Development of a Watershed TMDL for the Lower Fox River Basin and Green Bay Area of Concern

Dean Maraldo[1]*, Nicole Richmond[2], Laura Blake[3]
(1: US EPA; 2: Wisconsin Department of Natural Resources; 3: The Cadmus Group, Inc.)
*US Environmental Protection Agency, Region 5
77 W. Jackson Blvd (WW-16J)
Chicago, IL 60604

ABSTRACT

The Lower Fox River (LFR) Basin and Green Bay Area of Concern (AOC) are impaired by excessive phosphorus and sediment loading, which leads to nuisance algae growth, oxygen depletion, lack of submerged aquatic vegetation, and water clarity problems. Although phosphorus is an essential nutrient for plant growth, excess phosphorus in the bay increases the occurrence of unwanted algae blooms, which can damage the ecology and aesthetics of the bay, impair swimming restrictions, and affect the economic well-being of the surrounding community. Excessive algae growth also depletes the supply of oxygen in the hypolimnion of the bay, endangering fish and other aquatic life. Excess sediments in the LFR Basin and Green Bay AOC reduce light availability to critical aquatic plants, restricting their ability to grow. Aquatic plants serve as vital habitat and food sources for fish, birds, frogs, turtles, insects, and other kinds of wildlife. They also produce life-giving oxygen, help stabilize bottom sediments, protect shorelines from erosion, and take up nutrients that would otherwise be available for nuisance algae growth. When aquatic plants die due to excess sediments in the river or bay, water quality is degraded. This paper will provide an overview of the approach being used to establish a phosphorus and total suspended solids (TSS) watershed TMDL for the LFR and Green Bay AOC, as well as a Watershed Management Plan (WMP) for the impaired waters within the boundary of the Oneida Nation Reservation. The overview will introduce some of the unique aspects of the TMDL development and implementation planning approach including stakeholder input, integration of Clean Water Act programs, use of BMP cost-effectiveness models and social science and marketing tools, and the identification of potentially restorable wetlands.

KEYWORDS

TMDL, TMDL implementation, nutrients, watershed approach

INTRODUCTION

The 638 mi^2 LFR Basin is located in northeastern Wisconsin and encompasses the following counties: Brown, Calumet, Outagamie, and Winnebago, and most of the Oneida Nation Reservation (Figure 1). The Lower Fox River drains into Lower Green Bay; the Green Bay AOC includes the downstream portion of the Lower Fox River north of the De Pere Dam to approximately 21 mi^2 of southern Green Bay out to Point au Sable and Long Tail Point. The

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Lower Fox River and Green Bay are important environmental and economic resources for the state, as well as the local community. People have long used the river and bay for transportation, commerce, energy, food, and recreation. Green Bay is the largest freshwater estuary in the world; the bay itself is an inflow to Lake Michigan. The wetlands along Green Bay's west shore, as well as the wetlands lining the Lower Fox River, provide critical fish spawning habitat for perch, northern pike, walleye, and spotted musky. The natural resources of the LFR Basin and Green Bay support popular recreational activities such as boating and fishing.

The Wisconsin Department of Natural Resources (WDNR) has given the LFR Basin and Green Bay AOC a high priority for the development of a total maximum daily load (TMDL) to address the phosphorus and sediment impairments. Three of the impaired segments in the basin are within the boundary of the Oneida Nation Reservation. A watershed plan will be developed simultaneously with the TMDL to address the phosphorus and sediment impairments on the segments within the boundary of the Oneida Nation Reservation.

Restoring water quality in the LFR Basin and Green Bay AOC will involve the implementation of multiple best management practices (BMPs) and other watershed management activities to address both nonpoint sources and point sources of phosphorus and sediment. Sources of phosphorus and sediment loading to the LFR Basin and Green Bay AOC include polluted runoff from nonpoint sources, such as pastures and crop land, rural and urban land, and construction sites and treated effluent from permitted municipal and industrial point source dischargers. Point source facilities have already begun to reduce their discharge of phosphorus as part of their permit requirements established by WDNR. While additional reductions from point source facilities may be needed to restore water quality in the river and bay, reducing phosphorus and sediment loading to the LFR Basin and Green Bay AOC will require significant reductions in polluted runoff from nonpoint sources.

