



St. Croix Basin

Phosphorus-Based Water-Quality Goals



Report on the
Recommended
Water-Quality Goals of the
St. Croix Basin Water
Resources Planning Team

and the Proceedings of the
5th Annual Conference
“Protecting the St. Croix:
Reducing and Managing
Nutrients and Sediments”



August 2004



Photo: Nite Fellows

St. Croix Basin

Phosphorus-Based Water-Quality Goals

Report on the
Recommended Water-Quality Goals
of the St. Croix Basin
Water Resources Planning Team

and the Proceedings of the
5th Annual Conference
“Protecting the St. Croix: Reducing and
Managing Nutrients and Sediments”

Partners

Minnesota Department of Natural Resources (MDNR)
Minnesota Pollution Control Agency (MPCA)
St. Croix National Scenic Riverway-National Park Service (SACN-NPS)
Wisconsin Department of Natural Resources (WDNR)

Cooperating Members

Metropolitan Council Environmental Services (MCES)
Minnesota Board of Water and Soil Resources (BWSR)
Minnesota Department of Agriculture (MDA)
St. Croix County, Wisconsin
St. Croix Watershed Research Station (Science Museum of Minnesota)
United States Geological Survey (USGS)
University of Minnesota (UMN)
University of Wisconsin Extension (UW)

Prepared by

Pamela J. Davis, Coordinator
St. Croix Basin Water Resources Planning Team

August 2004

For more information, see the following Web sites:

- www.pca.state.mn.us/water/basins/stcroix/index.html
- www.dnr.wi.gov/org/gmu/stcroix/index/htm
- <http://clean-water.uwex.edu/stcroix>

Cover photographs:

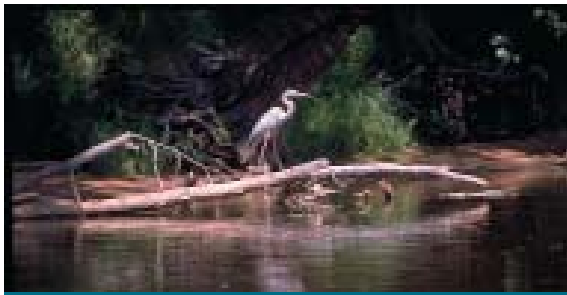
John Hensel, MPCA

Printed on paper with at least 30 percent postconsumer waste content.

This publication can be made available in other formats, such as Braille, large type, audiotape or computer disk, upon request.

August 2004

wq-b6-01



St. Croix Basin Phosphorus-Based Water-Quality Goals

Table of Contents

Abstract	1
Introduction	1
Background	2
Study Results	4
Nutrient Goal Setting	6
References	8

Figures

Figure 1. St. Croix River Basin 1992 Land Cover	2
Figure 2. Projected Population Growth in the St. Croix Basin by County, 2000-2010	3

Appendices

■ Appendix 1: Participants in the St. Croix Nutrient Goal-Setting Process.....	9
■ Appendix 2: Nutrient Goal-Setting Scenarios Spreadsheet.....	10
■ Appendix 3: Nutrient Goal-Setting Scenarios Spreadsheet Data Sources.....	11
■ Appendix 4: <i>The Nutrient Subcommittee Goal-Setting Process</i> , Kohlasch et al., Minnesota Pollution Control Agency, St. Croix Basin Team.....	12
■ Appendix 5: <i>Insights from 25 Years of Water-Quality Monitoring: Trends and Patterns on the Lower St. Croix</i> , Lafrancois et al., National Park Service.....	14
■ Appendix 6: <i>Nutrient and Suspended Sediment Concentrations and Loading from Tributaries to the St. Croix River</i> , <i>Wisconsin and Minnesota, 1998-99</i> , Lenz et al., United States Geological Survey.....	16
■ Appendix 7: <i>A Historical Reconstruction of Sediment and Phosphorus Loading to Lake St. Croix</i> , Triplett et al., University of Minnesota, St. Croix Watershed Research Station.....	18
■ Appendix 8: <i>Historical Trends in Phosphorus Loading to the St. Croix Drainage from Permitted Point-Source Discharges</i> , Edlund, St. Croix Watershed Research Station.....	20
■ Appendix 9: <i>Response of the St. Croix River Pools, Wisconsin and Minnesota, to Various Phosphorus-Loading Scenarios</i> , Robertson and Lenz, United States Geological Survey.....	22
■ Appendix 10: <i>Volunteer Monitoring on Lake St. Croix from 1999-2002</i> , Davis et al., St. Croix Basin Water Resources Planning Team, Minnesota-Wisconsin Boundary Area Commission, Metropolitan Council Environmental Services.....	23
■ Appendix 11: <i>A Next Step: Soil and Water Assessment Tool (SWAT) Modeling for the St. Croix River Basin</i> , Almendinger et al., St. Croix Watershed Research Station.....	25
■ Appendix 12: <i>Results from the 5th Annual Conference Protecting the St. Croix: Reducing and Managing Nutrients and Sediments</i>	27

