We used their estimated population growth rates for each period, but used the actual population for 2010 as reported by the U.S. Census Bureau, rather than the Department of Administration's projection for 2010.For each future year, we used the current percentage of population that fishes and current number of trips per fisher to estimate the total number of fishing trips with current water quality, and the predicted percentage of fishers and number of trips to estimate the total number of fishing trips under the new regulations. We similarly calculated the number of swimming trips for each year under the current quality and under the new regulations.

We also developed population projections for the assumed home states of nonresident anglers, Michigan, Indiana, Illinois, Iowa, and Minnesota, based on projections from the U.S. Census Bureau (n.d) and adjusted to use actual 2010 population counts (U.S. Census Bureau 2011) rather than 2010 projections. We used these projections to calculate the numbers of anglers and of trips under the status quo and under the new regulations.

Applying shadow prices to numbers of fishing and swimming trips

After calculating the increased number of fishing and swimming trips due to the phosphorus regulations, we multiply the number of trips under the status quo and under the regulations by their shadow prices. We use shadow prices from Kaval and Loomis (2003), which compiled hundreds of US studies on willingness to pay for recreational activities and reported means and ranges of estimates for each activity. Kaval and Loomis averaged 177 different estimates for the value of a day spent fishing and 26 estimates for the value of a day spent swimming to obtain means of $56.71 and $51.33, respectively (in 2011 dollars). We use these means for the values of fishing and swimming trips. Kaval and Loomis also reported the standard errors of each shadow price. In order to address the uncertainty associated with estimated shadow prices, we conduct sensitivity analysis using higher and lower values for the two shadow prices obtained by adding and subtracting their standard errors to their means. The high- and low-range values for the fishing shadow price are $62.49 and $50.93, and the corresponding shadow prices for swimming are $58.71 and $43.95.

Calculating increased expenditures

We did not use shadow prices for the increased fishing trips of nonresident anglers, because the shadow prices measure the benefit that anglers receive from the opportunity to fish, and in this analysis we count only benefits accruing to Wisconsin residents. It is the expenditures that out-of-state visitors bring to Wisconsin, rather than the visitors' enjoyment, that bring benefits to Wisconsin. We used numbers reported in the Fish & Wildlife Service Survey to calculate the increased revenues resulting from the regulations. The Survey divided expenditures into two categories, trip-related expenditures and equipment and other expenditures. We assumed that the value per angler of equipment and other expenditures was spent by each angler each year, and that the value per angler per day of trip-related expenditures was spent by each angler per day of fishing. Additional expenditures resulted from both the increased number of anglers and the increased days of fishing per angler.

Final gross recreational values

We calculated total recreational benefits separately using the larger phosphorus reductions of the high point source region and the smaller reductions of the medium point source region, and weighted the results by the percentage of population living in each region (for benefits to Wisconsin residents) or by the percentage of surface area of each region (for nonresident anglers). This assumes that Wisconsin residents recreate in their home region, and that nonresident anglers are dispersed evenly throughout the state. We added the value of increased recreational benefits for Wisconsin residents to the value of increased expenditures of nonresident visitors. We then discounted the benefits for each year at 3.5 percent.

Avoiding double-counting between recreational benefits and property value increases

Wisconsin residents who live on water will have all or part of their recreational benefit captured in property values; in order to avoid double-counting, we must account for this. We assume that the entire recreational benefit for waterfront property owners is capitalized in property values, and assume that none of the recreational benefit for non-waterfront property owners is captured in their property values. We count as benefits in the recreational category only the recreational benefits accruing to non-waterfront property owners.

A lower bound for the proportion of Wisconsin anglers who do not own waterfront property can be estimated from trip expenses reported in the Fish and Wildlife Service Survey. Among the categories listed under "Trip Expenses" in Table 21 are "Food and Lodging" and "Transportation." Unlike other equipment-related expenses, these expenses can be assumed to be zero for anglers who fish on water directly adjoining their property. These categories will be positive only for those anglers who do not own property on water (or who fish on lakes or rivers that they do not live on, and therefore derive benefits from the lakes that are not captured in their property values). Average expenditure in Wisconsin per resident angler for these two categories was $325.00.The average expenditure for nonresidents was $650.00.

If we were to assume that non-waterfront property owner resident expenditures were equal in these areas to nonresidents' expenditures, then we would conclude that because 325 is 50 percent of 650, then 50 percent of Wisconsin anglers are non-waterfront property owners. However, it is highly likely that nonresident anglers spent more per angler on food, lodging and transportation than resident anglers who did not live on water, which would increase the percentage of resident anglers who do not live on water. We treat 50 percent as the lower bound and 100 percent as the upper bound for the percentage of Wisconsin anglers who do not live on waterfront or who fish on water that they do not live on. We assume that these percentages represent upper and lower bounds for swimmers as well. We perform sensitivity analysis to estimate the effects on our total calculation of benefits of different assumptions regarding the percentage of recreational users who do not live on waterfront.

Results

Table K-1
Per Year and Total Calculated Recreational Benefits (2011 $).

