Wetlands Restoration Strategy

A Framework For Prioritizing Efforts in Minnesota

January 2009

Supplement to the Minnesota Wetlands Conservation Plan 1997

Minnesota Department of Natural Resources

Minnesota Department of Transportation

Minnesota Board of Water & Soil Resources

Minnesota Department of Agriculture — From the Farm to Your Family

Minnesota Pollution Control Agency

TABLE OF CONTENTS

Minnesota Board of Water and Soil Resources
January 2009
520 Lafayette Road North
St. Paul, Minnesota 55155
Phone: (651) 296-0884 ■ Fax: (651) 297-5615 ■ TTY: (800) 627-3529
www.bwsr.state.mn.us

Wetlands Restoration Strategy for Minnesota

Overview

This strategy was developed to provide a statewide perspective and improved approach for restoration of wetlands. State and federal agencies, local government units, and non-governmental organizations combine and coordinate their efforts to achieve the shared goal of greater net gains in wetland functional benefits. The long-term vision for this strategy is:

> **Minnesotans will enjoy significant improvements in habitat, water quality, surface water flows, and ground water interactions that are attributable to wetlands restoration.**

Key elements of this statewide wetlands restoration strategy are:

- Prioritize restorations based on desired outcomes — specifically water quality improvements, habitat gains, flood damage reduction, and other hydrologic benefits
- Improve coordination of wetlands restoration efforts
- Design and produce better wetland restorations that stand the test of time, and provide lasting functional benefits

Prioritization is the heart of this strategy because financial resources are limited and must be used where there is the greatest return on our investment. Regardless of available resources, choices will always have be made. Greater strides can be made if wetland restorations are prioritized according to their potential for delivering functional benefits needed on the landscape and in Minnesota communities.

A wetlands restoration strategy provides guidance for strategic decision making by a variety of government officials, land and water managers, and non-governmental organizations. The approach is to restore wetlands in order to gain functional benefits that are valued and needed in watersheds and communities and for Minnesota citizens. Wetlands restoration is one of many management tools available to resource managers and decision makers.

This strategy emphasizes the need to strategically target public funding for wetlands restoration to sites that provide the greatest environmental benefits at a landscape, watershed, or flyway scale. It is also important, however, to recognize the desire of many private landowners to restore wetlands for the site-scale benefits they provide—on sites that may or may not be considered high-priority by government programs—and to acknowledge landowners' considerable investment in wetland restoration projects.

This wetlands restoration strategy is consistent with the Minnesota Statewide Conservation and Preservation Plan, July 2008 (SCPP). The two documents were developed during the same time frame and the correlation between them is noteworthy. The SCPP emphasizes the importance of prioritizing wetland restorations to achieve desired outcomes.

This strategy recommends developing a prioritization methodology that uses identified restorable wetlands as a base layer to which filters may be applied to prioritize certain potential restoration sites. The concept of prioritization is to narrow the sometimes daunting number of possible wetland restoration sites in a given watershed down to a manageable set of choices based on their ability to positively affect any of three primary categories of functional benefits: water quality improvement; wildlife habitat improvement; and water quantity management. Furthermore, 21 specific strategies are outlined to support this prioritization approach.

Wetlands Restoration Strategy for Minnesota

Strategic Vision for Wetland Restoration in Minnesota

Wetlands provide important landscape functions in Minnesota including fish and wildlife habitat, improving water quality, flood damage reduction, and ground water recharge. In the past 100 to 200 years the majority of wetlands in most of Minnesota have been converted to agriculture or development.

This strategy was developed to provide a statewide perspective and improved approach for restoration of wetlands. State and federal agencies, local government units, and non-governmental organizations combine and coordinate their efforts to achieve the shared goal of greater net gains in wetland functional benefits. The long-term vision for this strategy is:

> **Minnesotans will enjoy significant improvements in habitat, water quality, surface water flows, and ground water interactions that are attributable to wetlands restoration.**

This vision is grounded in state policies for no net loss and improvement established in *Minnesota Statutes*, section 103A.201, subd. 2 (b):

> The legislature finds that the wetlands of Minnesota provide public value by conserving surface waters, maintaining and improving water quality, preserving wildlife habitat, providing recreational opportunities, reducing runoff, providing for floodwater retention, reducing stream sedimentation, contributing to improved subsurface moisture, helping moderate climatic change, and enhancing the natural beauty of the landscape, and are important to comprehensive water management, and that it is in the public interest to:
>
> (1) Achieve no net loss in the quantity, quality, and biological diversity of Minnesota's existing wetlands
>
> (2) Increase the quantity, quality, and biological diversity of Minnesota's wetlands by restoring or enhancing diminished or drained wetlands

The Governor's Clean Water Cabinet's interpretation of these policies in February 2006 set the stage for developing this state wetlands restoration strategy:

> We will protect, restore, and enhance the values and benefits Minnesotans receive from wetlands, adding to their quantity, quality and biological diversity. We will do this by coordinating spending, policy, and partnerships to implement our priority strategies. We will target restorations to enhance wetland values and optimize benefits, recognizing regional differences and strategically locating mitigation sites, banking sites and voluntary restorations. We will coordinate and integrate local, state, and federal regulation and restoration to provide clear direction, increase efficiency, improve accounting, promote participation, and improve environmental benefits. We will engage interested Minnesotans and leverage partnerships to ensure the success of these efforts.

Strategic Approach to Wetlands Restoration

Key elements of this statewide wetlands restoration strategy are:

- **Prioritize restorations based on desired outcomes — specifically water quality improvements, habitat gains, flood damage reduction, and other hydrologic benefits**
- **Improve coordination of wetlands restoration efforts**
- **Design and produce better wetland restorations that stand the test of time, and provide lasting functional benefits**

Prioritization starts with identifying desired outcomes (functional benefits gained by restoring wetlands) and potentially restorable sites. That information will inform the decisions of government officials, project partners, and landowners, along with other decision tools like local and state plans for land use, water, and economic development. This strategy recommends prioritizing restoration opportunities that will produce the greatest singular or multiple benefits and focuses on the functional benefit categories of water quality, wildlife habitat, and hydrologic functions. Other outcomes may also be factored in depending on the circumstances and preferences (e.g., climate change; carbon sequestration).

IMPORTANCE OF PRIORITIZING

Prioritization is the heart of this strategy because financial resources are limited and must be used where there is the greatest return on our investment. Wetland restorations throughout Minnesota occur on public and private lands for a variety of reasons. Wetland restoration planning and implementation usually depend on many factors that vary by location, conditions on site and in the watershed, and public preferences. Furthermore, funding and technical resources for wetland restorations are often not coordinated and will never be as great as the potential for restoration. Greater strides can be made if wetland restorations are prioritized according to their potential for delivering functional benefits needed on the landscape and in Minnesota communities.

Prioritization means identifying which wetland restorations are most effective at filtering different types of surface water pollutants, providing different types of aquatic and wildlife habitat, reducing flood damage, and other desired outcomes,

so that → We can prioritize wetland restorations for targeted outcomes

so that → Decision makers can use limited funding more effectively

so that → Wetland restorations play a more effective role in resource management efforts

so that → Minnesotans benefit from good water quality and abundant fish and wildlife

IMPROVING COORDINATION AND RESULTS

A wetlands restoration strategy provides guidance for strategic decision making by a variety of government officials, land and water managers, and non-governmental organizations. The approach is to restore wetlands in order to gain functional benefits that are valued and needed in watersheds and communities and for Minnesota citizens. Wetlands restoration is one of many management tools available to resource managers and decision makers.

The strategic vision for wetlands restoration can be accomplished through both local and state efforts on environmental and economic planning and development. While much work has been done on regional restoration acreage targets for waterfowl habitat, prioritization related to water quality and other desired outcomes are so location-specific that statewide targets can be, at best, an aggregate of local and regional decision making. It is important to note that regulatory mitigation for new wetland impacts is governed by specific rules and procedures that take precedence over this strategy. However, this strategy can inform decisions about restoring wetlands in mitigation situations.

ACKNOWLEDGING LANDOWNERS' ROLE AND PERSPECTIVES

This strategy emphasizes the need to strategically target public funding for wetlands restoration to sites that provide the greatest environmental benefits at a landscape, watershed, or flyway scale. It is also important, however, to recognize the desire of many private landowners to restore wetlands for the site-scale benefits they provide—on sites that may or may not be considered high-priority by government programs—and to acknowledge landowners' considerable investment in wetland restoration projects.

For example, since the late 1980s, Minnesota landowners have voluntarily restored more than 500,000 acres of wetlands and surrounding upland buffers on privately owned farmlands with help from government programs. Nearly 35% of these restored acres are protected by permanent easements. Landowners have invested significantly in these restorations. In one cooperative program alone (Conservation Reserve Program) landowners' estimated out-of-pocket share of the cost of wetland restoration projects since 1997 exceeds $18 million (Minnesota Department of Agriculture, 2007). Additionally, an unknown number of voluntary wetland restorations have been financed entirely by landowners and/or private organizations.

This strategy is not meant to discourage private wetland restoration efforts but, rather, to encourage government agencies to adopt a more strategic approach in deciding which of several potential restorations to fund with taxpayer dollars. Also, since private landowners are key partners in achieving wetland functions and values at the landscape or watershed scale, it is important for programs that fund wetland restorations—without sacrificing high standards for restoration design and implementation—to be flexible enough to meet reasonable needs of landowners.