Over the years, water quality issues have grown in complexity. As a result, addressing water quality issues requires an integrated problem-solving framework. The use of an integrated watershed approach increases the potential to achieve greater effectiveness in addressing complex water quality problems. This project utilizes the integrated watershed approach through the inclusion of stakeholder input, application of innovative technical approaches, integration of Clean Water Act programs, and examination of potential social barriers.

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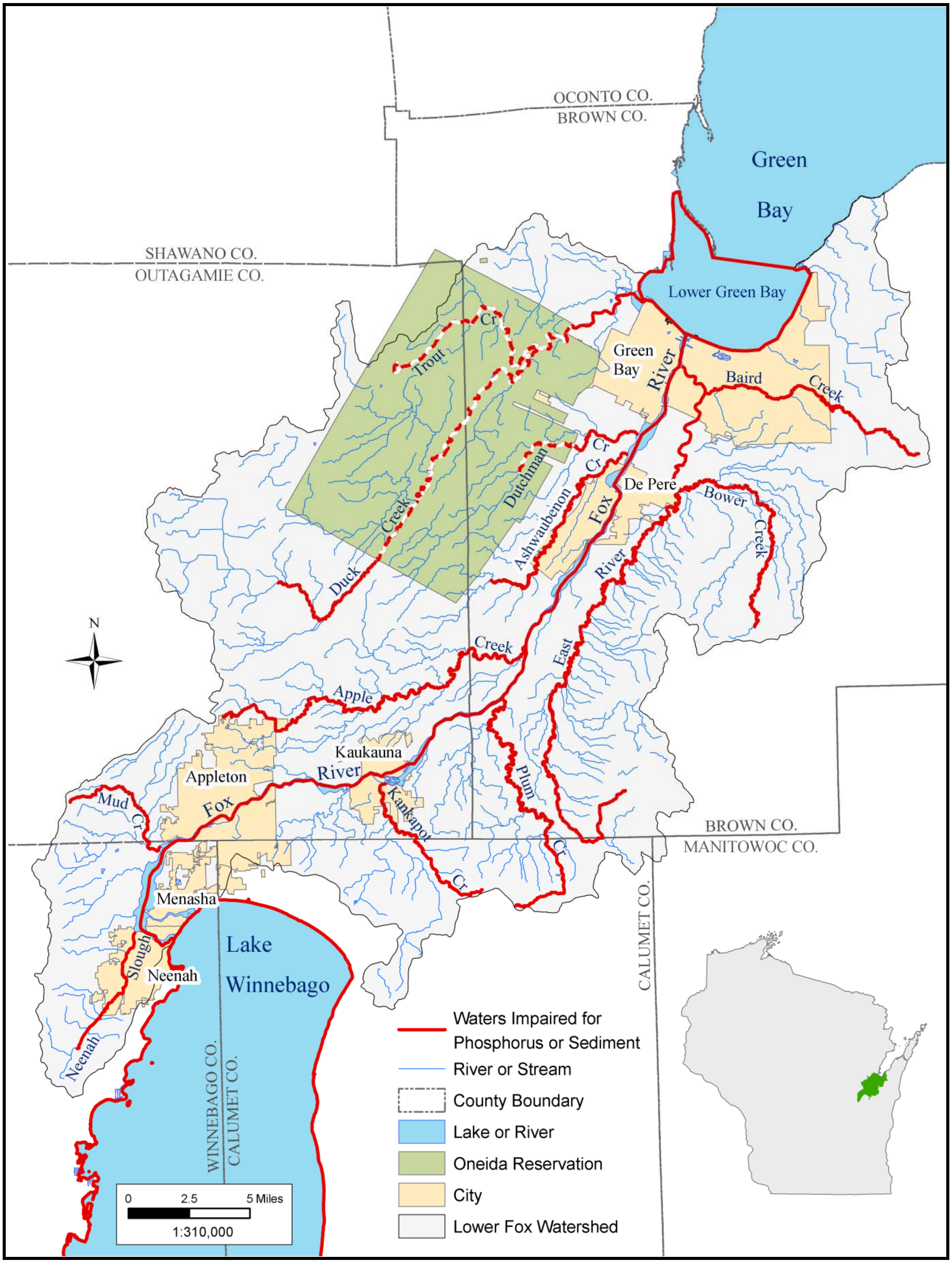
Figure 1. Map of the Lower Fox River Basin and Green Bay