Year	WI Resident Benefits	Nonresident Expenditures	Total Recreational Benefits	Present Value of Benefits
0	0	0	0	0
1	6,666,912	1,204,193	7,871,105	7,604,933
2	13,939,959	2,505,823	16,445,782	15,352,314
3	21,895,118	3,918,330	25,813,449	23,282,252
4	30,614,924	5,457,953	36,072,877	31,435,428
5	40,235,441	7,137,772	47,373,213	39,886,974
6	40,523,527	7,158,614	47,682,141	38,789,452
7	40,813,675	7,179,555	47,993,230	37,722,245
8	41,105,901	7,200,595	48,306,496	36,684,511
9	41,379,592	7,221,735	48,601,326	35,660,299
10	41,630,352	7,236,103	48,866,455	34,642,349
11	41,882,632	7,250,540	49,133,172	33,653,556
12	42,136,441	7,265,048	49,401,489	32,693,080
13	42,391,788	7,279,627	49,671,414	31,760,109
14	42,633,393	7,294,276	49,927,670	30,844,405
15	42,833,770	7,305,891	50,139,661	29,927,893
16	43,035,089	7,317,567	50,352,656	29,038,675
17	43,237,354	7,329,307	50,566,661	28,175,934
18	43,440,570	7,341,109	50,781,679	27,338,883
19	43,635,278	7,352,975	50,988,253	26,521,830
20	43,785,383	7,364,905	51,150,288	25,706,390
Total				596,721,511

Source: Authors.

Appendix L: Selected Data from Recreational Benefits Calculations

Note: For current water quality, the fishing participation rate is assumed to remain at 37.4 percent each year. The annual numbers of trips per fisherman and per swimmer remain at 17 and 5, respectively. The phosphorus regulations do not affect the swimming participation rate, which is assumed to remain at 41.7 percent.

Table L-1

Changes in WI Resident Recreation Demand, High Point Source Region

Year	Fishing Participation Rate	Trips / Fisher	Trips / Swimmer
0	0.373998397	16.7988	5
1	0.374867167	16.85537876	5.010236212
2	0.375802692	16.91645914	5.021271758
3	0.376813997	16.98266772	5.033216213
4	0.377911908	17.05475973	5.046201351
5	0.379109549	17.13365506	5.060387277
6-20	0.379109549	17.13365506	5.060387277

Source: Authors.

Table L-2

Changes in WI Resident Recreation Demand, Medium Point Source Region

Year	Fishing Participation Rate	Trips / Fisher	Trips / Swimmer
0	0.373998	16.7988	5
1	0.374179	16.81054	5.002125
2	0.374362	16.82246	5.004283
3	0.374548	16.83458	5.006475
4	0.374737	16.84689	5.008702
5	0.374929	16.85941	5.010964
6-20	0.374929	16.85941	5.010964

Source: Authors.

Table L-3

Population Projections

Year	Wisconsin	High Region	Medium Region	Surrounding States
0	5729524.655	2635581.341	1489676.41	37,571,828
1	5772381	2655295.26	1500819.06	37,716,095
2	5815558.913	2675157.1	1512045.317	37,861,098
3	5859059.294	2695167.275	1523355.416	38,006,840
4	5899679.276	2713852.467	1533916.612	38,153,327
5	5941920.98	2733283.651	1544899.455	38,300,563
6	5984465.134	2752853.962	1555960.935	38,412,196
7	6027313.905	2772564.396	1567101.615	38,524,356
8	6070469.472	2792415.957	1578322.063	38,637,049
9	6110887.794	2811008.385	1588830.827	38,750,276
10	6147919.775	2828043.096	1598459.141	38,864,042
11	6185176.168	2845181.037	1608145.804	38,941,363
12	6222658.336	2862422.835	1617891.167	39,019,060
13	6260367.645	2879769.117	1627695.588	39,097,135
14	6296047.695	2896181.94	1636972.401	39,175,589
15	6325639.119	2909793.995	1644666.171	39,254,427
16	6355369.623	2923470.026	1652396.102	39,316,929
17	6385239.86	2937210.336	1660162.364	39,379,768
18	6415250.487	2951015.224	1667965.127	39,442,945
19	6444004.815	2964242.215	1675441.252	39,506,461
20	6466172.192	2974439.208	1681204.77	39,570,318

Note: The high point source region represents 46 percent of Wisconsin's population; the medium point source region represents 26 percent of Wisconsin's population. The surrounding states are Michigan, Indiana, Illinois, Iowa, and Minnesota.

Source: Authors.

Table L-4

Recreational Benefits for Wisconsin Residents under Status Quo and New Regulations

Year	Fishing Benefits		Swimming Benefits		Total Recreational Benefits	
	Status Quo	Regulations	Status Quo	Regulations	Status Quo	Regulations
0	1469807970	1469807970	441497667	441497667	1911305637	1911305637
1	1480802006	1486818876	444800031	445450073	1925602037	1932268949
2	1491878534	1504461842	448127174	449483824	1940005708	1953945667
3	1503037785	1522805570	451479165	453606499	1954516950	1976412069
4	1513458122	1541103559	454609203	457578690	1968067324	1998682249
5	1524294482	1560634410	457864204	461759717	1982158686	2022394127
6	1535208430	1571808552	461142512	465065917	1996350943	2036874469
7	1546200523	1583062701	464444293	468395789	2010644815	2051458490
8	1557271318	1594397430	467769714	471749503	2025041032	2066146933
9	1567639923	1605013227	470884212	474890499	2038524134	2079903726
10	1577139820	1614739607	473737770	477768336	2050877591	2092507943
11	1586697288	1624524929	476608621	480663612	2063305909	2105188541
12	1596312673	1634369550	479496869	483576433	2075809543	2117945984
13	1605986328	1644273830	482402620	486506907	2088388949	2130780736
14	1615139412	1653645128	485152004	489279682	2100291416	2142924809
15	1622730567	1661417260	487432218	491579296	2110162785	2152996556
16	1630357401	1669225921	489723149	493889719	2120080551	2163115640
17	1638020081	1677071283	492024848	496211000	2130044929	2173282283
18	1645718775	1684953518	494337365	498543192	2140056140	2183496710
19	1653095188	1692505788	496553076	500777754	2149648264	2193283542
20	1658781836	1698328008	498261218	502500430	2157043054	2200828438