CONSISTENCY WITH MINNESOTA STATEWIDE CONSERVATION AND PRESERVATION PLAN

This wetlands restoration strategy is consistent with the Minnesota Statewide Conservation and Preservation Plan, July 2008 (SCPP). The two documents were developed during the same time frame and the correlation between them is noteworthy. Each of the following selected quotes from the **SCPP** emphasizes the importance of prioritizing wetland restorations to achieve desired outcomes:

> **Habitat Recommendation 5: Restore Land, Wetlands, and Wetland-Associated Watersheds**
> "Minnesota must invest in prioritized areas to restore degraded and rare land features, wetlands (especially the many that have been drained and converted), and watershed associated with wetlands. This will provide benefits for wildlife, species of greatest conservation need, water quality, and important ecological processes." [pg. 74]
>
> **Habitat Recommendation 8: Review and Analyze Drainage Policy**
> "The LCCMR should invest in a comprehensive review and analysis of existing Minnesota statutes relating to drainage...and make recommendations to the legislature that remove barriers and better facilitate the restoration of critical wetlands in order to improve water quality and aquatic habitats." [pg. 81]
>
> **Land Use Strategy 2: Reduce streambank erosion through reductions in peak flows**
> "Invest in strategically targeted programs for reduction of peak flows through increased water detention in agricultural drainage systems, including wetland construction and restoration, in-ditch storage, and conservation drainage. Targeted drainage water detention will reduce peak flows and attendant streambank erosion. It will also reduce sediment and nutrient contributions from uplands through sediment deposition and denitrification." [pp. 122-123]

General Principles

- **Wetlands provide well-established environmental and economic benefits**
- **Restoration of depressional wetlands with long retention times can be a leading priority when water quality, flood water retention, and wildlife habitat outcomes are needed**
- **Riverine wetlands restoration can be a priority when floodwater retention, wildlife habitat, and certain water quality outcomes are needed within river and stream corridors**
- **Restorations in the upper reaches of tributaries within watersheds generally provide the greatest benefits**
- **Wetland restorations for ground water recharge can be a priority anywhere in the state**

The benefits of wetland functions and values for fish and wildlife habitat, surface water quality, floodwater reduction, and ground water recharge are well-established, but opportunities to restore wetlands vary widely across the state. Regardless of the region, opportunities to restore and protect wetlands that contribute to ground water recharge should be a priority. Its importance for a) potable drinking water, b) the long-term timetable for recharge (decades to centuries?), and c) the potential for long term water storage, makes this a priority.

In general, the most effective restorations for ground water recharge are depressional wetlands without outlets or any wetlands with lengthy retention times. When local information is available on important recharge areas it should be used to help prioritize restoration opportunities.

Depressional wetlands with long retention times are also generally the highest value for improving surface water quality, floodwater retention, and wildlife habitat. When the possibility exists for undesirable fish to invade the restored wetland, fish barriers should be an important restoration design criteria.

Riverine wetland systems are also important as a component of stream or river corridors that provide multiple benefits. Restoring watercourses is important statewide, particularly those with adjacent permanently vegetated floodplain corridors.

Wetland restorations that provide the most benefit tend to be in the upper reaches of watersheds. In general, the lower in a watershed that a wetland restoration occurs (as the watershed to restored wetland acre ratio increases) the relative value to ground water retention, surface water quality and wildlife habitat decreases. This is due largely to the difficulty of sustaining wetland quality and functions when wetlands receive excessive runoff and sediment. Prioritizing restorations adjacent to permanent upland native vegetation and a wetland complex that includes a diversity of wetland types will minimize that problem.

SCOPE OF THE STRATEGY

The goal of restoring wetlands is to restore environmental benefits lost due to wetland conversion or degradation. This strategy therefore includes wetland restoration via re-establishment and rehabilitation, and in some cases wetland enhancement, but not wetland creation. Each of these activities is defined below for the purposes of this strategy. The definitions are similar to those recently published in rule for the Clean Water Act Section 404 program (33 CFR section 332.2).

Activity	Included in this strategy?
RESTORATION involves re-establishment or rehabilitation (further defined below) at the site of a former or degraded wetland, with the goal of restoring natural, historic wetland functions. **RE-ESTABLISHMENT**: Restoring wetland functions lost due to conversion of a wetland that existed within the last 100-200 years. Provides a gain in wetland acres. **REHABILITATION**: Repairing or increasing the functionality of an existing degraded wetland. Does not provide a gain in wetland acres.	**Yes**
ENHANCEMENT involves heightening, intensifying or improving a single, specific function of an existing wetland, potentially to the detriment of other functions. It does not provide a gain in wetland acres.	**Yes**
CREATION involves converting an upland site to a wetland where no wetland has existed within the last 100-200 years. While it may provide a gain in wetland acres and functions, it is not considered a “restoration” activity.	No

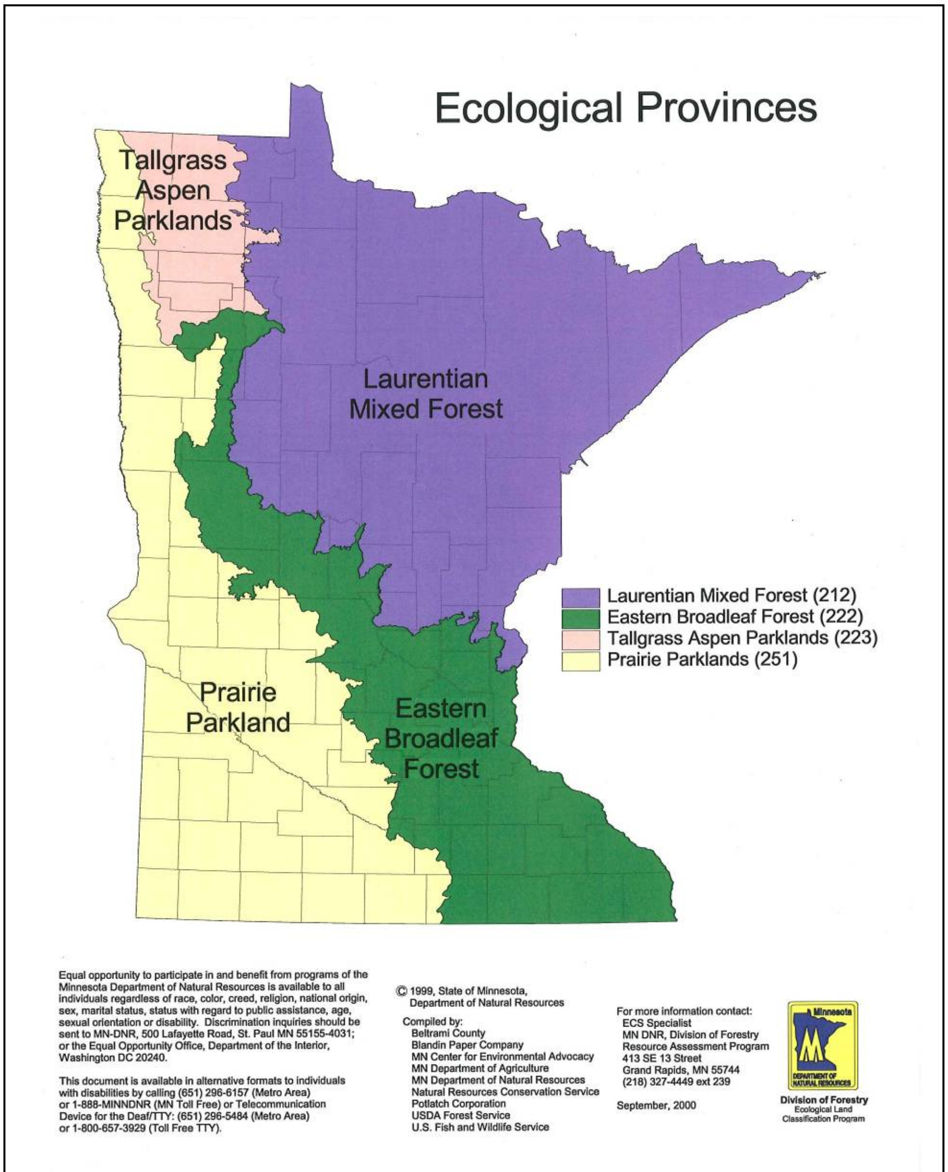
STATEWIDE GOALS FOR WETLANDS RESTORATION

The *Minnesota Wetlands Conservation Plan 1997* (MWCP) lacked a wetlands restoration strategy — a gap that is now filled by this strategy supplement. The MWCP listed two general wetland management strategic goals for broad regions of the state:

Net gain through restoration of wetland functions is the general wetland management goal for the ecological provinces experiencing conditions of degraded water quality, hydrologic instability, and degraded or lost fish and wildlife habitat. These areas include the Prairie Parkland, Tallgrass Aspen Parklands, and Eastern Broadleaf Forest provinces.

Maintaining the high quality of existing wetland resources is the primary wetland management goal in the northeastern Laurentian Mixed Forest province. There are still benefits to be gained from wetlands restoration in the northeastern part of the state, as noted in the following section.

Figure 1. Ecological provinces map



Identifying Desired Outcomes

The following chart lists general desired outcomes that could be attained through wetlands restoration, with acknowledgement of regional differences. Desired outcomes from restoring wetlands will vary depending on the degree of wetland loss over the last 100-200 years and on local conditions that can be positively impacted by wetland restoration. Some kinds of restoration outcomes are less relevant in areas of the state that have experienced little overall loss of wetlands. This is not an exhaustive list of potential desirable outcomes, which can and should be described more precisely as identified at the local level of scale.