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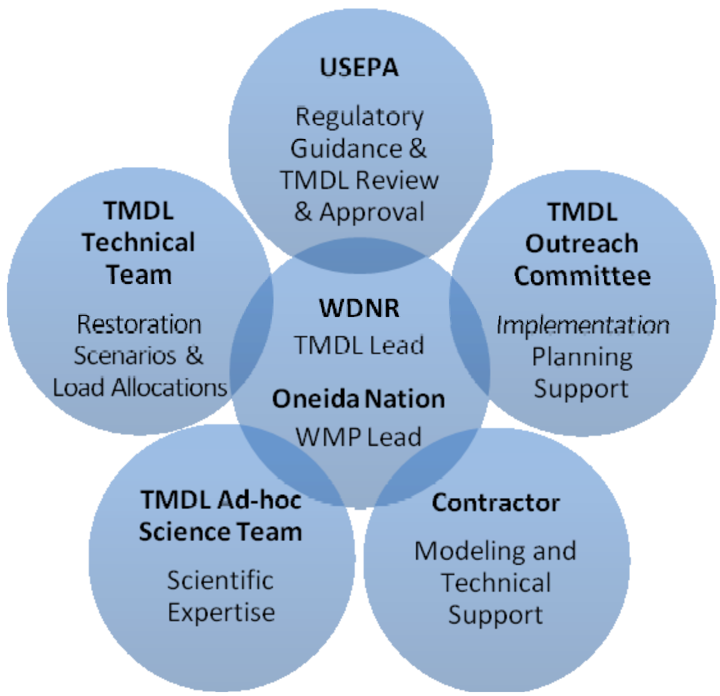
The Integrated Watershed Approach

Coordinated Stakeholder Input

The integrated watershed approach began with the formation of multiple workgroups responsible for carrying out specific elements of the TMDL process. Figure 2 illustrates the organizational structure and role of those involved with the TMDL for WDNR and the WMP for the Oneida Nation Reservation. The TMDL development process is led by WDNR, with guidance from EPA. Several committees have been formed to support the development and implementation of the TMDL and WMP: The *Outreach Committee*, the *Ad-Hoc Science Team*, and the *Technical Team*.

Figure 2. Organizational Structure for the Development of the TMDL and WMP



Outreach Committee: The *Outreach Committee* plays a key role in public and stakeholder outreach for both development and implementation of the TMDL. Objectives for this committee include but are not limited to: developing key messages, developing and implementing a communication and outreach strategy for TMDL development and implementation, and meeting with key stakeholder groups. The committee works closely with key stakeholders (agriculture, stormwater, industrial and municipal dischargers, etc.) to determine and analyze Best Management Practice (BMP) scenarios as part of the pollutant load reduction optimization modeling. Members of the *Outreach Committee* are asked to share any information gathered

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through outreach tools (media, stakeholder meetings, social indicators) with the TMDL Technical Team when considering the feasibility of the allocation and restoration scenarios.

The *Outreach Committee* includes representatives from various organizations but is not limited to WDNR, EPA, University of Wisconsin-Green Bay (UW-GB), UW-Extension, UW-Sea Grant, Oneida Nation, Brown County Land Conservation Department (LCD), and Green Bay Metropolitan Sewerage District (GBMSD).

Established in Fall of 2006, the *Outreach Committee* meets approximately every two months and has held a series of stakeholder outreach meetings to inform the community about the TMDL, answer questions, and listen to stakeholder concerns. Meetings of the *Outreach Committee* facilitated stakeholder discussions on the restoration and protection goals for the TMDL, including identification of potential sources of phosphorus and sediment loads to the watershed and bay.