Note: The value (benefit) of one fishing trip = $56.71; the value of one swimming trip = $51.33 (2011 dollars).

Source: Authors.

Table L-5

Nonresident Expenditures under Status Quo and New Regulations

Year	High Region		Medium Region		Total	
	Status Quo	Regulations	Status Quo	Regulations	Status Quo	Regulations
0	189031493.1	189031493.1	153109621	153109621	342141114	342141114
1	189758238.7	190789330.4	153698262	153871363	343456501	344660694
2	190488691.9	192644131.6	154289906	154640290	344778598	347284421
3	191222876.9	194609239.2	154884573	155416541	346107450	350025780
4	191960818.7	196700791.3	155482283	156200263	347443102	352901054
5	192520317.5	198750398.4	155935460	156843151	348455777	355593550
6	193082463.4	199330735.7	156390780	157301122	349473244	356631858
7	193647273.2	199913823.1	156848259	157761264	350495532	357675087
8	194214763.8	200499678	157307908	158223589	351522672	358723267
9	194784952.3	201088318.3	157769743	158688112	352554696	359776430
10	195172482	201488388.6	158083630	159003826	353256112	360492215
11	195561895.3	201890403.6	158399043	159321075	353960938	361211478
12	195953203.1	202294374.3	158715990	159639867	354669193	361934241
13	196346416	202700311.9	159034480	159960211	355380896	362660523
14	196741545	203108227.5	159354522	160282116	356096067	363390344
15	197054806.1	203431626	159608254	160537325	356663060	363968951
16	197369751.8	203756763.5	159863350	160793906	357233102	364550669
17	197686390.3	204083648.6	160119818	161051866	357806208	365135515
18	198004730	204412290	160377663	161311212	358382393	365723502
19	198324779.5	204742696.5	160636893	161571951	358961673	366314648
20	198646547.1	205074876.7	160897515	161834090	359544062	366908967

Source: Authors.

Table L-6

Total Recreational Benefits Resulting from Regulations

Year	Resident Recreational Benefits	Nonresident Expenditures	Total Net Recreational Benefits	Present Value of Benefits
0	0	0	0	0
1	6666912.141	1204193.052	7871105.193	7604932.6
2	13939958.94	2505823.359	16445782.3	15352314
3	21895118.49	3918330.202	25813448.7	23282252
4	30614924.22	5457952.772	36072877	31435428
5	40235440.83	7137772.447	47373213.28	39886974
6	40523526.59	7158614.244	47682140.83	38789452
7	40813675.04	7179554.805	47993229.84	37722245
8	41105900.95	7200594.761	48306495.71	36684511
9	41379591.74	7221734.743	48601326.48	35660299
10	41630352.06	7236102.568	48866454.63	34642349
11	41882632	7250540.232	49133172.23	33653556
12	42136440.75	7265048.134	49401488.88	32693080
13	42391787.58	7279626.671	49671414.25	31760109
14	42633393.37	7294276.244	49927669.61	30844405
15	42833770.31	7305890.535	50139660.85	29927893
16	43035089.04	7317567.279	50352656.31	29038675
17	43237353.95	7329306.786	50566660.74	28175934
18	43440569.52	7341109.367	50781678.88	27338883
19	43635278.11	7352975.336	50988253.45	26521830
20	43785383.47	7364905.008	51150288.47	25706390
Total				**$596,721,511**

Note: Benefits are discounted at 3.5 percent annually. Values are 2011 dollars.

Source: Authors.

Table L-4

Recreational Benefits from High Point Source Region under Status Quo and New Regulations

Year	Fishing Benefits		Swimming Benefits		Total Recreational Benefits	
	Status Quo	Regulations	Status Quo	Regulations	Status Quo	Regulations
0	950290954	950290954	282067953.7	282067953.7	1232358908	1232358908
1	957399047.5	963038855	284177797.4	284779586.4	1241576845	1247818441
2	964560475.9	976394270	286303472.1	287563548.8	1250863948	1263957819
3	971775388.2	990431454.2	288445022.1	290427624.6	1260220410	1280859079
4	978512561.8	1004699383	290444768.3	293221923.1	1268957330	1297921306
5	985518711.7	1020072976	292524352.8	296180747.5	1278043065	1316253723
6	992575025.7	1027376698	294618827.2	298301401.6	1287193853	1325678100
7	999681862.9	1034732716	296728298	300437239.7	1296410161	1335169955
8	1006839585	1042141402	298852872.6	302588370.3	1305692458	1344729772
9	1013543311	1049080174	300842691	304603060.3	1314386002	1353683235
10	1019685384	1055437600	302665797.7	306448954.9	1322351182	1361886555
11	1025864677	1061833552	304499952.4	308306035.6	1330364630	1370139588
12	1032081417	1068268263	306345222.1	310174370.1	1338426639	1378442634
13	1038335831	1074741969	308201674.2	312054026.8	1346537505	1386795996
14	1044253674	1080867304	309958224.5	313832533.1	1354211898	1394699837
15	1049161666	1085947380	311415028.2	315307546	1360576694	1401254926
16	1054092726	1091051333	312878678.8	316789491.4	1366971405	1407840824
17	1059046962	1096179274	314349208.6	318278402.1	1373396170	1414457676
18	1064024482	1101331317	315826649.9	319774310.5	1379851132	1421105627
19	1068793635	1106267685	317242242.8	321207597.6	1386035878	1427475283
20	1072470285	1110073246	318333556.1	322312551.7	1390803841	1432385798