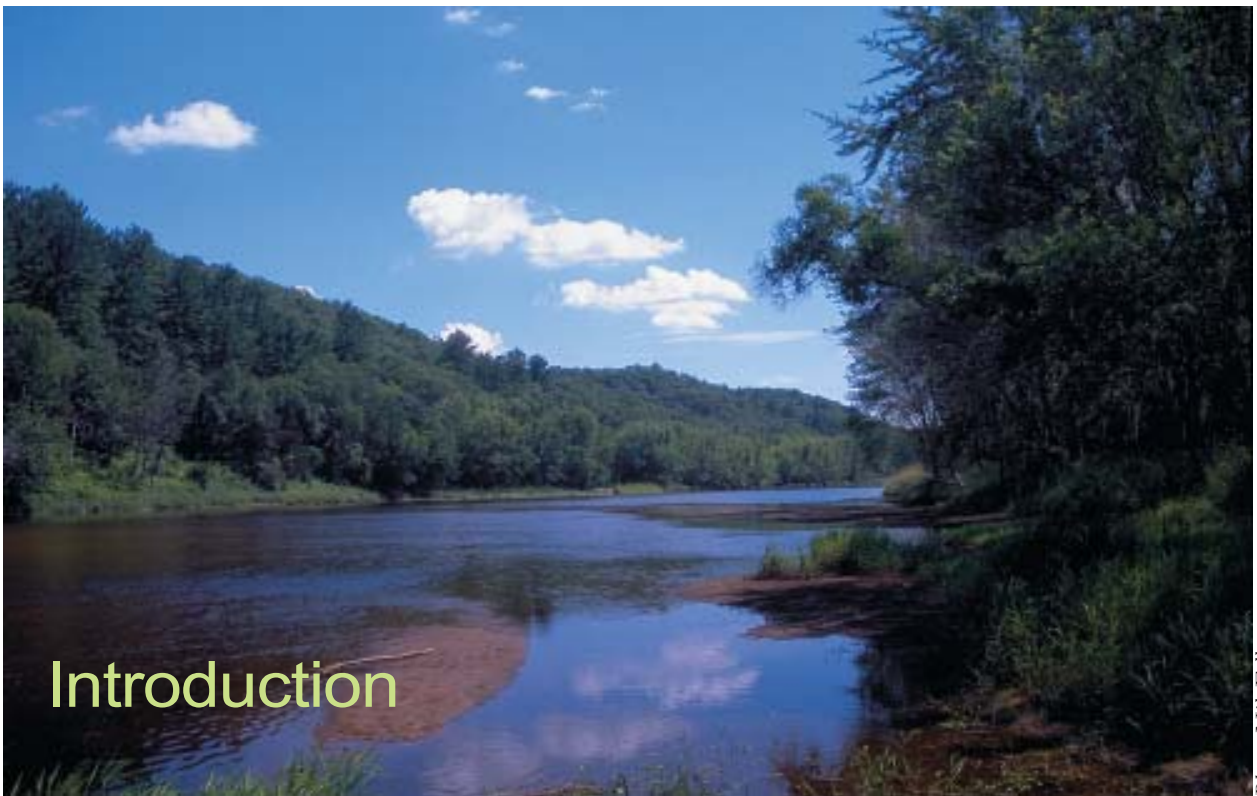


Photo: Nile Fellows

Introduction

Abstract

Rapid population growth and accompanying land-use changes have affected the water resources of the St. Croix River Basin, which forms most of the northern half of the border between the states of Minnesota and Wisconsin. Based on the 39-percent projected population growth in the St. Croix Basin by the year 2020, the water resources will continue to degrade within the current regulatory path.