Where there has been since the late 1800s:

HIGH LOSS .... ***vs.*** .... **LOW LOSS**

The appropriate overall management goal is:

Net gain in functional benefits..................................**Existing functional benefits maintained**

PRIMARY FUNCTIONS	***Desired outcomes from wetlands restorations:***	
WATER QUALITY	*This outcome may be needed regardless of location:* Cleaner surface water, as characterized by: • Reduced sediment and nutrient loads reaching water bodies • Decreased compaction of soils • Increased assimilation of nutrients within watercourse corridors • Maintenance of biological diversity (flora and fauna) and native plant communities	
	These outcomes may be needed in areas with high net loss of wetlands: Cleaner surface water, as characterized by: • Safe drinking water supplies • Healthy and sustainable aquatic plant and animal communities • Healthy invertebrate communities Lower costs for: • Water treatment at cities that use surface waters • Long term maintenance of drainage systems	
WILDLIFE HABITAT	*These outcomes may be needed in areas with moderate to high net loss of wetlands:* • Habitat benefits year-round for resident and migrant wildlife • Fisheries habitat benefits • Improved production of waterfowl, wildlife, and fish • Increased recreational opportunities • Viable populations of species in greatest conservation need	*This outcome may be needed where there is low net loss of wetlands:* • Reduced fragmentation of lands, which in turn will reduce overall habitat loss or degradation
SURFACE WATER FLOWS AND GROUND WATER INTERACTIONS *(hydrologic functions)*	*These outcomes may be needed in areas with moderate to high net loss of wetlands:* • Reduced flood damages • Self-sustaining river and stream corridors • Ground water recharge for water supply locally or further down the major watershed • Ground water recharge areas restored for fens (discharge-type wetlands)	*This outcome may be needed where there is low net loss of wetlands:* • Ground water recharge for water supply locally or further down the major watershed

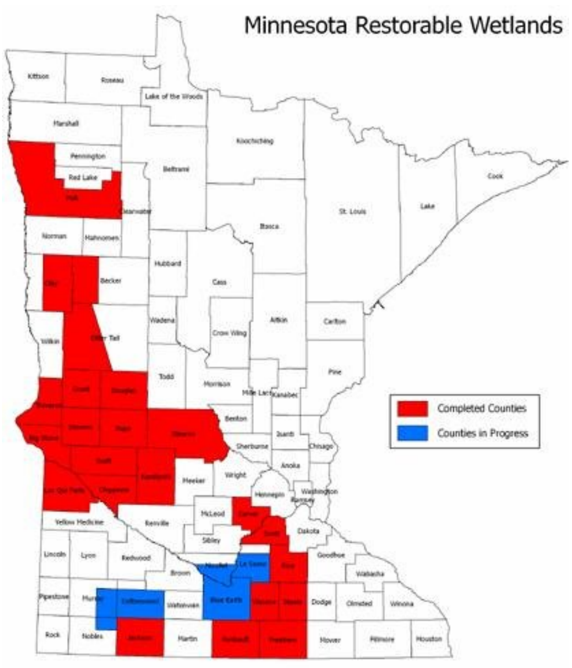
Identifying Restorable Wetlands

This strategy highlights two approaches for identifying potentially restorable sites. Restorable wetlands have been mapped at a detailed level in western and southern Minnesota counties that are part of the prairie pothole region. In places where that information will not be mapped, an alternative method is described for identifying potential restoration sites.

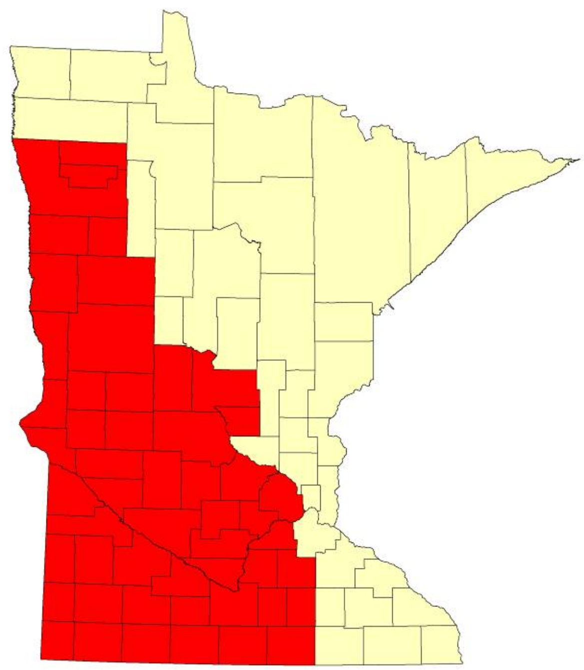
RESTORABLE WETLANDS INVENTORY (RWI)

The U.S. Fish and Wildlife Service Habitat and Population Evaluation Team (HAPET) in Fergus Falls, Minnesota, has developed a Restorable Wetlands Inventory (RWI) to identify potential depressional wetland restoration sites in the 55 prairie pothole counties in Minnesota. The RWI consists of spatial data (polygons) created using manual stereoscopic photo-interpretation of high-altitude color infrared aerial photographs. The HAPET office has produced RWI data for over 16,500 square miles so far.

Figure 2. Current progress of RWI coverage



Total area targeted for RWI coverage



The RWI is only mapping depressional wetlands. For more information about the Restorable Wetland Inventory, visit the HAPET Web site at Habitat and Population Evaluation Team (HAPET).

GIS TERRAIN ANALYSIS

Another promising approach to identifying restorable wetlands is through GIS-based digital terrain analysis of digital elevation models (DEMs). One such type of analysis uses the Compound Topographic Index (CTI). CTI values are a function of slope and catchment area. Upland depressions on the landscape (i.e., places where water tends to collect, including existing wetlands) can be identified by mapping areas that have both a CTI value greater than 11.5 and poorly or very poorly drained soils, according to USDA’s Soil Survey Geographic (SSURGO) Database. National Wetlands Inventory data can be used to exclude existing wetlands, leaving only the restorable sites.

The University of Minnesota Department of Soil, Water, and Climate has explored using the CTI to identify upland depressions as part of a broader project using several types of GIS-based terrain analysis to identify critical places on the agricultural landscape where appropriate soil and water conservation practices are most likely to reduce sediment loads to impaired waters. The project, which ends in June 2009, is funded by a Clean Water Legacy Act FY07 research appropriation to the MN Department of Agriculture.

Based on this work, it appears that GIS terrain analysis could be an important supplementary tool for identifying restorable wetlands in parts of the state that currently lack RWI data (see RWI status map, above). GIS terrain analysis can be applied to either high-resolution DEMs (e.g., LiDAR-derived) or the lower-resolution (30-meter) DEMs available statewide. Clearly, the best results will be obtained with high-resolution DEMs. Until such time as high-resolution DEMs are more widely available, however, GIS terrain analysis of 30-meter DEMs offers a fast means of identifying restorable wetlands at a coarser resolution in places where RWI data are unavailable. An area of nearly 1 million acres (the size of some of Minnesota's larger 8-digit watersheds) can be analyzed in a matter of days using this approach. Additional research is needed to evaluate the use of GIS terrain analysis with high-resolution DEMs to identify both depressional as well as riverine restorable wetlands.

The Minnesota Board of Water and Soil Resources is the most appropriate agency to check for currently available data and technologies for wetlands restoration, as well as the best information available for particular locations.

Prioritizing Wetlands for Restoration

This strategy recommends developing a prioritization methodology that uses identified restorable wetlands as a base layer to which filters may be applied to prioritize certain potential restoration sites. The concept of prioritization is to narrow down the sometimes daunting number of potential wetland restoration sites in a given watershed to a manageable set of choices, based on their ability to positively affect any of three primary categories of functional benefits:

- Water quality improvement
- Wildlife habitat improvement
- Water quantity management (e.g. flood water retention)

Although it is recognized that ground water recharge is a priority when considering wetland restoration, due to lack of data and limited resources ground water recharge analysis has not been included in the current restoration strategy.

For each of the three primary functional benefits categories, a score from 1-10 can be applied to each restorable wetland polygon in a GIS data set, based on professionally agreed upon parameters that affect its ability to positively influence that management goal. The scores for each functional benefit category can be combined to judge the site's ability to achieve multiple desired outcomes.

Prioritizing wetland restoration opportunities is a complex decision making challenge. The comparatively simple choice-making situation concerning just one functional benefit (e.g., habitat) instantly becomes more complex when multiple benefits are wanted from wetland restoration in a watershed. As is usually the case in this state with distinct regional differences, one size cannot fit all. This strategy offers a path worth pursuing and describes the further work needed to develop a decision tool that is easy to use.

See Appendix A for descriptions of current progress on ways to prioritize wetland restoration opportunities for desired outcomes related to water quality, wildlife habitat, and water quantity functional benefits.

This strategy has identified the general categories of water quality, wildlife habitat, and hydrologic functions (surface water flows and ground water interactions) as the three primary functions provided by wetlands. Ideally, standardized landscape models would be available to assess how well a potential wetland restoration site achieves these three functions. These models would then provide an objective way to compare the benefits of one restoration site to another. For example, if two wetland restoration sites were being considered, one might rank higher for water quality benefits and another might rank higher for wildlife habitat. With this information, the sponsor and funder of the wetland restoration could determine which restoration to complete.

Unfortunately, these types of standardized models have not been developed statewide. The U.S. Fish and Wildlife Service has developed several models to help prioritize wetland restorations for wildlife benefits in the prairie pothole region of Minnesota (see Appendix A). No statewide model has been developed for the water quantity functions of wetlands. Several approaches to developing models for water quantity are described in Appendix A. The next section of this document provides examples of models that can help determine relative value of restorations for water quality.

Strategies for Prioritization, Coordination, and Sustainability

1. MAKE OUTCOME-BASED CHOICES FOR WETLANDS RESTORATION

Strategies	Implementation roles
1.1 Identify desired outcomes or benefits from wetland restoration and prioritize wetland restorations for greatest effect in achieving multiple benefits or exceptional single-benefit outcomes. Use a contributing watershed approach for water quality and water quantity objectives.	LOCAL GOVERNMENT UNITS, WITH SUPPORT OF STATE AND FEDERAL AGENCIES, PROJECT PARTNERS
1.2 Promote the prioritization concept recommended in this document	BWSR, WITH SUPPORT OF OTHER STATE AGENCIES
Strategies 1.3–1.6 require additional funding for implementation	
1.3 Fund and staff a project to develop computer desktop tools that allow local users to input their own priority parameters to get locally determined priority maps.	STATE AND FEDERAL AGENCIES
1.4 Finish updating the National Wetlands Inventory and complete the Restorable Wetlands Inventory.	U.S. FISH AND WILDLIFE SERVICE, PROJECT PARTNERS
1.5 Increase support for existing and expanded monitoring of the effectiveness of restored wetlands.	BWSR, WITH SUPPORT OF STATE AND FEDERAL AGENCIES
1.6 Support development of statewide LiDAR data.	STATE AGENCIES, LOCAL GOVERNMENT UNITS, U.S. ARMY CORPS OF ENGINEERS

2. COORDINATE WETLANDS RESTORATION EFFORTS

Strategies	Implementation roles
2.1 Encourage local government units to set priorities and targets based on local, regional, and statewide needs.	STATE AGENCIES, LOCAL GOVERNMENT UNITS
2.2 Communicate state and regional desired outcomes to other government units and coordinate work on identifying high priority restorations for those outcomes.	STATE AGENCIES, LOCAL GOVERNMENT UNITS
2.3 Develop partnerships to coordinate restoration funding and tools across geographic areas and levels of government.	BWSR WITH SUPPORT OF OTHER STATE AGENCIES
2.4 Establish an intergovernmental coordination system.	BWSR WITH SUPPORT OF OTHER STATE AGENCIES
Strategies 2.5–2.7 require additional funding for implementation	
2.5 Agencies make staff available to participate in development of local resource plans.	STATE AGENCIES, U.S. ARMY CORPS OF ENGINEERS
2.6 Improve ability of state and federal agencies to pursue restoration opportunities in competitive land markets.	STATE LEGISLATURE, U.S. CONGRESS
2.7 Remove tax disincentives for restoring wetlands.	STATE LEGISLATURE, U.S. CONGRESS