Note: The value of one fishing trip = $56.71; the value of one swimming trip = $51.33 (2011 dollars).

Source: Authors.

Table L-5

Recreational Benefits from Medium Point Source Region under Status Quo and New Regulations

Year	Fishing Benefits		Swimming Benefits		Total Recreational Benefits	
	Status Quo	Regulations	Status Quo	Regulations	Status Quo	Regulations
0	537120974	537120974	159429713	159429713	696550687	696550687
1	541138592	541797592	160622233	160692836	701760825	702490428
2	545186356	546527406	161823702	161967074	707010058	708494480
3	549264350	551308849	163034143	163252519	712298493	714561368
4	553072318	555840837	164164434	164459954	717236752	720300791
5	557032315	560547614	165339852	165714887	722372167	726262501
6	561020667	564561135	166523685	166901405	727544352	731462540
7	565037575	568603392	167715995	168096420	732753569	736699812
8	569083244	572674593	168916841	169299990	738000085	741974583
9	572872306	576487567	170041521	170427221	742913827	746914788
10	576343913	579981082	171071973	171460010	747415885	751441092
11	579836557	583495767	172108669	172499058	751945226	755994825
12	583350366	587031752	173151647	173544402	756502014	760576153
13	586885470	590589164	174200946	174596081	761086416	765185245
14	590230337	593955141	175193779	175591166	765424116	769546306
15	593004420	596746730	176017190	176416444	769021610	773163174
16	595791541	599551439	176844471	177245601	772636011	776797041
17	598591761	602369331	177675640	178078656	776267401	780447987
18	601405142	605200467	178510715	178915625	779915857	784116092
19	604100750	607913086	179310833	179717558	783411583	787630644
20	606178857	610004307	179927662	180335787	786106519	790340094

Source: Authors.

Table L-6

Total Recreational Benefits

Year	High Region Net Recreational Benefits	Medium Region Net Recreational Benefits	Total Net Recreational Benefits	Present Value of Benefits
0	0	0	0	0
1	6241596.57	729602.851	6971199.421	6735458.4
2	13093870.84	1484422.58	14578293.42	13608993
3	20638668.48	2262874.75	22901543.23	20655880
4	28963976.4	3064039.21	32028015.61	27910565
5	38210658.84	3890333.67	42100992.51	35447906
6	38484247.16	3918188.46	42402435.62	34494409
7	38759794.37	3946242.69	42706037.06	33566559
8	39037314.49	3974497.79	43011812.28	32663667
9	39297232.24	4000960.74	43298192.98	31769225
10	39535373.47	4025206.56	43560580.03	30880915
11	39774957.83	4049599.31	43824557.15	30017443
12	40015994.08	4074139.89	44090133.96	29178114
13	40258491	4098829.17	44357320.18	28362255
14	40487938.38	4122189.85	44610128.23	27559325
15	40678231.69	4141564.14	44819795.83	26752516
16	40869419.38	4161029.49	45030448.87	25969326
17	41061505.65	4180586.33	45242091.98	25209065
18	41254494.73	4200235.09	45454729.82	24471060
19	41439404.93	4219061.31	45658466.24	23749511
20	41581956.49	4233574.88	45815531.37	23025323
Total				**$532,027,515**
50% Total				**$266,013,757**

Note: Benefits are discounted at 3.5 percent annually. Dollar values are 2011 dollars.

Source: Authors.

Appendix M: Reduced Costs of Lake Cleanup

It is difficult to predict how much Wisconsin currently spends annually managing eutrophic lakes. Lake management is often handled by many different organizations besides the DNR—counties, parks, and private lake associations. It is primarily funded through various grants aimed at a wide range of lake restoration needs, ranging from cleaning pollution to habitat restoration. The DNR does not track how often lakes are cleaned in Wisconsin, let alone how treatments are a result of excess phosphorus.

Because of the difficulties in predicting what lakes are being managed, how often they're cleaned, and by whom, we worked with lake management specialists at the DNR to come up with a reasonable estimate. Wisconsin is required by the EPA (through the Section 303(d) of the Clean Water Act) to monitor the cleanliness its bodies of water. If a body of water is too polluted to meet its "specified use" (e.g., swimming, fishing, etc.) the EPA designates it as impaired. Wisconsin is thus obligated to restore that body of water to its designated state. We decided to use these most extreme cases of eutrophic waters as a proxy for lakes requiring extra treatment in Wisconsin.