The St. Croix Basin Water Resources Planning Team (St. Croix Basin Team), citing recently completed nutrient and sediment research, has recommended a 20-percent reduction in total phosphorus loading within the St. Croix Basin. A 20-percent reduction in total phosphorus loading will approximate the ecological conditions of Lake St. Croix prior to 1950, before the major ecological changes currently experienced.

This report presents a summary of the significant research reviewed by the nutrient subcommittee of the St. Croix Basin Team and presented at its 5th annual conference, "Protecting the St. Croix: Reducing and Managing Nutrients and Sediments," held in February 2004. The report addresses the nutrient subcommittee's nutrient goal-setting process and contains recommended nutrient goals and suggested strategies for implementation.



The St. Croix Basin Water Resources Planning Team (St. Croix Basin Team), comprised of representatives from state, federal and local units of government and other organizations, is working cooperatively to address the issue of nutrient management. The St. Croix Basin Team, created by a *Memorandum of Understanding* among units of government, gathered in 1994 to develop water-resource goals and a plan to accomplish these goals.

Through a scoping session of interested citizens and personnel from state and local agencies, nutrient and sediment loading was determined to be the top issue affecting water quality in the St. Croix River. To address this issue, the St. Croix Basin Team formed a nutrient subcommittee in 1997.

The nutrient subcommittee involves staff from the Minnesota Pollution Control Agency, Metropolitan Council Environmental Services, National Park Service, St. Croix Watershed Research Station/Science Museum of Minnesota, United States Geological Survey and Wisconsin Department of Natural Resources (Appendix 1 lists participants' names). In 1998, the nutrient subcommittee secured funding and personnel to support a plan for monitoring, modeling, goal setting and yearly conferences for public interaction.

In 2003, the nutrient subcommittee began a year-long series of meetings to assess water-quality data and modeling results from nutrient and sediment studies.

The research and assessment has revealed that major ecological changes have occurred in Lake St. Croix, located at the downstream end of the St. Croix Basin. Since the mid-1900s, total phosphorus loading has increased sharply and diatom communities, the dominant type of algae in this aquatic ecosystem, have changed drastically.

With continued rapid population growth in the St. Croix Basin, water quality will continue to degrade under the current regulatory path. Accordingly, the St. Croix Basin Team recommends a 20-percent reduction in total phosphorus loading in the basin.

A 20-percent reduction in total phosphorus loading will approximate the ecological conditions of Lake St. Croix prior to 1950, before a peak in nutrient loadings during the period 1950-1960 and before major changes in diatom communities and productivity occurred (see Appendix 2).

This report summarizes the results of that research as presented at the 5th annual conference sponsored by the St. Croix Basin Team in 2004: “Protecting the St. Croix: Reducing and Managing Nutrients and Sediments.” It reviews the process through which the nutrient subcommittee addressed nutrient management, provides the nutrient subcommittee’s recommended nutrient goals and suggests strategies for implementation.



Background

Draining an area of 20,098 square kilometers (7,760 square miles), the St. Croix River is a sixth-order stream with average annual mean discharge of 120 m³/sec. This scenic waterway flows through picturesque bluffs, forests, floodplain communities and prairies.