3. DESIGN AND PRODUCE BETTER WETLAND RESTORATIONS

Strategies		Implementation roles
3.1	Promote high standards in the design and execution of wetland restorations to project participants and through funding sources for restorations.	STATE AND FEDERAL AGENCIES, PROJECT PARTNERS
3.2	Use the Minnesota Wetland Restoration Guide.	BWSR AND PROJECT PARTNERS
3.3	Keep the Wetland Restoration Guide up-to-date.	BWSR
3.4	Give precedence to priority restorations in funding eligibility and selection. Promote alignment with federal and state clean water programs and conservation programs based on water quality and/or habitat modeling showing that the restored wetlands will provide needed benefits more effectively or as effectively as other conservation practices.	MPCA, MDA, DNR, MDH, USDA
3.5	Use evaluation results and lessons learned to improve restoration project performance.	STATE AGENCIES, LOCAL GOVERNMENT UNITS
3.6	Identify funding sources for maintenance and monitoring of restored wetlands.	STATE AGENCIES
Strategies 3.7–3.8 require additional funding for implementation		
3.7	Provide extra incentives for restoration projects that offer greater functional benefits.	STATE AGENCIES, STATE LEGISLATURE
3.8	Ensure stable funding to achieve wetland functional benefits for water quality, wildlife, and other priorities.	STATE LEGISLATURE, U.S. CONGRESS

STRATEGY IMPLEMENTATION

Strategy development has been completed with this document. It was developed using currently available information and tools. Participants are anticipating moving from planning to action. The following commitments are what it will take to implement this strategy:

- Action plans developed by government agencies - the steps they can take separately and collectively to implement this strategy through their agency operations
- Follow-through on the action plans by government agencies
- Communications outreach about the strategy led by BWSR to other agencies, local government units, and project partners.
- Continued improvement of the restoration guidance for water quality improvements and hydrologic benefits
- Development of computer desktop tools for prioritizing wetland restorations to inform decision making
- Continued development and compilation of input data for prioritization analyses, such as high resolution DEMs, Restorable Wetland Inventory data, and local inputs to parameters of prioritization models
- Monitoring and assessment of progress over time

Additional funding will be needed for full implementation of some specific strategies, as noted above.

CONSISTENCY WITH MINNESOTA STATEWIDE CONSERVATION AND PRESERVATION PLAN

The specific strategies outlined above address the themes of prioritization and investment for desired outcomes in these general recommendations in the LCCMR-funded *Statewide Conservation and Preservation Plan* (SCPP), June 2008 draft:

> **Habitat Recommendation 5: Restore Land, Wetlands, and Wetland-Associated Watersheds**
> "Minnesota must invest in prioritized areas to restore degraded and rare land features, wetlands (especially the many that have been drained and converted), and watershed associated with wetlands. This will provide benefits for wildlife, species of greatest conservation need, water quality, and important ecological processes." [pg. 74]
>
> **Habitat Recommendation 8: Review and Analyze Drainage Policy**
> "The LCCMR should invest in a comprehensive review and analysis of existing Minnesota statutes relating to drainage...and make recommendations to the legislature that remove barriers and better facilitate the restoration of critical wetlands in order to improve water quality and aquatic habitats." [pg. 81]
>
> **Land Use Strategy 2: Reduce streambank erosion through reductions in peak flows**
> "Invest in strategically targeted programs for reduction of peak flows through increased water detention in agricultural drainage systems, including wetland construction and restoration, in-ditch storage, and conservation drainage. Targeted drainage water detention will reduce peak flows and attendant streambank erosion. It will also reduce sediment and nutrient contributions from uplands through sediment deposition and denitrification." [pp. 122-123]

Appendix A. Prioritization for Desired Functional Benefits

This appendix describes a process for prioritizing restorable wetlands, using the Chippewa River and Wild Rice watersheds as examples. These examples are not necessarily complete or comprehensive but rather provide a snapshot of the current understanding and professional judgment of the restoration strategy participants. The examples may be useful to local governments in designing their own prioritization approach. In no way are the parameters and criteria described below meant to be prescriptive; nor are they suggested to be appropriate for all areas of the state. The intent of these examples is to provide a loose framework that local planners can tailor to their own management priorities and restoration goals.

The Wild Rice and Chippewa River major watersheds were chosen as pilot areas for creating examples of how local governments might use the Restorable Wetlands Inventory (RWI) and selected criteria to prioritize wetland restorations for water quality, wildlife habitat, and flood water retention benefits. In the Chippewa River example, approximately 3% (3,720 out of 141,909) of potentially restorable wetlands ranked highly for both water quality improvement and wildlife habitat potential. In the Wild Rice example this number was approximately 5% (964 out of 18,255 restorable wetland basins). With respect to flood water retention, less than 1% (50 out of 18,255) of the restorable wetland basins in the Wild Rice example ranked highly. (Flood water retention was not included in the Chippewa River example. It is important to note that at the time of this analysis RWI data were only available for approximately 20% of the Wild Rice watershed area. (Numbers for the Chippewa watershed refer to the entire watershed. Numbers for the Wild Rice watershed refer only to those portions for which data were available from the Restorable Wetlands Inventory.)

WATER QUALITY PRIORITIZATION: DESCRIPTION OF PROCESS USED FOR CHIPPEWA & WILD RICE WATERSHED EXAMPLES

An interdisciplinary technical committee was formed to provide technical recommendations for the prioritization piece of the restoration strategy. The water quality modeling example below is based on recommendations from this group along with further suggestions from participants in a Chippewa River Watershed meeting (see Appendix D).

Sean Vaughn of the DNR, who is currently involved in creating lakeshed-level watershed data as well as flow network data statewide, provided several data sets used in this analysis. A hydrologically corrected digital elevation model (DEM) provided by the DNR was used to create a flow accumulation grid for the test area. The flow accumulation grid connects the direction of flow from cell to cell and calculates a value for each cell representing the number of "upstream" cells contributing to that cell. This flow accumulation grid was the basis for subsequent hydrologic analysis and calculation of values for the contributing water quality factors.

- Initial weighting factors considered in water quality prioritization were based on suggestions from Jim Ellickson who was involved in a previous iteration of water quality modeling for restorable wetlands. They are as follows:
    - Polygon size – the surface area of restorable wetland
    - Distance from restorable wetland to nearest stream network – the path distance calculated with spatial analyst that uses a 30 meter digital elevation model (DEM) to take surface distance and vertical cost factors into account
    - Stream distance to polygon – the hydrologic distance to the restorable wetland (i.e. the distance water travels through the stream network from the wetland to the pour point of the watershed)
    - Wetland basin to watershed ratio – this is the ratio of the surface area of the restorable wetland to the size of its total contributing watershed
- Discussions with both the interdisciplinary technical committee and Chippewa River watershed representatives suggest the use of a simpler initial model involving only polygon

size and wetland/watershed ratio as the weighting factors, with the other two factors eliminated due to perceived redundancy.

- The value set for wetland surface area is ½ acre, meaning all restorable wetlands with a surface area of less than ½ acre are not considered for restoration. This is not intended to imply that wetlands less than ½ acre should not be restored. However, the strategy design group did note some concern about the costs vs. benefits of restoring wetlands less than ½ acre, and ultimately decided not to include them in this model because confidence in the accuracy of the RWI data is dramatically lower for polygons less than ½ acre in size.
    - Recommendations for ranking (on a scale of 1 to 10) based on watershed –to–wetland ratio fall roughly into these categories:

Ratios	Rankings
Less than 5:1	10
5:1 to 10:1	10 to 5
10:1 to 20:1	5 to 1
Greater than 20:1	0

    - It was suggested to add a third weighting factor that accounts for the effect of existing wetlands on water quality. To use this weighting factor, a previously determined target or goal is needed—e.g., the percentage of a minor watershed that would need to be maintained as (or restored to) wetlands to provide the desired water quality benefits. Restorable wetlands in watersheds that have not reached the specified target would be ranked higher.
        - Based on sampling research, Paul Wymar in Chippewa County determined that 4% of the Chippewa River Watershed needs to be maintained as (or restored to) wetlands to provide acceptable water quality benefits.
        - Different watersheds will have different goals or targets.
        - Due to time and resource constraints, existing wetlands and watershed goals were not analyzed for the examples in this Appendix.

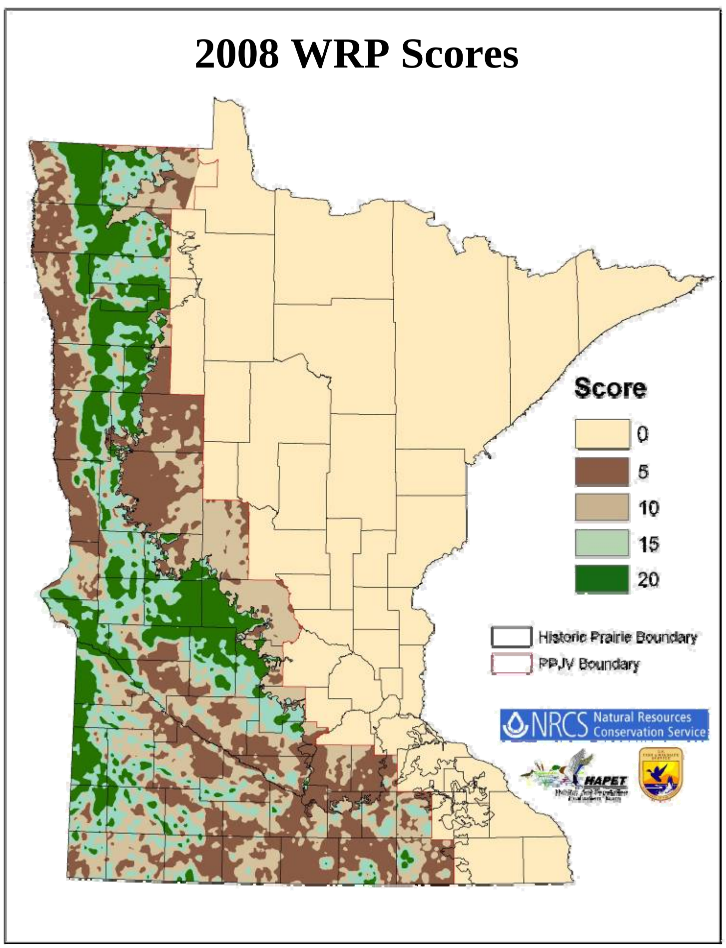
It is generally agreed that closed wetland basins (i.e., those that do not contribute to downstream flow) are the most desirable restoration sites for mitigating phosphorous and sediment loading. The implication is that wetlands with a larger (i.e., closer to a 1:1) wetland/watershed ratio are more isolated than those with a smaller ratio, hence the scoring criterion presented in these examples. However, while restoring wetlands without defined or regulated outlets is preferred, closed basins are often difficult to restore due to design considerations including acceptable water level fluctuations, water encroachment, and landowner needs. In addition isolated wetlands usually are not the most efficient option for mitigating watershed nitrogen impairments, especially in landscapes that are predominantly agricultural. For more information, see Appendix C: How Wetland Restoration Can Assist with Water Quality Improvements.