There are 47 lakes (48,850 acres total) impaired from eutrophication and excess algal growth in Wisconsin (Wisconsin DNR). Adjusted for inflation (using an online Bureau of Labor and Statistics calculator), alum treatments in Wisconsin range from $344 to $861 per acre and last for eight years (Wisconsin DNR, Alum treatments). According to past alum treatments conducted by the DNR, pre-treatment research and planning averages out to $25,000 per lake treatment (Schaal, personal communication).

We assumed that the lakes would receive these treatments every eight years, and that the treatment of all the lakes would be spread out over the eight years. We totaled the costs of research and alum treatments (once for our high-cost estimate and once for low-cost estimate), and then divided the amount by eight for annual treatment costs. We assumed that the treatments would occur for every eight years indefinitely without the new regulations, and for only two treatments per lake (sixteen years of annual treatments) with the new regulations. We summed the costs out over both sixteen and twenty years, discounting annually at 3.5 percent. The equation is as follows:

annual cost of lake cleanup= [(research costs)(number of impaired lakes) + (number of acres)(cost of alum treatment)]/8.

We assumed two additional cycles even with the new regulations because of the lag in issuing permits, as well as the tendency of phosphorus to load and recycle in through waterways. Sixteen years is a reasonable assumption for removing excess phosphorus and allowing all permits to be issued. This, using our time horizon, gives us four years of avoided costs in our time horizon. In reality, the benefits would extend far into the future.

Table M-1

Wisconsin Lake Management Info

Wisconsin Lake Management Info	
Number of impaired lakes	47
Total acreage	48,851
Alum research costs per lake	$25,000
Alum cost per acre (low estimate)	$344 (adjusted to 2011 dollars)
Alum cost per acre (high estimate)	$861 (adjusted to 2011 dollars)

Source: Wisconsin DNR, "Alum Treatments to Control Phosphorus in Lakes." March 2003.

Calculations:

Low end cost estimate: [(47 lakes)($25,000) + (48,851)($344)]/8 = $2,247,425 per year

High end estimate: [(47 lakes)($25,000) + (48,851)($861)]/8 =$5,404,356 per year

The avoided costs, taken out to twenty years and discounted at 3.5 percent, range from $4,760,690 to $11,447,974.

Appendix N: Potential Algae Related Illnesses Reported in Wisconsin

Health Impacts Due to Harmful Algae Blooms (HABs)

Synopsis of 2010 Harmful Algal Bloom Season

Beginning in 2008, Wisconsin joined ten other states who received funding from the Centers for Disease Control and Prevention to expand surveillance of harmful algal blooms (HABs) and their associated adverse human and animal health effects. This effort includes a standardized national data entry system and additional outreach to the public. During the summer and fall of 2010 the Wisconsin Department of Health Services received a total of 27 HAB-related health complaints. There were no reported animal illnesses or deaths related to harmful algal blooms during 2010.

The reported health events were concentrated in three general areas of the state, with 10 of the 27 reported cases coming from one single body of water, Castle Rock Lake in Adams County. Reported symptoms fell into four general categories: dermal rashes, gastrointestinal distress, respiratory complaints, and flu-like illness. The majority of the reported cases involved direct exposure to the water—these individuals swam, or otherwise recreated in water experiencing an algal bloom. There were a small number of individuals who had no direct contact with affected waters who reported illness. Their symptoms were more consistent with non-specific flu-like illness; some experienced respiratory irritation.

Table N-1

Wisconsin's 2010 Harmful Algae Bloom Season

Body of Water	**# of Cases**
Castle Rock Lake	10
Tainter Lake	5
Lake Kegonsa	3
Lake Camelot	2
Lake Monona	1
Beaver Dam Lake	1
Peters Lake	1
Two Lakes South	1
Lake Petenwell	1
Green Lake	1
Lyman Lake	1

Case Reported By	**# of Cases**
Private Citizen	11
Wisconsin Poison Center	15
State Agency	1

Chief Health Complaint	**# of Cases**
Dermal Rash	5
Respiratory Irritation	2
Gastrointestinal Distress	15
Cold/Flu-like Illness (i.e. fever, nasal congestion, sore throat, etc.)	4

Geographic Distribution	**# of Cases**
Adams County	13
Dane County	4
Dunn County	5
Dodge County	1
Oneida County	1
Green Lake County	1
Douglas County	1
Walworth County	1

Source: Wisconsin Department of Health Services

Synopsis of 2009 Harmful Algal Bloom Season

During the summer and fall of 2009 the Wisconsin Department of Health Services received a total of 35 HAB-related health complaints. In addition to these 35 human health complaints, there were also at least two dog deaths resulting from exposure to harmful algal blooms.

These health events were widely distributed across the state. The cases can be broadly divided into two routes of exposure, the first group being comprised of individuals who swam, or otherwise recreated in water experiencing an algal bloom. The second group included individuals who had no direct contact with affected waters, and their symptoms were more consistent with non-specific flu-like illness; some experienced acute respiratory distress.

In the late summer of 2009, there were a number of significant algal mats on Tainter Lake and Lake Menomin, two highly-eutrophic lakes in Dunn County. As these mats began to decompose, they emitted a strong manure-like odor. In the first three weeks of September, many local residents complained of odor-related health problems such as flu-like illness, respiratory distress and gastrointestinal distress. In almost all cases, there were no reports of direct contact with either of the lakes.