Ad-Hoc Science Team: The role of the *Ad-Hoc Science Team* is to contribute local data and scientific expertise to set the numeric targets and restoration goals of the TMDL. The *Ad-Hoc Science Team* includes: staff from WDNR, UW-GB, UW-Milwaukee Water Institute, GBSMD, UW-Sea Grant, Oneida Nation and EPA. The *Ad-Hoc Science Team* held a series of discussions to analyze the numeric targets for the TMDL. The goal of the team was to support WDNR efforts to develop numeric TMDL targets for total suspended solids (TSS) and phosphorus (P) in the watershed. With the target selection process now complete the team is still available to provide scientific expertise to the Technical Team.

Technical Team: The role of the *Technical Team* is to evaluate and comment on various load allocation scenarios and restoration strategies that have been selected by WDNR. WDNR will consider comments from the technical team when deciding on the final methodology to ensure that the allocation scenario is feasible and will meet water quality standards.

Members were solicited for this team, from those attending various TMDL outreach meetings. However, due to the large number of people interested in participating, WDNR selected members from each key stakeholder group (county land and water conservation departments, stormwater consultants, point source facilities, agricultural producers, municipalities, etc.). Members with various backgrounds and interests were chosen to ensure broad representation. While the load allocations and wasteload allocations for the TMDL will be determined by the WDNR, the decision making process will be informed by the allocation scenario chosen by the *Technical Team*.

Technical Approach to Cost Optimization

The goal of this project was to develop TMDLs and design an optimization framework for identifying the optimal combination of watershed management practices (i.e., BMPs) for reducing phosphorus and sediment loading in the LFR Watershed and Green Bay AOC. A preliminary optimization analysis was completed for this project before TMDL development began with the goal of defining a cost-effective combination of BMPs that would result in a 50% reduction (or as close to 50% as possible) in phosphorus loading in the watershed.

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The analysis was accomplished using the Soil & Water Assessment Tool (SWAT) in conjunction with an Optimization Model (OptiMod) to compare multiple combinations of BMP scenarios along with their costs of implementation. Restoring water quality in the LFR Watershed and Green Bay AOC will need reduced loading from both agricultural and urban sources; however, the focus of the initial phase of this project was on agricultural BMPs and, to a lesser extent, potential reductions from industrial and municipal wastewater treatment facilities (WWTFs). OptiMod will be expanded upon during the development of the TMDL to also take into consideration costs of urban stormwater BMPs.

Integration of Clean Water Act Programs

Both regulatory Clean Water Act programs (e.g., point source facility permitting) and non-regulatory pollutant reduction measures (e.g., BMPs) were evaluated for their ability to reduce phosphorus and sediment loading in the LFR Watershed and Green Bay AOC. Taking into account both point and nonpoint sources of phosphorus and sediment loading reflects an understanding of the need to utilize a watershed-based approach to restore water quality in the watershed and bay. As the project proceeds to the final TMDL development phase, other Clean Water Act programs (e.g., stormwater permitting and wetlands) will be examined as additional means of reducing phosphorus and sediment loading in the watershed.

Consideration of Social Issues

Nonpoint source (NPS) pollution can often be traced back to the way humans use and change the natural environment (McDermaid and Barnstable, 2001). As a result, NPS implementation projects often require the need to influence human behavior. The *LFR Watershed and Green Bay AOC Outreach Committee* is conducting an assessment to identify socioeconomic indicators that will be used to gain a better understanding of the social systems that influence water quality in the LFR Watershed and Green Bay AOC. The use of social indicators in the planning process for the TMDL will help to gauge the potential effectiveness of the various BMPs that have outreach and behavior change components.

Social indicators can help resource managers understand the knowledge and skills needed by landowners in order to properly implement comprehensive nutrient management plans. They can also help to determine why certain populations will install BMPs when others will not, thus helping managers determine when a preliminary outreach component will be most useful. Social indicators can also be used to measure the environmental outcomes of NPS projects. For example, increasing a landowner's understanding of the benefits of using fertilizer containing lower levels of phosphorous may lead to their use of soil tests to modify the amount of phosphorus applied to a lawn or agricultural crops. Documenting intermediate outcomes, such as changes in the knowledge of a target audience, helps demonstrate accountability for the use of NPS funds (University of Wisconsin Extension, 2007).