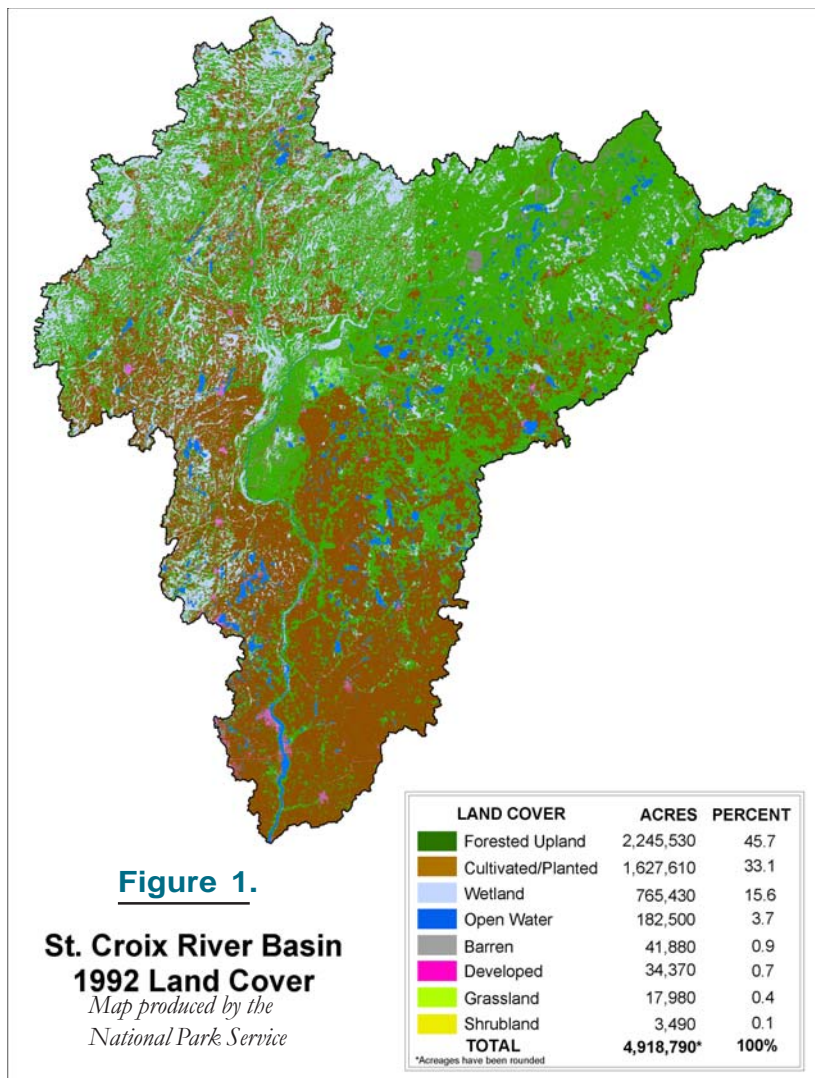


Figure 1.

St. Croix River Basin 1992 Land Cover

Map produced by the
National Park Service

The river crosses three major aquatic ecoregions, originating in a region of northern spruce and pine forests, flowing southwesterly through hardwood forests and prairie, and eventually joining the Mississippi River (Figure 1). The lower St. Croix River is one of the richest freshwater mussel habitats in the world, with species including two that are federally endangered: the Higgins’ eye pearly mussel (*Lampsilis higgins*) and the winged mapleleaf (*Quadrula fragosa*).

During the 1950s and ‘60s, a burgeoning population from St. Paul and Minneapolis (Twin Cities), Minnesota, began a push for development and increased recreational usage of the St. Croix River. Worried that continued urban stresses would put the natural resources of the watershed at risk, concerned citizens and politicians worked for the St. Croix to be included in the original National Wild and Scenic Rivers Act of 1968. The St. Croix National Scenic Riverway, which includes the

Namekagon River (Wisconsin) and the Upper St. Croix River, was established as a unit of the National Park System in 1968. The Lower St. Croix National Scenic Riverway was added in 1972. Lake St. Croix, formed at the downstream end of the basin, is a focal point for recreation and development and acts as a barometer for changes in the basin that affect water quality.

Continuing development and recreational demands related to the expanding Minneapolis-Saint Paul Metropolitan Area are putting pressure on the Lower St. Croix and threatening water quality and diverse biological resources. Recreational use of the riverway has more than doubled in the last 25 years to more than one million visitors annually. Recent demographic studies by the Metropolitan Council in St. Paul, Minnesota, and the 2000 U. S. government census predict a 39-percent population growth in the St. Croix Basin by the year 2020¹. Figure 2 shows the projected population growth by 2010. The sometimes conflicting uses are threatening the St. Croix's National Scenic Riverway designation and its outstanding resource value.