Table N-2

Wisconsin 's 2009 Harmful Algae Bloom Exposure

Case Reported By	**# of Cases**
Private Citizen	32
Wisconsin Poison Center	2
Health Care Provider	1

Geographic Distribution	**# of Cases**
Adams County	4
Burnett County	1 (canine)
Dane County	4
Dunn County	17
Oneida County	1 (canine)
Racine County	1
Winnebago County	2

Symptoms	**# of Cases**
Dermal Rash	4
Acute Respiratory Distress	3
Gastrointestinal Distress	17
Cold/Flu-like Illness (i.e. fever, nasal congestion, sore throat, etc.)	14

Source: Wisconsin Department of Health Services

Table N-3

Wisconsin Cases Reported as Potential Algae-Related Illnesses Years 2009 &2010

Symptoms	Cases	% of Reported Cases
Dermal Rash	9	14.5
Respiratory Irritation	5	8.1
Gastrointestinal Distress	32	51.6
Cold/Flu-like Illness	18	29.0
Total Reported Cases*	**62***	

*Many cases included a combination of symptoms such as a rash and gastrointestinal distress. This explains why there are more symptoms than there are cases.

Source: Data Retrieved from DHS and Table Developed by Authors

Appendix O: Monte Carlo and Sensitivity Analysis

Table O-1

*Variable Inputs to the Monte Carlo**

Variable Inputs	Minimum	Maximum
Cost of lake cleanup ($)	4,760,690.00	11,447,974
Benefits to recreations ($)	542,835,098	650,607,924
Variable point source WAM costs ($)	18,604,960	223,259,521
Variable point source equipment costs ($)	0.00	952,488,012

*10,000 of trials are performed in Monte Carlo analysis

Lake cleanup uses a uniform distribution across the range.
Recreation benefits use a normal distribution across the range.
WAM costs uses a normal distribution, ranging from 4% to 48% with the peak being centered at 24%, concluded as being the most reasonable based on analysis and discussions with DNR personnel.
Variable point source equipment uses the inverse of the normal distribution in WAM costs due to the directly related and mutually exclusive nature of the equipment.

Source: Authors.

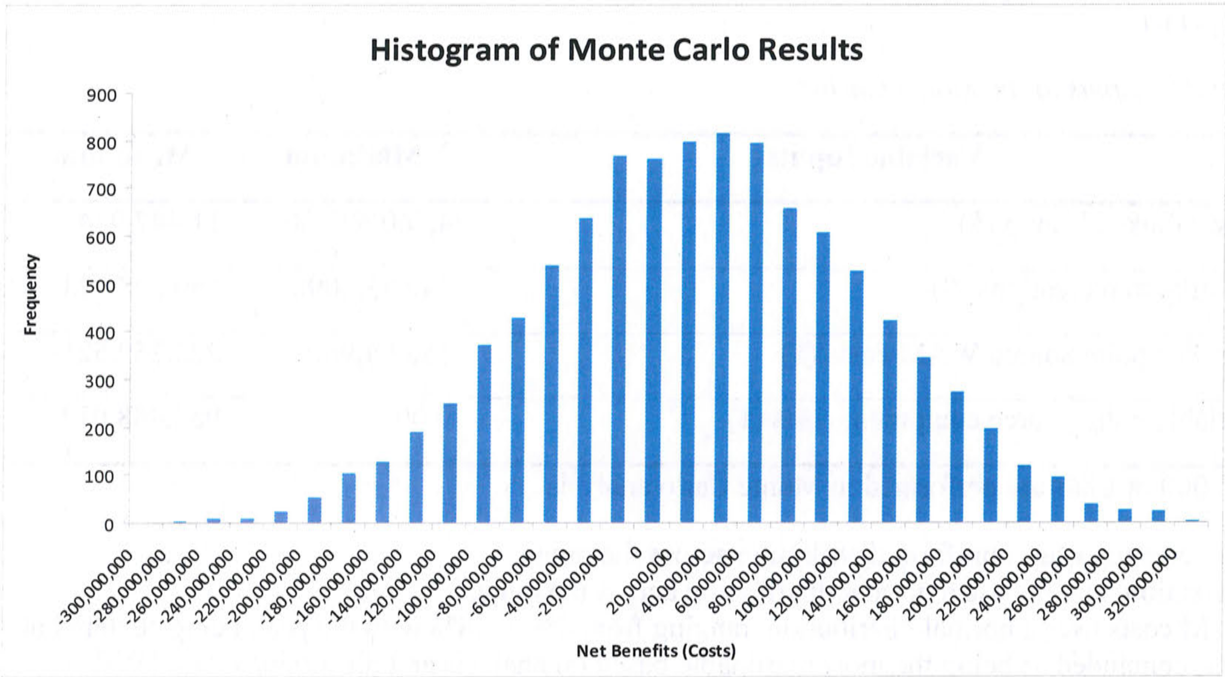
Table O-2

Fixed Inputs to the Monte Carlo

Fixed Inputs	Value
Discount rate (%)	3.50
Benefits to property value ($)	1,094,270,756
Fixed point source equipment cost ($)	1,082,208,462

Source: Authors

Figure O-1



Source: Authors.