HABITAT PRIORITIZATION: DESCRIPTION OF PROCESS USED FOR CHIPPEWA & WILD RICE WATERSHED EXAMPLES

Wetland wildlife population increases are driven primarily by wetland abundance, particularly seasonal wetlands. The production of many wetland wildlife species depends on the quality and degree of nesting opportunities adjacent to wetlands. In the prairie and transition zones of the state, grasslands provide these nesting opportunities. The best wetland wildlife habitat occurs within wetland-to-grassland habitat complexes 4 to 9 square miles in size, where at least 20% of the area is wetland and 40% is grassland. At least half of the wetland acreage should be temporary or seasonal basins and ideally each complex should include one shallow lake over 50 acres. Half of the grasslands should be under long-term protection. In summary, the value of any wetland restoration from a wildlife standpoint depends on the quality of the wetland/grassland habitat complex that the restoration is part of.

The U.S. Fish and Wildlife Service's Habitat and Population Evaluation Team (HAPET) has assigned an approximate score to each 40-acre parcel in Minnesota's prairie region, based on the habitat complex of which it is a part. They have created several maps using various grassland and wetland bird models to predict priority habitat areas for grassland nesting birds. These models have been used in various combinations to map priority areas for federal conservation programs such as the Conservation Reserve Program (CRP) and the Wetlands Reserve Program (WRP). The graphic below, for example, was created by the HAPET office to identify priority areas for 2008 WRP signups in Minnesota's prairie pothole counties.

Figure 4. Wildlife Priority Areas for 2008 WRP sign-ups



It is important to recognize that these scores reflect existing habitat conditions. Even areas with low scores can have high wildlife value if the restoration is part of a larger plan to develop a quality wetland/grassland habitat complex.

In the forest zone of Minnesota, the nesting cover adjacent to wetlands for many species consists of either trees that provide cavities for nesting or shoreline bog areas dominated by sedge. The value of potential restoration projects for wetland wildlife habitat in the forest zone must be evaluated individually by site.

The models used to create the prairie pothole region wetland restoration priorities were also used to identify priority areas for grassland and wetland conservation and restoration for waterfowl habitat. These data were used to score RWI (Restorable Wetlands Inventory) polygons based on their proximity to grassland and wetland conservation and restoration priority areas.

One of the underlying principles in this approach is focusing wetland restoration in areas with sufficient grassland for nesting habitat. For more information about the underlying models used to create these data, visit the U.S. Fish and Wildlife Service Habitat and Population Evaluation Team (HAPET) website at Habitat and Population Evaluation Team (HAPET).

WATER QUANTITY MANAGEMENT: DESCRIPTION OF PROCESS USED FOR CHIPPEWA & WILD RICE WATERSHED EXAMPLES

Conversations with various private, state, federal, and local stakeholders suggest some key considerations when prioritizing restorable wetlands for the purpose of flood water retention. Some of these considerations are:

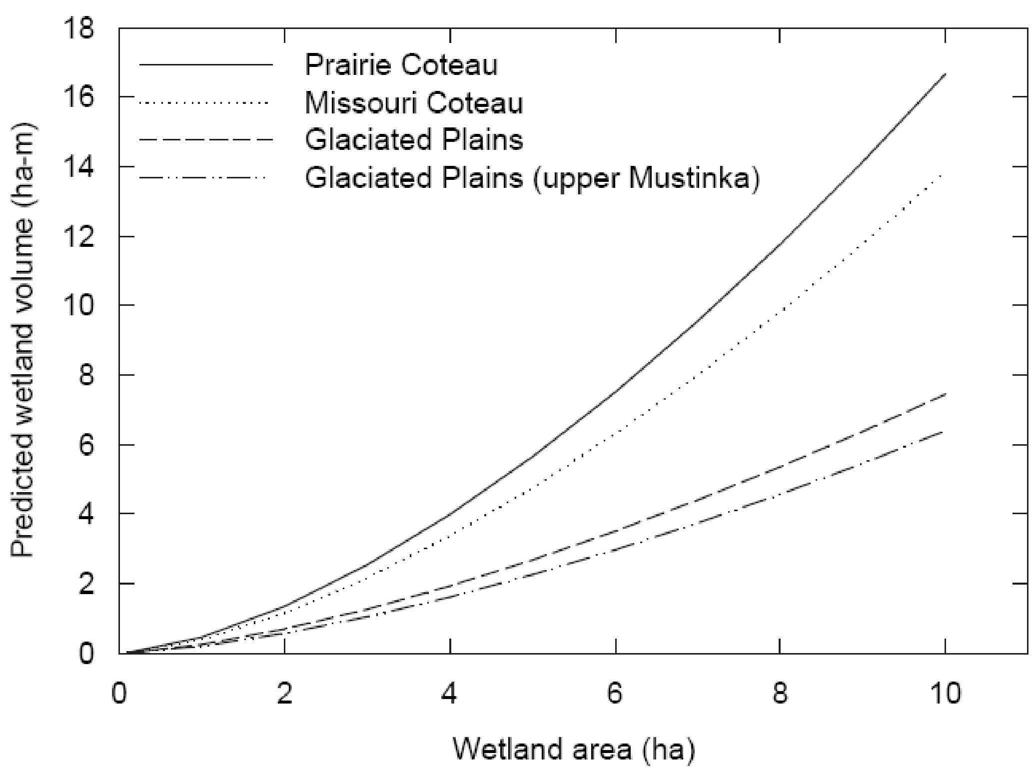
- The volume of the wetland (surface area and depth)
- The watershed to wetland ratio (ratio of the area of the total contributing watershed to the area of the restorable wetland). The current recommendation is a minimum of 10:1.
- Specific to the Red River Valley, the timing of a given sub-watershed's flood hydrograph peak relative to the hydrograph peak of the main stem.

Volume

Larger basins have greater storage capacity and a higher cost-to-benefit ratio for building control structures. There is no consensus on minimum surface area, however, with suggestions ranging from 20 acres to greater than 50 acres.

Based on a 2006 publication by Gleason and Tangen on floodwater storage and a USGS model developed for the upper Mustinka sub-basin in Grant County, the volume of a restorable wetland may be estimated based on surface area-volume relationships within different physiographic areas.

Figure 5. Comparison of surface area-volume relationships among the model developed for the upper Mustinka subbasin and models for the three physiographic regions of the Prairie Pothole Region (Gleason and Tangen, 2006).

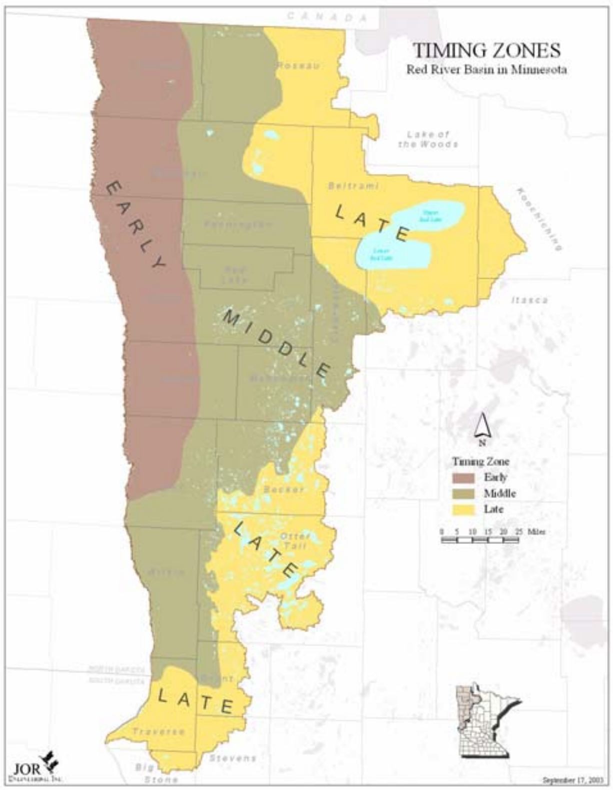


Hydrograph Peak Timing

According to the Red River Flood Damage Reduction Work Group's Technical and Scientific Advisory Committee, the timing of the hydrograph peak for a sub-watershed relative to the peak of the main stem is an important factor when considering flood storage strategies (Anderson and Kean, 2004). In general, peak contributions from areas lower in the Red River basin arrive early in the hydrograph of the main stem. Likewise peak contributions from areas in the middle and upper portions of the basin tend to arrive in the middle and late portions of the main stem hydrograph respectively.

Anderson and Kean suggest that restoration efforts in the middle and late zones of main stem contribution will most effectively reduce the peak flow of the main stem.

Figure 6. Early, middle, and late runoff areas within the Red River basin relative to the main stem.



Inputs used to develop the Red River basin map above include evaluations of historical flood hydrographs, knowledge of recent floods, and runoff travel times compiled using digital elevation data (Anderson and Kean, 2004). The same inputs could be used to develop similar maps at sub-watershed scales to provide more specific guidance for strategizing within smaller watershed delineations.