Both the dam-impounded reservoir at St. Croix Falls, Wisconsin, through which the St. Croix River flows, and Lake St. Croix, whose outlet forms the mouth of the St. Croix River, have been affected by sediment and nutrients from the tributaries of the St. Croix River. By 1994, evidence was accumulating that land uses in the tributary watersheds of the St. Croix were elevating nutrient levels.

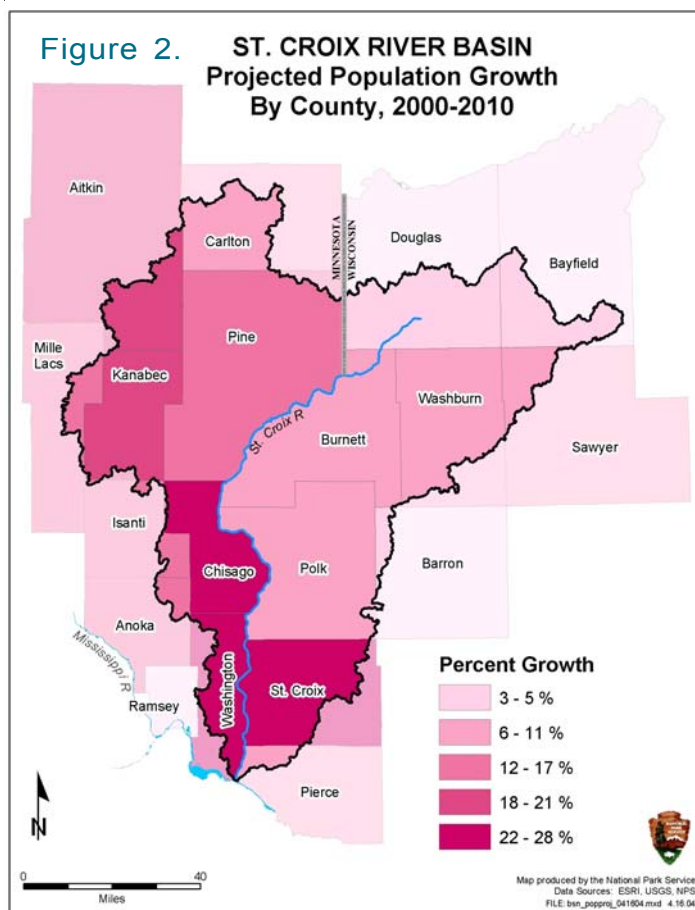
During the fall of 1996, an ecological risk assessment workshop for the St. Croix River was convened (Harris et al., 1997). This ecological risk assessment provided a framework for decision making based on ecological information. Nutrient loading was rated highest of the stressors identified, and habitat modification was rated the most important immediate threat to St. Croix River water quality.

In 1997, a survey of resource-management professionals identified nutrient impacts as the top three out of 133 issues regarding St. Croix River protection needs (Holmberg et al., 1997). Subsequently, managing agencies expressed a need for nutrient goals to protect the quality of water resources in the basin.

(See the Planning Status Reports prepared by the St. Croix Basin Team, Davis, 2001 - 2003.)

The nutrient subcommittee coordinated an interagency main stem, tributary and point-source monitoring program during the summer of 1999 to gather data for modeling nutrient loads, in particular phosphorus. A citizen monitoring effort was organized to accompany the study to provide additional data and increase citizen awareness about the water quality of Lake St. Croix. Two USGS studies (Lenz et al., 2001; and Fallon and McNellis, 2000) identified nutrient levels in the major tributaries; the highest contributions came from the Clam, Kettle, Snake, Sunrise and Apple Rivers.

Parallel to the Basin Team nutrient study, the St. Croix Watershed Research Station (Science Museum of Minnesota) was funded by MCES and MPCA to complete a sediment study to determine conditions in Lake St. Croix since the



¹ The 39-percent increase is based on the 2000 federal census and information provided by the Metropolitan Council (St. Paul, Minn.), which projects population growth for Washington, Chisago, St. Croix, Polk and Pierce counties in the St. Croix Basin.

beginning of European settlement. Continued research is underway for SWAT (Soil and Water Assessment Tool) modeling through the TAPwaters program established by the St. Croix Watershed Research Station. SWAT modeling will provide subwatershed nutrient loading information.