Appendix P: Plain Language Analysis of ch. NR 102.06 and 217

The following is taken from the DNR's notice of public hearing (DNR 2010):

Plain language analysis of the rule:

The proposed rule has two parts. The first is a set of phosphorus water quality standards criteria for rivers, streams, various types of lakes, reservoirs and Great Lakes. The second is procedures for determining and incorporating phosphorus water quality based effluent limitations into Wisconsin Discharge Pollutant Elimination System (WPDES) permits under chapter 283, Stats. Pursuant to 40 CFR 131.11, states are required to adopt water quality standards criteria that are protective of the designated uses of surface waters. Pursuant to section 303(c)(4) of the Clean Water Act, EPA may step in and promulgate the criteria for the state, if the state does not. Development of point source permit procedures is required as part of the state's point source permit delegation agreement. EPA approval of state water quality criteria is required under 40 CFR ss. 131.5, 131.6 and 131.21.

Phosphorus Water Quality Standards Criteria

The proposed rule establishes phosphorus water quality criteria of 100 ug/l (parts per billion) for rivers specifically identified in the rule and of 75 ug/l for smaller streams and rivers. No criteria are proposed at this time for ephemeral streams or streams identified in ch. NR 104, Wis. Adm. Code as limited aquatic life waters. Both of the criteria are intended to prevent in-stream algae and other plant growth to the extent that is detrimental to fish and aquatic life. For example, extensive algae or macrophyte (large plants growing on the beds of streams) consume oxygen during the night to the extent that may leave too little oxygen for certain fish species and for certain aquatic insects. About half of Wisconsin's rivers and streams meet the proposed criteria.

For lakes and reservoirs, the proposed rule has a suite of criteria for five different types of lake ranging from 15 ug/l for lakes supporting a coldwater fishery, such as lake trout or cisco in its bottom waters, to 40 ug/l for shallow drainage lakes and reservoirs. The criteria are intended to prevent or minimize nuisance algal blooms; prevent shifts in plant species in shallow lakes; maintain adequate dissolved oxygen in the bottom of "two-story" lakes with a warmwater fishery in top waters and coldwater fisheries in bottom waters; and to maintain fisheries. "Toxic" algae concerns may also be addressed. For millponds and similar impoundments, the upstream river or stream criteria would apply. More than half of Wisconsin's lakes meet the proposed criteria with the percent varying by lake type. No criteria are proposed at this time for marsh lakes and other wetlands since they will be part of future wetlands nutrient criteria adoption.

For the Great Lakes, phosphorus criteria are proposed for the open waters of Lake Superior (5 ug/l), the open waters of Lake Michigan (7 ug/l) and the nearshore waters of Lake Michigan (7 ug/l). Presently, for the open waters both Lake Michigan and Lake Superior are meeting the criteria. For the nearshore waters of Lake Michigan, the zone from the beaches to a depth of 10 meters, where there are concerns with the Cladophora algal mats forming on beaches, the criteria may be exceeded in some locations.

Below is a table showing the proposed phosphorus water quality standards criteria by type of water body. The specific water body types are defined in the proposed rules, and there are some exclusions based on size or flow conditions.

Proposed Phosphorus Criteria by Type of Water Body	Total Phosphorus in ug/l
Listed rivers	100
All other streams	75
Stratified reservoirs	30
Non-stratified reservoirs	40
Stratified "two-story" fishery lakes	15
Stratified drainage lakes	30
Non-stratified (shallow) drainage lakes	40
Stratified seepage lakes	20
Non-stratified (shallow) lakes	40
Impoundments	Same as inflowing river or stream
Lake Michigan open and nearshore waters	7
Lake Superior open and nearshore waters	5

WPDES Effluent Standards and Limitations

The current regulations for phosphorus establish specific procedures for including technology based limitations and standards in WPDES permits (existing chapter NR 217). There is also an existing rule (s. NR 102.06) that generally states the department may establish water quality based limits for phosphorus in permits on a case-by-case basis using an evaluation of phosphorus sources in a watershed, but this rule is being repealed and replaced with a proposed new subchapter in chapter NR 217 that includes detailed procedures for establishing water quality effluent limitations for phosphorus.

Specifically, there are provisions for determining when a water quality based effluent limitation is needed in a WPDES permit; equations and procedures for calculating effluent limits based on different types of waters and stream flow assumptions; and provisions for expressing permit compliance averaging periods, such as a monthly average. The rule requires concentration limits, as commonly used in permits. However, it also specifies where and how mass limits are required, such as for discharges to impaired waters, where there is a downstream lake and where there is a downstream outstanding or exceptional resource water. The rule also addresses the relationship and procedures for including a various types of phosphorus limits in permits such as a phosphorus limit based on a total maximum daily load, a technology based phosphorus limit and a water quality based phosphorus limit calculated under the new procedures in chapter NR 217.

The proposed rule allows the department to include compliance schedules in permits. The compliance schedule provisions specify factors the department may consider when establishing the length of a compliance schedule. One of the options for a compliance schedule provision for discharges to nonpoint source dominated waters includes an adaptive management option where interim limits may be phased in, if phosphorus concentrations improve in the receiving water.

There are also provisions for a streamlined approach for processing variances for stabilization pond and lagoon systems that mimic the procedures for ammonia variances in ch. NR 106. These special provisions are based on the knowledge that presently there are few means to control phosphorus being discharged from these systems and that the construction of a mechanical plant is not affordable for smaller municipalities. The inclusion of streamlined procedures for stabilization pond and lagoon systems should not be interpreted to mean that these are the only systems that may obtain a variance, where appropriate. There are standard procedures for variances in statutory language and other administrative codes.