Due to funding and time constraints, high resolution elevation data based on LiDAR technology was not used in this iteration of the restoration strategy. However, with dedicated resources, LiDAR data could be utilized with tools such as ArcHydro and the HEC-GeoRAS Extension for ArcGIS to provide more detailed hydrologic modeling for flood water retention. This could potentially be a highly accurate and reliable method for predicting areas where wetland restoration can best assist in flood abatement.

Appendix B. Local Meeting Notes And Example Maps

The Wild Rice and Chippewa River major watersheds were chosen as pilot areas for developing examples of how the Restorable Wetland Inventory (RWI) could be used locally to prioritize wetland restorations for water quality, wildlife habitat, and flood water retention benefits. Meetings were held in Chippewa and Clay counties to gather local input for the prioritization examples. Below are synopses of these meetings. The maps on the following pages the show the results of applying the prioritization processes described in Appendix A to the Chippewa River and Wild Rice Watersheds.

CHIPPEWA RIVER WATERSHED

A meeting was held in January 2008 in Chippewa County to get input from local stakeholders regarding the Chippewa River watershed prioritization example. Attendees included staff from the watershed district, local SWCDs, counties, BWSR and NRCS. Much of the technical input was provided by Paul Wymar, an SWCD and watershed technician with considerable experience in water quality and land use issues in the Chippewa River watershed. There was significant general support for the draft Wetland Restoration Strategy as it was being developed, and a general sentiment that the strategy, beyond a technical process, has potential to help the watershed district with funding requests by enabling them to quantify and target specific restoration goals.

It was agreed that wetlands of less than half acre might not be worthwhile to restore on an individual basis. However, the interdisciplinary technical committee suggests that this rule-of-thumb may be overlooked when opportunities arise to restore areas in which many smaller wetlands contribute to a larger wetland complex.

Hydrology was felt to be directly related to water quality. The earliest precipitation events in spring are thought to contribute 70% of total sediment loading in a short period of time. How this water is held back and treated directly affects water quality. Early spring precipitation events may allow basin levels to fluctuate or “bounce” more without affecting wildlife.

There was general agreement by the interdisciplinary technical committee as to watershed to wetland ratios (i.e., that a ratio greater than 50:1 is too large and that wetland benefits increase as the ratio gets nearer to 1:1). It was also noted that research by Paul Wymar suggests that for the Chippewa River watershed, maintaining existing wetland area in excess of about 4% of the watershed area adequately protected water quality, so an effort should be made to screen potential restorations using National Wetland Inventory data.

WILD RICE WATERSHED

A meeting was held in March 2008 in Clay County to get input from local stakeholders regarding the Wild Rice watershed prioritization example. Attendees included staff from the watershed district, local SWCDs, USFWS, MPCA, BWSR, and NRCS as well as a Clay County Commissioner. There was general support for the Wetland Restoration Strategy as it was being developed.

The parameters for water quality and wildlife scoring previously suggested by the strategy design team, the interdisciplinary technical committee, and representatives from the Chippewa County meeting were generally accepted. In addition, water quantity parameters were discussed and the consensus was essentially that restorations with the largest impact on flood abatement are moderate to large in size (10-20 acres) and have a relatively large contributing watershed (10:1 minimum watershed to wetland ratio).

This meeting reiterated the importance of flood control as a design element. It was noted that the Mediation Agreement produced by the Red River Basin Flood Damage Reduction Working Group (December 8, 1998) suggests a 2-foot bounce limitation. An earlier suggestion by the wetlands restoration strategy design team to delineate early, middle and late flooding zones was discussed and it was generally agreed that this could be used as a screening tool (see Appendix C, Hydrograph Peak Timing). Although this information is unavailable for most of the state, it could be created using local hydrograph data.

Figure 7. Prioritization example for a portion of the Chippewa River Watershed

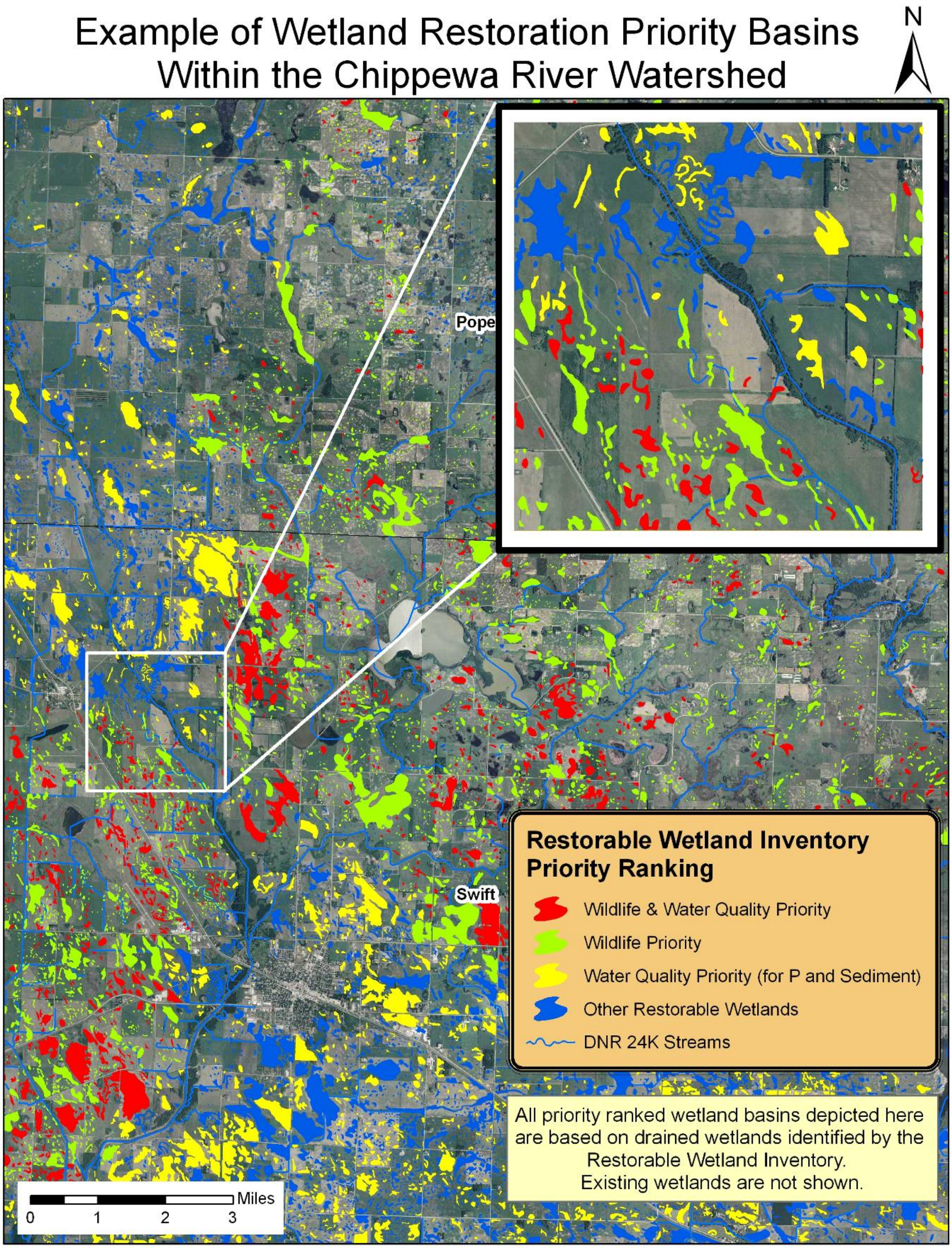
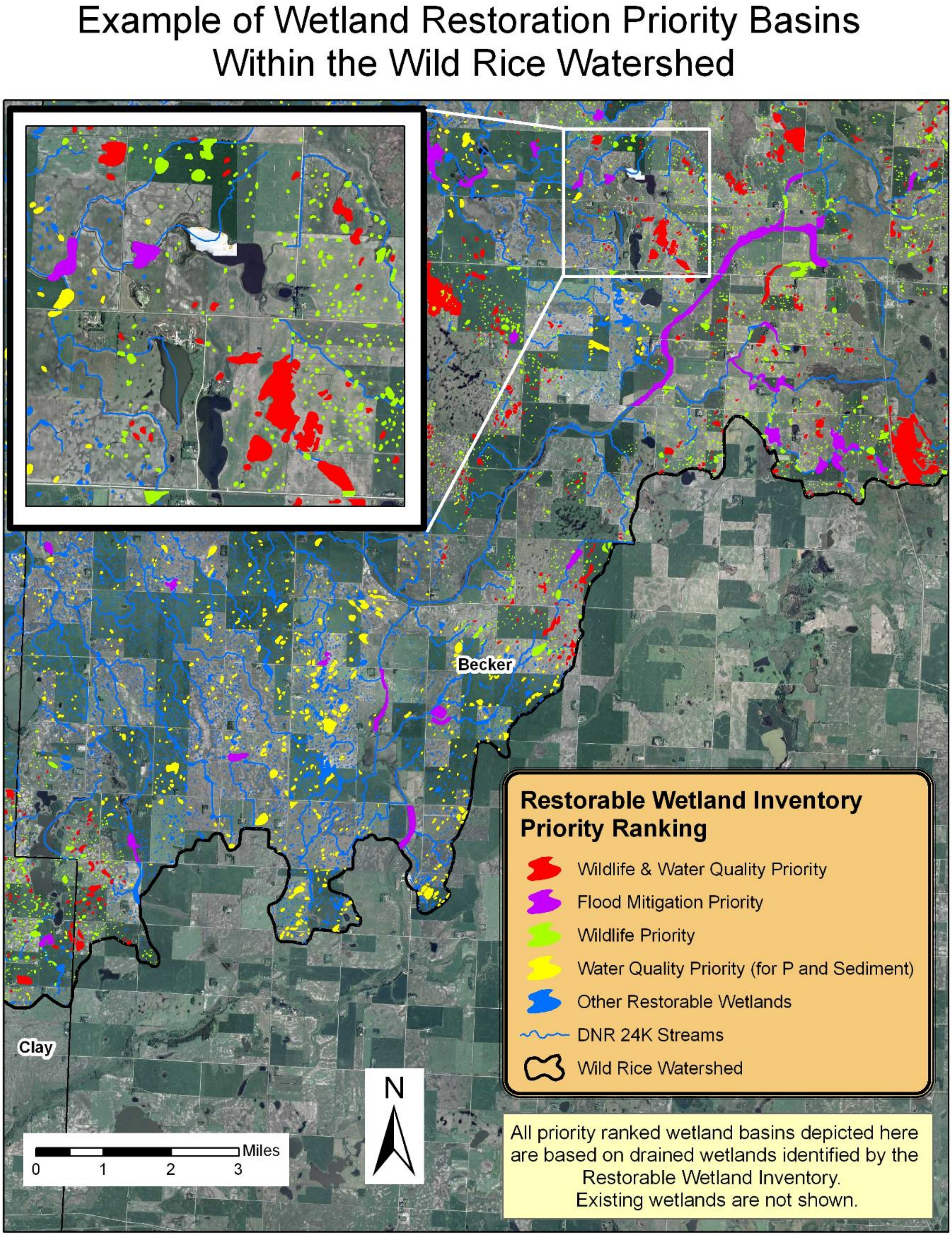


Figure 8. Prioritization example for a portion of the Wild Rice Watershed



Appendix C. How Wetland Restoration Can Assist With Water Quality Improvements

HOW DO RESTORED WETLANDS IMPROVE WATER QUALITY?