Many of the BMPs necessary to achieve the phosphorus and sediment reduction goals for the LFR Watershed and Green Bay AOC will require voluntary cooperation from landowners. If landowners are expected to voluntarily implement the elements of a TMDL implementation plan, the plan must not only address ecological functions in the watershed, but also consider issues that

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directly impact the individual. The consideration of social issues in the TMDL planning process for the LFR Watershed and Green Bay AOC will increase the chances of successfully reducing pollutant loading from nonpoint sources through implementation of BMPs.

METHODOLOGY

Define Numeric Targets

WDNR has not yet promulgated numeric water quality criteria for phosphorus, nor do they have numeric criteria for sediment. However, a numeric target was needed for the TMDL and WMP in order to calculate reductions in phosphorus and sediment loading necessary to meet water quality objectives and protect designated uses. WDNR evaluated the best available relevant scientific data linking phosphorus concentrations to a myriad of biological responses that are representative of the fish and aquatic life communities of the Lower Fox River and Green Bay AOC, and has established water quality target values (in lieu of numeric criteria) for the TMDL. The University of Wisconsin Green Bay and the University of Wisconsin Sea Grant Institute (Harris, Sager & Qualls, 2009) recently established a relationship between TP and TSS levels and light extinction and secchi depth for the bay. The data used to establish this relationship were collected weekly at multiple sample stations in the Lower Fox River and zones 1 and 2 of Green Bay during the summer months (i.e., June through September), from 1993-2005 (post zebra mussel invasion). Through regression analyses, equations were developed to relate secchi depth to light extinction coefficients, and light extinction coefficients to TP and TSS concentrations. Between the years of 1993-2005, concentrations of total phosphorus (TP) in the river ranged from 60 to 740 µg/L (0.74 mg/L) with a median concentration of 180 µg/L (0.18 mg/L), while the median total suspended solids (TSS) concentration in the river was 36 mg/l (range varied from 15.5 to 175.5 mg/L).

Using this regression model, a 45% reduction in the baseline median TP and median TSS concentrations were estimated to result in an average light extinction coefficient of about 1.5, which translates to a secchi depth measurement of 1.14 meters (on average) for the bay.

WDNR's TMDL targets for P and TSS for the Lower Fox River and tributary streams are:

Tributary Streams in the Lower Fox River Basin	0.075 mg/l(TP)	TBD for each tributary stream (TSS)
Lower Fox River (main stem from the outlet of Lake Winnebago to the mouth of Green Bay)	0.10 mg/l(TP)	20 mg/l(TSS)
Lower Green Bay (Area of Concern) Narrative Target for the TMDL	Water clarity and other conditions suitable for support of a diverse biological community, including a robust and sustainable area of submersed aquatic vegetation in shallow water areas.	

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Assuming the numeric targets of 0.10 ug/L TP and 20 mg/L TSS will be met in the Lower Fox River, we expect a biological response of increased water clarity and other conditions suitable for support of a diverse biological community, including an expanded area of beneficial submerged aquatic vegetation (SAV) levels in the bay. Other benefits from reaching upstream targets in the Lower Fox River include: an increased area of littoral zone habitat for fish and invertebrates, reduced density and frequency of nuisance blue-green algae blooms, increased water clarity for recreational uses, and increased dissolved oxygen concentrations that will benefit fish and aquatic life uses. The targets chosen reflect what is both feasible and reasonable to meet water quality restoration goals.

Loading Analysis Using SWAT

The SWAT model was selected to simulate phosphorus and sediment loading in the watershed, including the estimated load reductions associated with the implementation of the agricultural BMPs. SWAT is a distributed parameter, daily time-step model that was developed by the U.S. Department of Agriculture - Agricultural Research Service (USDA-ARS) to assess nonpoint source pollution from watersheds and large complex river basins (Arnold, Williams, Srinivasan, & King, 1996; Neitsch, Arnold, Kiniry, & Williams, 2001). With SWAT, a large heterogeneous river basin can be divided into hundreds of subwatersheds; thereby, permitting more realistic representations of the specific soil, topography, hydrology, climate and management features of a particular area. Crop and management components within the model permit reasonable representation of the actual cropping, tillage, and nutrient management practices typically used in northeastern Wisconsin. SWAT also utilizes the QUAL2E in-stream sub-model to simulate nutrient transport.