Summary of, and comparison with, existing or proposed federal regulation:

The proposed phosphorus criteria for streams of 75 ug/l and rivers of 100 ug/l are similar to EPA's guidance values for the southern half of Wisconsin. EPA recommended 70 ug/l of phosphorus for both rivers and streams in the southwestern driftless area of the state and 80 ug/l of phosphorus for both rivers and streams in the remainder of the southern half of the state. EPA, did however, recommend a criterion of 29 ug/l for a band or area stretching west to east though the middle of the state and 10 ug/l for the forested northern part of the state. All of the EPA guidance numbers are based on the 25th percentile of available data from a number of states and do not represent a cause-effect situation. We could not find concentrations as low at 10 ug/l even for pristine conditions in most of the forested northern portion of Wisconsin.

For lakes, the proposed criteria that range from 15 to 40 ug/l based on the type of lake are different than EPA's guidance values that range from 9.7 ug/l for northern lakes to 36 ug/l for driftless area lakes. EPA's guidance values are based on data from multiple states and represent the 25th percentile of available data. They do not differentiate based on the type of lake.

The proposed criteria for Lake Michigan and Lake Superior are the same as the values derived for the federal Great Lakes Water Quality Agreement.

The proposed WPDES permit procedures, including water quality based effluent limitations, are based on general EPA regulations and guidelines.

Comparison with similar rules in adjacent states:

All states, including adjacent states, are required by EPA to promulgate nutrient water quality standards criteria under EPA's Clean Water Act authority. In addition, all states delegated National Pollutant Discharge Elimination System permit authority by EPA, including all adjacent states, are required to issue point source permits that will meet water quality standards.

To date, Minnesota has promulgated phosphorus criteria for lakes which are very similar to what is proposed in this rule. Minnesota is now in the process of developing proposed criteria for rivers and streams. Illinois has had phosphorus criteria for lakes and Lake Michigan in its water quality standards for some years, but is in the process of developing phosphorus criteria for streams and rivers. Michigan and Iowa are developing criteria, but to date have not publicly proposed criteria. None of the adjacent states or Wisconsin has proposed criteria for nitrogen, except for ammonia.

All adjacent states have provisions for developing water quality based effluent limits, but none to date have proposed rules that specifically deal with the issues uniquely related to phosphorus.

Summary of factual data and analytical methodologies used and how any related findings support the regulatory approach chosen:

The proposed water quality standards phosphorus criteria for streams and rivers are based on results of a number of Wisconsin studies aimed at determining when biotic effects occur and how these effects relate to protection of designated uses. The primary studies were jointly conducted by department and USGS staff and their results are reported in "Nutrient Concentrations and Their Relations to the Biotic Integrity of Wadeable Streams in Wisconsin", USGS Professional Paper 1722, by Robertson, Graczyk, Garrison, Wang, LaLiberte and Bannerman, 2006; and "Nutrient Concentrations and Their Relations to the Biotic Integrity of Nonwadeable Rivers in Wisconsin", USGS Professional Paper 1754, by Robertson, Weigel and Graczyk, 2008. These studies identified a suite of breakpoints or thresholds for effects of phosphorus on algae, aquatic insects and fish. Based on discussions involving a number of experts in the scientific field, the department used an averaging method of the suite of breakpoints to derive the proposed criteria. These proposed criteria were compared to Department studies of trout streams in southwestern Wisconsin, the early 1980's Department study of phosphorus in streams and studies cited in EPA's "Nutrient Criteria Technical Guidance Manual: Rivers and Streams", EPA-822-B-00-002, 2000.

The proposed water quality standards phosphorus criteria for lakes and reservoirs are based on methods commonly used for decades in lake management in Wisconsin and adjacent states. Specifically, for most types of lakes, the proposed criteria are based on limiting the risk of nuisance algae conditions (20 ug/l chlorophyll a) to no more than 5 percent of the time (e.g. less than one week per year from June though September) using work by Walmsley (Journal of Environmental Quality, 13:97-104, 1988) and Heiskary and Wilson ("Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria", Minnesota Pollution Control Agency, September 2005). These concentrations were also determined to be sufficient to protect sport fisheries in lakes again using information from Heiskary and Wilson ("Minnesota Lake Water Quality Assessment Report: Developing Nutrient Criteria", Minnesota Pollution Control Agency, September 2005). For the relatively few lakes that support a cold water fishery in the lower waters, the department's objective was to maintain 6 mg/l for dissolved oxygen in the lower waters. To determine the appropriate phosphorus concentrations, the Department examined sediment cores and current water concentrations to determine undisturbed conditions. The proposed criteria were compared to literature information summarized in EPA's "Nutrient Criteria Technical Guidance Manual: Lakes and Reservoirs", EPA-822-B-00-001, 2000.

For development of the water quality based effluent limitation procedures for permits, the department reviewed existing state and federal regulations and guidance for the point source discharge permit programs, consulted with EPA representatives, and received input from a technical advisory committee that met several times in 2008 through 2009. The technical advisory committee was comprised of representatives of municipal and industrial wastewater dischargers, municipal storm water dischargers, agricultural interests, water user groups and environmental groups. Staff from EPA and USGS also attended committee meetings as advisories to the committee and the Department.