Restored wetlands improve water quality by reducing concentrations of targeted pollutants (nitrogen, phosphorus, sediment) in runoff or subsurface flows before they reach other surface waters. The basic biogeochemical processes involved in nutrient and sediment removal as well as mercury methylation are discussed below

WHICH WETLAND RESTORATIONS ARE BEST FOR IMPROVING WATER QUALITY?

Where water quality benefits are a priority, the following types of wetland restoration sites or projects are typically the most beneficial:

- Drained wetlands with effective rate controls at the outlet to maximize retention or residence time. (The less frequent the outflow and thus the longer the residence time, the better.)
- Projects that include a surrounding upland buffer (immediately adjacent catchment area) with high quality upland vegetation, such as warm season grasses, to reduce the amount of pollutants entering the wetland.
- Sites where the wetland catchment area is no more than 5 times the size of the wetland basin (a 5:1 catchment area to ponded area ratio).

Additional considerations are discussed below relative to specific pollutants.

NITROGEN & WETLANDS RESTORATION

How do restored wetlands reduce nitrogen loads in downstream waters? Nitrate removal or denitrification occurs mainly through plant uptake and microbial mediated processes. Nitrogen is an essential plant nutrient and some plants are able to absorb and use nitrate directly as a nitrogen source for their growth h, however denitrification is a more important process for nitrogen removal. Denitrification requires a retention time long enough to maximize nitrate removal, anoxic conditions (without oxygen) and enough organic carbon to support bacterial activity. Since denitrification is a biological process, it is also temperature-dependent (Kadlec and Knight 1996, Crumpton 2001).

Which sites are best for denitrification? Where nitrogen reduction is a priority, the following characteristics—in addition to those listed above for water quality concerns in general—may be especially important in selecting among potential wetland restoration projects.

- Drained wetlands in agricultural landscapes, especially if the restored wetland will receive tile-flow.
- Restorations with or without through-flow, including riverine and other riparian wetlands. (
- Wetlands with a larger ratio of catchment area to ponded water, as long as residence time is adequate. Increased retention time with ponded water will generally improve nitrate removal.
- Wetland restorations coupled with nutrient best management practices on upland crops and animal feeding operations.

Examples of wetlands restored primarily for denitrification purposes:

- In Minnesota, between approximately 2002 and 2006, a Brown-Nicollet-Cottonwood Water Quality Board project helped landowners restore wetlands primarily for the purpose of nitrate removal in the heavily agricultural Seven Mile Creek Watershed. Monitoring data show that the restored wetlands have reduced nitrates by 75% on average (Kuehner 2007). These wetlands could prevent as much as 6,000 pounds of nitrates and 1,250 tons of sediment from reaching the Minnesota River every year (Sands and Johnson 2007). The cost per pound of nitrate removed due to this type of wetland restoration compares favorably with other agricultural conservation practices that reduce nitrate concentrations in water.

- According to Sands and Johnson (2007), "studies by Iowa State University have shown that one acre of wetland can efficiently filter nitrates from up to 100 acres of cultivated land." Specifically, the research indicated that restored wetlands sited to receive significant portions of watershed flow have removed 35% of the annual nitrate load from the Walnut Creek watershed (Crumption 2001).
- Other investigators have reported nitrate reductions of up to 99% in strategically located, properly designed wetland restorations and engineered wetland treatment systems (Newbold 2005). Several such projects, including wetlands restored as part of Iowa's Conservation Reserve Enhancement Program (CREP), were designed to intercept significant portions of the watershed (Crumpton 2001; Sands and Johnson 2005)

PHOSPHORUS & WETLAND RESTORATIONS

How do restored wetlands reduce phosphorus loads in downstream waters? Phosphorus reduction and cycling in wetlands is a highly complex process. Initially, the restored wetland can intercept and retain a significant amount of phosphorus. However, as the wetland matures and reaches a saturation point (or as the water regime changes) the wetland begins to export phosphorus (Kadlec and Knight, 1996).

Wetlands are more prone to phosphorus saturation when they are well connected to upstream drainage networks, especially a drained catchment area more than 5 times the size of the wetland basin. Once a wetland is saturated, phosphorus may pulse out of the wetland into downstream lakes and streams via the drainage network.

Which wetlands restorations are best for reducing phosphorus in downstream waters?

- Where phosphorus reduction is a priority, choosing restorable sites that are more "isolated," i.e., less connected to other waters and more dispersed throughout the watershed is preferred over more hydrologically connected wetlands (Almendinger 1999, Loucks 1992, and Newbold 2005).
- A small catchment area to wetland ratio(from 2:1 to 5:1) is preferred to reduce phosphorous loading and the potential for phosphorus to pulse out of the wetland into downstream waters
- The other recommendations above relative to all water quality concerns also apply.

Identifying priority sites: See Appendix D for an example of a GIS-based process for identifying high-priority restorable wetland sites relative to excess phosphorus and sediment.

SEDIMENT & WETLAND RESTORATIONS

How do restored wetlands reduce phosphorus loads in downstream waters? During rainfall events and snowmelt periods, fine sediments are transported from land to rivers, streams, lakes, and wetlands via overland runoff and, to a lesser extent, via drainage systems. The sediment load is related to the hydraulic energy of overland or subsurface flows. High-energy flows also significantly increase streambank erosion, which increases sediment loads in streams. Properly designed wetland restorations can reduce the hydraulic energy of the water flowing through them and intercept sediments before they reach other waters.

Which wetland restorations are best for reducing sediment loads downstream? Generally, sites and projects effective at reducing phosphorus also effectively reduce sediment loading. However, significant sediment reduction can result from restoring wetlands drained by ditches, including partially drained wetlands with ditches flowing through them. Restoring the hydrology in these locations will dampen downstream flows and reduce stream bank scouring and sediment transport. Restoring ditch drained wetlands is especially valuable when the adjacent upland is restored to native plant cover or when management practices are applied to reduce upland sediment transport into the wetland. Wetlands that intercept large amounts of sediment will be unable to sustain their beneficial functions over time.

METHYL MERCURY & WETLAND RESTORATIONS

Mercury is a potent neurotoxin. Environmental exposure and damage from mercury is particularly problematic when the mercury is methylated. Mercury methylation is a complex biogeochemical change that occurs in wetlands. Methyl mercury (MeHg) is more toxic and bioavailable than elemental mercury (Hg). Mercury methylation is known to occur in inundated and saturated soil wetlands and, therefore, the production and release of methyl mercury (MeHg) due to wetland restorations has been suggested as a potential pollution concern. However wetlands can also effectively capture and remove mercury from downstream waters.

The MPCA recently compared mercury cycling in three types of wetlands: natural wetlands, stormwater wetlands and wetlands that receive water from agricultural lands (MPCA 2007). All behaved similarly in terms of mercury removal and MeHg production. However, through-flow wetlands receiving extensive urban or agricultural drainage water had a higher percentage of MeHg to total Hg. This may be at least partly due to the residence time and drainage area. However, other studies have also indicated fluctuating water levels as a key factor in mercury methylation:

- Increases in the release of MeHg from aquatic systems with fluctuating water levels were reported by Sorenson et al (2005) in northeastern Minnesota lakes and by Brigham et al., (2002) in temporarily flooded flood-control impoundments in Minnesota's Red River Valley.
- Snodgrass et al (2000) found fluctuating water levels to be a primary factor in controlling the bioavailability of Hg in southeastern U.S. depressional wetlands.

WHERE DO RESTORED WETLANDS IMPROVE WATER QUALITY?

The effectiveness of restored wetlands in reducing phosphorus, nitrogen, and/or sediment loads downstream is likely to vary from one region to another. This is partly due to the effect of different soil landscapes on wetland biogeochemical processes and partly a matter of land use and physiogeographic structure or, as termed by Almendinger (1999) "problem effectiveness," i.e., whether a pollutant is a significant problem in the region, as determined by water quality assessments, Total Maximum Daily Load (TMDL) listings or watershed planning.

LITERATURE CITED IN THE WETLAND RESTORATION STRATEGY

Almendinger, J.E. 1999. A Method to Prioritize and Monitor Wetland Restoration for Water Quality Improvement. *Wetlands Ecology and Management* 6: 241-251

Anderson, C. and A. Kean. 2004. *Red River Basin Flood Damage Reduction Framework: Technical Paper No. 11*. Red River Basin Flood Damage Reduction Work Group Technical and Scientific Advisory Committee.

Brigham, M.E., D.P. Krabbenhoft, M.L. Olson and J.F. Dewild. 2002. Methylmercury in flood-control impoundments and natural waters of Northwestern Minnesota, 1997-1999. *Water, Air and Soil Pollution.* 138: 61-78.

Chippewa River Watershed Project. 2006. "Chippewa River Watershed Monitoring Summary."

Crumpton, W.G. 2001. Using wetlands for water quality improvement in agricultural watersheds; the importance of a watershed scale approach. *Water Science and Technology.* 44 (11-12):559-564.