Identify Restoration Scenarios

WDNR, the Oneida Nation Reservation, and the Technical Team will identify potential restoration scenarios to analyze with the load reduction optimization modeling framework. Both agricultural and urban stormwater best management practices (BMPs), as well as point source facility upgrades will be considered. The agricultural BMPs evaluated in the initial phase of this project have been reevaluated; and additional agricultural BMPs have been identified for inclusion in the optimization analysis. WDNR, the Oneida Nation Reservation, and the *Technical Team* will also identify urban stormwater BMPs to include in the optimization analysis.

WDNR, the Oneida Nation Reservation, and the *Outreach Committee* had preliminary discussions with stakeholders to discuss BMP options and assess the potential for implementation success based on the BMP’s feasibility, acceptability, and sustainability. Many of the BMPs necessary to achieve the phosphorus and sediment reduction goals for the LFR Basin and Green Bay AOC will require voluntary cooperation from landowners. The *Outreach Committee* has been conducting an assessment to identify socioeconomic indicators to gain a better understanding of the social systems that influence water quality in the LFR Basin and Green Bay AOC. The results of the social indicators work will be used to help to gauge the potential effectiveness of the various BMPs that have outreach and behavior change components.

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The final list of BMPs and other restoration scenarios will be included in the cost and load reduction optimization analysis, ultimately supporting the final TMDL implementation plan.

Perform Cost Analysis of Restoration Scenarios

Site-specific (i.e., local) total annual costs associated with implementation of each of the agricultural and urban stormwater BMPs in the LFR Basin will be calculated. This estimate will include all costs associated with the BMP, including implementation expenses and costs associated with incentives (e.g., provided by the government or other agency). Costs will also take into account both initial implementation costs and annual operation and maintenance (O&M) costs. In 1991, the Southeast Wisconsin Regional Planning Commission (SEWRRC) prepared a technical report entitled "Costs of Urban Nonpoint Source Water Pollution Control Measures," which includes estimated costs for urban BMPs. The costs of some of the BMPs in this report (i.e., those selected by WDNR, the Oneida Nation Reservation, and the *Outreach Committee*) will be updated to reflect current costs. WDNR will seek cost data from municipal and industrial dischargers in the Lower Fox River Basin, and if time permits, to the best extent, incorporate these costs into the analyses. This information may be used in developing the implementation plan for the TMDL and the WMP.

BMPs have varying lifetimes; therefore all costs will be reduced to their annual values. Annualizing BMP costs provides a means of comparing BMPs by cost and supplying cost values that can be utilized in conjunction with average annual TP and TSS load reduction estimates associated with the BMPs to identify the optimal combination of BMPs. Further, current estimated costs associated with point source facility upgrades (including O&M costs) will be calculated. This information will be incorporated into the implementation plan for the TMDL and WMP.

Perform Load Reduction Optimization Analysis

The project will utilize a watershed-level optimization modeling framework for determining the optimal combinations of BMPs and potential point source facility upgrades for reducing TP and TSS loading in the LFR Basin and Green Bay AOC. Site-specific BMP and point source facility upgrade costs will be used, in conjunction with estimated load reductions (from SWAT) associated with implementation of the BMPs and facility upgrades, to identify the ten most cost-effective combinations of implementation scenarios that achieve the TMDL targets for TP and TSS. The optimization analysis will be conducted using SWAT in conjunction with the OptiMod model. Figure 3 illustrates the optimization modeling framework.