Dortch, M.S. J. A. Gerald. 1995. *Screening-level model for estimating pollutant removal by wetlands.* U.S. Army Corps of Engineers WRP-CP-9.

Gleason, R.A., B.A. Tangen, M.K. Laubhan, K.E. Kermes, N.H. Euliss Jr. 2007. *Estimating Water Storage Capacity of Existing and Potentially Restorable Wetland Depressions in a Subbasin of the Red River of the North.* U.S. Geological Survey Open-File Report. 1159.

Kadlec, R. H. and R. L. Knight. 1996. *Treatment Wetlands.* Lewis Publishers, Boca Raton, FL.

Kuehner, K. 2007. Wetland Restorations for Hydrology and Water Quality. PowerPoint presentation.

Loucks, O. 1992. Restoration of the pulse control function of wetlands and its relationship to water quality objectives. In J. A. Kusler and M. E. Kentula (eds.). *Wetland Creation and Restoration: The Status of the Science.* Island Press, Washington D.C.

Minnesota Department of Agriculture. 2007. Agriculture's Contribution to Restoring Minnesota's Wetlands. Fact sheet.

Minnesota Pollution Control Agency. 2007. Effectiveness of Stormwater Ponds/Constructed Wetlands in the Collection of Total Mercury and Production of Methylmercury. Final Project Report Draft.

Newbold, S. C. 2005. A combined hydrologic simulation and landscape design model to prioritize sites for wetlands restoration. *Environmental Modeling and Assessment.* 10: 251-263.

Sands, G., and Johnson, S. 2007. Assessing the barriers to and potential for wetland restoration in agricultural watersheds. *CURA Reporter*, 37:3-12.

Sorenson, J.A., L.W. Kallemeyn and M. Sydor. 2005. Relationship Between Mercury Accumulation in Young of the Year Perch and Water-Level Fluctuations. *Environmental Science and Technology* 39(23):9237-9243.

Snodgrass, J. W. C. H. Jagoe, A. L. Bryan, H. A. Brant and J. Burger. 2000. Effects of trophic status and wetland morphology, hydroperiod, and water chemistry on mercury concentrations in fish. *Canadian Journal of Aquatic Science.* 57:171-180.

ADDITIONAL USEFUL REFERENCES

Note: This is not an exhaustive list

Bedford, B. L. 1999. Cumulative effects on wetland landscapes: links to wetland restoration in the United Sates and Southern Canada. *Wetlands*, 19: 775-788.

Cappiella, K., Kitchell, A., & Schueler, T. 2006. Using local watershed plans to protect wetlands. *Wetlands and Watersheds Article Series*. Center for Watershed Protection and USEPA. No. 2.

Crumpton, W.G., Kovacic, D.A., Hey, D.L., and Kostel, J.A. 2008. Potential of Restored and Constructed Wetlands to Reduce Nutrient Export from Agricultural Watersheds in the Corn Belt. *Upper Mississippi River Sub-basin Hypoxia Nutrient Committee Final Report: Gulf Hypoxia and Local Water Quality Concerns Workshop*, American Society of Agricultural and Biological Engineers. pp. 29-42.

Environmental Law Institute. 2003. *Conservation Thresholds for Land Use Planners*. Environmental Law Institute, Washington, D.C.

Environmental Law Institute. 2007. *Conference Summary Report: Workshop to Explore Opportunities to Integrate the State Wildlife Action Plans into Improved Wetland Conservation and Restoration*. July 16-17, 2007, in Washington D.C.

Galatowitsch, S.M. and A.G. van der Valk. 1994. *Restoring Prairie Wetlands: An Ecological Approach.* Iowa State University Press, Ames.

Galatowitsch, S., A.G. van der Valk, and R.A. Budelsky. 1998. Decision-making for prairie wetland restorations. *Great Plains Research.* 8: 137-155.

Gleason, R. A., Laubham, M. K., & N.H. Euliss, J. 2008. *Ecosystem services derived from wetland conservation practices in the United States Prairie Pothole Region with an emphasis on the U.S. Department of Agriculture Conservation Reserve and Wetlands Reserve Programs.* U.S. Geological Survey Professional Paper No. 1745.

Harr, R. 2005. *Breeding bird, invertebrate, and wetland plant seed responses to USDA Farmable Wetland Program restorations in north-central Iowa and eastern South Dakota.* Iowa State University, Ames.

Hey, D. L., & Philippi, N. S. 1995. Flood reduction through wetland restoration: the Upper Mississippi River Basin as a case history. *Restoration Ecology*, 3(1):4-17.

Interagency Work Group on Wetland Restoration. 2002. *An Introduction and User's Guide to Wetland Restoration, Creation, and Enhancement.* 105pp.

Jacobson, R. 2005. *Guidelines for Restoring and Managing Native Wetland Vegetation.* Minnesota Board of Water and Soil Resources and Minnesota Department of Transportation.

Johnston, C. A., Detenbeck, N. E., & Niemi, G. J. 1990. The cumulative effect of wetlands on stream water quality and quantity: a landscape approach. *Biogeochemistry*. 10:105-141.

Knutson, M. G., Sauer, J. R., Olsen, D. A., Mossman, M. J., Hemesath, L. M., & Lannoo, M. J. 1999. Effects of landscape composition and wetland fragmentation on frog and toad abundance and species richness in Iowa and Wisconsin, USA. *Conservation Biology*, 13:1437-1446.

Kusler, J. 2003. *Wetlands and Watershed Management.* Association of State Wetland Managers.

Kusler, J., Willard, D. E., & H.C. Hull, J. 1995. Wetlands and Watershed Management: Science Applications and Public Policy. *Wetlands and Watershed Management.* Association of State Wetland Managers.

Maderik, R. A., Gagnon, S. R., & Makuch, J. R. 2006. *Wetlands in Agricultural Landscapes: A Conservation Effects Assessment Project (CEAP) Bibliography*. USDA Agricultural Research Service.

Marble, A.D. 1992. *A Guide to Wetland Functional Design.* Lewis Publishers, Ann Arbor, Michigan.

Mulholland PJ, et al. 2008. *Stream denitrification across biomes and its response to anthropogenic nitrate loading*. Nature. 452 (7184):162-3.

Paulson, J. 1994. Great Lakes wetlands restoration: linking wetlands restoration and watershed planning. *Great Lakes Wetlands*, Vernal Equinox: 1-4.

Pease, J. L., Rankin, M. L., Verdon, J., & Reisz, R. 1996. *Summary: Why landowners restore wetlands: a national survey*. Iowa State University.

Peterson BJ, et al. 2001. *Control of nitrogen export from watersheds by headwater streams*. Ecosystems Center, Marine Biological Laboratory, Woods Hole, MA. 292(5514):86 –90.

Shaw, D. 2000. *Native Vegetation in Restored and Created Wetlands: Its Establishment and Management in Minnesota and the Upper Midwest.* Minnesota Board of Water and Soil Resources.

Seitzinger S, Harrison JA, Böhlke JK, Bouwman AF, Lowrance R, Peterson B, Tobias C, Van Drecht G. 2006. *Denitrification across landscapes and waterscapes: a synthesis*. *Ecological Applications.* 16(6):2064–2090.

Vellidis, G., Lowrance, R., Smith, M. C., & Hubbard, R. K. 1993. Methods to assess the water quality impact of a restored riparian wetland. *Journal of Soil and Water Conservation.* 48: 223-230.

Whited, D., Galatowitsch, S., Tester, J. R., Schik, K., Lehtinen, R., & Husveth, J. 2000. The importance of local and regional factors in predicting effective conservation planning strategies for wetland bird communities in agricultural and urban landscapes. *Landscape and Urban Planning.* 49: 49-65.

Appendix E. Acknowledgements

This strategy was developed primarily through the dedicated efforts of a small work team. Efforts to communicate with and tap into the knowledge and perspectives of the wider array of stakeholders included a day-long kickoff meeting, informational postings on a project Web page, and two Web-based stakeholder feedback surveys. The greatest challenge for participants in the strategy design was time availability. The project concluded at the designated time and project staff delivered the strategy document to the Steering Committee in mid-2008 for further consideration.

Project Staff

Beth Carlson, Project Coordinator, Minnesota Department of Natural Resources (Policy, Research, & Planning Services)
Tabor Hoek, Technical Coordinator, Minnesota Board of Water and Soil Resources and Minnesota Department of Natural Resources (Working Lands Initiative)
Aaron Spence, GIS Specialist, Minnesota Board of Water and Soil Resources

Strategy Design Team Participants

David Weirens and Kevin Lines, Minnesota Board of Water and Soil Resources
Ray Norrgard and Doug Norris, Minnesota Department of Natural Resources (Division of Fish and Wildlife; Division of Ecological Resources)
Barbara Weisman and Paul Burns, Minnesota Department of Agriculture (Division of Agricultural Development and Financial Assistance)
Kevin Molloy and Mark Gernes, Minnesota Pollution Control Agency (Wetlands Program)
Sarma Straumanis, Minnesota Department of Transportation (Environmental Services – Engineering Services Division)
Henry Van Offelen, Minnesota Center for Environmental Advocacy (Natural Resource Specialist)
Jon Schneider, Ducks Unlimited (Manager, Minnesota Conservation Programs)
Chris Radatz, Minnesota Farm Bureau (Public Policy Director)
Scott Milburn, Midwest Natural Resources Inc. (Wetland Ecologist/Botanist)
Stephanie Berkland, Builders Association for Minnesota (Research Analyst)
Wayne Cymbaluk, Stearns County Soil and Water Conservation District (Wetlands Program)
Kelly Hogan and Sheldon Myerchin, U.S. Fish and Wildlife Service

Steering Committee

John Jaschke, Executive Director, Minnesota Board of Water and Soil Resources
Larry Kramka, Assistant Commissioner, Minnesota Department of Natural Resources
Steve Hirsch, Acting Director, Division of Ecological Resources
Dave Schad, Director, Division of Fish and Wildlife
Joe Martin, Assistant Commissioner, Minnesota Department of Agriculture
Peter Scheffert, Director, Division of Agricultural Development, and Financial Assistance
Paul Eger and Rebecca Flood, former and current Assistant Commissioner, Minnesota Pollution Control Agency
Frank Pafko, Director, Environmental Services, Minnesota Department of Transportation