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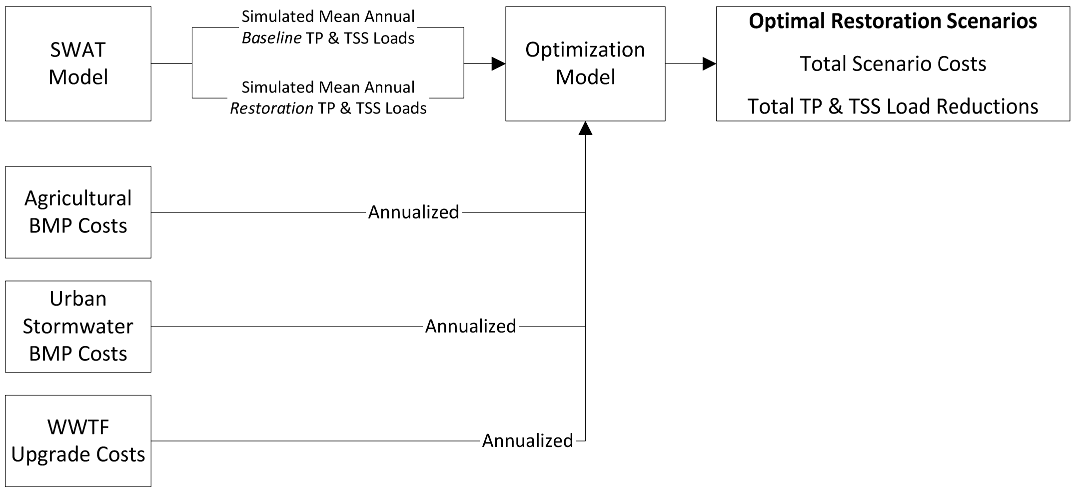
Figure 3. Pollutant Load Reduction Optimization Modeling Framework



During the initial phase of this project, only agricultural BMPs were considered in the analysis. OptiMod will be expanded upon to also take into consideration urban stormwater BMPs, as well as permitted point source dischargers. The refined OptiMod will have the capabilities to find "optimal" solutions to all of the following:

- The optimum combination of agricultural BMPs to reduce loading (by a given amount or percent) from just agricultural sources
- The optimum combination of urban stormwater BMPs to reduce loading (by a given amount or percent) from just urban sources
- The optimum combination of point source facility upgrades to reduce loading (by a given amount or percent) from just point source facilities
- The optimum combination of approaches to reduce loading (by a given amount or percent), taking all three (i.e., agricultural BMPs, urban BMPs, and point source facility upgrades) into consideration.

In addition to being able to find the optimal solutions for all of the above cases, the refined Optimization Model will also be able to optimize for just phosphorus, just sediment, and phosphorus and sediment combined. The most cost effective combinations of restoration scenarios that achieve the TMDL targets for TP and TSS will be identified and WDNR and Oneida Nation will choose the final scenario to serve as the basis for the implementation plan for the TMDL and WMP.

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Identify Potentially Restorable Wetlands

The project team will map potential wetland restoration sites using the methodology developed by WDNR and applied to the Rock River Basin in Wisconsin. Mapping potentially restorable wetlands provides the essential context for wetland assessment and planning at the watershed scale. The analysis will involve the use of hydric soils and current wetland inventory data layers to generate several key wetland attributes. The total area of hydric soils in a watershed or planning area provides an estimate of the "original" wetland acreage of the watershed. Areas with soils that once supported wetlands but are no longer wetlands are considered to be "lost" wetlands. After screening out these areas of limited restoration potential, such as locations in highly urbanized areas, the remaining areas are considered to be "*potentially* restorable wetlands," or PRWs.

The relative amounts of original lost, remaining, and PRW acres compared across the watersheds of a basin or parts of a larger planning area can be used for various types of "rough cut" optimization planning analyses. Alternative future land use scenarios can be generated that compare existing wetland sediment trapping to future conditions after restoration of all PRWs. Comparison of the relative gain in function allows the planner to target optimal areas for restoration. Watershed maps will be used to illustrate the results of the analysis (e.g., the location of the potentially restorable wetland sites). This analysis will be incorporated into the implementation plan for the TMDL and WMP.

RESULTS

The final TMDLs and WMP for LFR Basin and Green Bay AOC will be completed in 2010. Preliminary modeling completed as part of the initial phase of the project resulted in the identification of an optimal BMP scenario to support the development of the TMDL implementation plan. The Lower Green Bay Remedial Action Plan (1993) phosphorus load reduction goal of 50% was used as the overall reduction target for the initial BMP optimization modeling effort. Optimization modeling for the final TMDL implementation plan will be based on the TMDL phosphorus and sediment targets identified by WDNR.

Implementation of the *Optimal Scenario* of agricultural BMPs in the LFR Basin results in an estimated phosphorus load reduction of about 50,000 kg/yr (21%). Potential point source facility upgrades in the LFR Basin results in an estimated phosphorus load reduction of 45,045 kg/yr (19%). These potential reductions combined results in an estimated 40% decrease in phosphorus loading to Lower Green Bay (from 238,912 kg to 143,700 kg per year). While the 50% reduction goal was not achieved during the preliminary modeling phase, potential load reductions from urban stormwater BMPs were not considered. Also, as revealed during the analysis, the list of agricultural BMPs will be expanded upon to meet the 50% reduction goal.

The preliminary optimization model (US EPA, 2007) provided cost estimates for implementation of the *Optimal Scenario.* The cost of implementing all of the agricultural BMPs associated with the *Optimal Scenario* in the LFR Basin is $6.9 million per year, or about $138 per kilogram of total phosphorus reduced from agricultural nonpoint sources. The total estimated cost associated with point source facility upgrades in the LFR Basin is $10.8 million a year (on average), or

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about $240 per kilogram of total phosphorus reduced from point sources. The total cost of implementing the *Optimal Scenario* of agricultural BMPs and upgrading point source facilities in the entire LFR Basin is estimated to be $17.7 million per year, or $186 per kg of total phosphorus reduced.

As the preliminary analysis shows, applying a 50% reduction to all source categories (i.e., both point sources and nonpoint sources) may not be the most cost-effective strategy, as agricultural BMPs achieve the greatest phosphorus load reductions at the lowest cost. The final TMDL implementation plan will include a point source optimization tool, which will be incorporated into OptiMod and used to assess the cost-effectiveness of implementing nonpoint and point source facility controls and practices.

DISCUSSION

The integrated watershed approach used in the development of the LFR Watershed and Green Bay AOC TMDLs follows EPA's watershed approach framework (1996). The watershed approach is based on three guiding principles including partnerships, geographic focus, and the use of sound management techniques based on strong science and data. The LFR and Green Bay AOC TMDL process began in 2006 with a small group of interested individuals and now includes dozens of people representing the public, private, and non-profit sectors. Project partners are involved multiple workgroups and committees responsible for carrying on specific elements of the TMDL process as described above. In line with the watershed approach the TMDL process involves modeling and planning efforts at multiple scales, allowing stakeholders to engage in the process at various levels.

Another unique aspect of the LFR and Green Bay TMDL process is the upfront involvement of multiple water programs at the state and federal levels including nonpoint source, permits, and wetlands programs. The combination of program integration, coordinated stakeholder involvement, and the use of sound scientific tools and data will increase the potential to achieve greater effectiveness in addressing complex water quality problems through the TMDL process.

CONCLUSIONS

The tools developed for this demonstration project will continue to be used as part of the development of the TMDL for the LFR Watershed and Green Bay AOC. Further, the project partners will continue to utilize and an integrated watershed approach for developing the TMDL. Such an approach allows for the inclusion of previous and ongoing efforts, integrates multiple programs and approaches to restoring water quality, and also takes into consideration multiple stakeholder perspectives. The result will be a well-informed, concerted effort to restore water quality in the LFR Watershed and Green Bay AOC.

As illustrated in the preliminary modeling analysis, restoring water quality in the LFR Watershed and Green Bay AOC will require point source upgrades, as well as the extensive implementation of multiple BMPs and other watershed management activities to address nonpoint sources,

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including loading from urban stormwater runoff, which was not considered in this analysis, but will need to be during development of the TMDL. Implementing BMPs and upgrading point source facilities will require a significant amount of resources. The elements of the watershed approach applied in the LFR and Green Bay TMDL process, including coordinated stakeholder input, integration of Clean Water Act programs, the use of BMP cost-effectiveness models, social science and marketing tools, and the identification of potentially restorable wetlands will help managers to identify the most practical and cost-effective combination of agricultural BMPs, stormwater BMPs, and point source upgrades necessary to meet water quality goals for the LFR Watershed and Green Bay AOC.

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