Study Results

In 2003, the nutrient subcommittee analyzed the above studies during a year-long series of meetings. The conclusion of this intensive discussion was that ***based on the 39-percent projected population growth in the St. Croix Basin by the year 2020, the water resources will continue to degrade within the current regulatory path.*** The St. Croix Basin Team determined a 20-percent reduction in total phosphorus loading in the basin was needed. A 20-percent reduction in total phosphorus will approximate the ecological conditions of Lake St. Croix in the 1940s, after European settlement and major land-use changes in the late 1880s, but before large increases in nutrient loadings occurred during 1950-60, causing major changes in diatom communities and algal productivity (see Appendices 2, 3 and 4).

The following paragraphs review the significant research analyzed during 2003 that formed the basis for the 20-percent reduction in nutrient loading recommended goal. Also included is an abstract detailing the next step in research, SWAT watershed modeling, to better define subwatershed nutrient loading. For more detailed summaries of the research with accompanying figures, see Appendices 5-11.

■ **Insights from 25 Years of Water-Quality Monitoring: Trends and Patterns on the Lower St. Croix** (Brenda Lafrancois et al., National Park Service, Appendix 5). The Minnesota Pollution Control Agency and the Metropolitan Council Environmental Services have regularly monitored water quality in Lake St. Croix since the 1960s. Based on a compilation of 25 years of data, small but statistically significant improvements in most nutrient and sediment levels have occurred since 1975. However, some nutrients have significantly increased and nutrient and sediment concentrations remain well above pre-European-settlement levels. Future trends are uncertain due to increasing population growth and land-use change.

■ **Nutrient and Suspended Sediment Concentrations and Loading from Tributaries to the St. Croix River, Wisconsin and Minnesota, 1998–99** (Bernard Lenz et al., United States Geological Survey, Appendix 6). Nutrient and suspended sediment data were collected on major tributaries to the St. Croix River from 1997-99 as part of three studies. These studies showed that the Apple, Willow and Kinnickinnic Rivers were the major contributors of suspended-sediments and nutrients during base flow and storm-runoff events. Nitrate concentrations were highest during base flow in the agricultural tributaries of the Kinnickinnic, Apple and Willow Rivers, possibly from ground-water recharge contributions. Variability in 1999 rainfall intensity resulted in annual yields from several northern, forested basins being higher than those from the southern, agricultural areas. The Sunrise River had the highest annual suspended sediment and nutrient yields for 1999.

■ **A Historical Reconstruction of Sediment and Phosphorus Loading to Lake St. Croix** (Laura Triplett et al., University of Minnesota and St. Croix Watershed Research Station, Appendix 7). Lake St. Croix receives water and stores sediment from the St. Croix Basin, thus providing information about the water quality of the entire Basin. Twenty-four sediment cores were collected from Lake St. Croix to determine the nutrient and sediment loading history of the lake. Analysis of the sediment cores provided the following information:

- ◆ The timing of peak sediment and phosphorus loading to Lake St. Croix shows that early settlement activities, such as logging and conversion of forest and prairie to agricultural land between 1850-1890, had only modest impacts on the lake.
- ◆ By contrast, the mid-1900s brought major increases in sediment and phosphorus loading, suggesting that relatively recent activities in the watershed have caused the lake's current eutrophic condition.
- ◆ Diatom communities have changed drastically and all diatom groups have increased in abundance, likely in response to increased nutrient inputs.

- **Historical Trends in Phosphorus Loading to the St. Croix Drainage from Permitted Point-Source Discharges** (Mark Edlund, St. Croix Watershed Research Station, Appendix 8). Determining the timing and sources of historical phosphorus loading to the St. Croix River is critical in considering alternatives for phosphorus management. A study was completed to determine the historical contribution of point-source loadings to the St. Croix River. Some results are as follows:
 - ◆ The population of the largest counties of the St. Croix Basin (Washington, Chisago, Polk, St. Croix and Pierce) is expected to grow to more than 500,000 residents by the year 2020.
 - ◆ More than 160 municipal and industrial permitted point-source dischargers have operated in the St. Croix Basin since 1905.
 - ◆ When natural or background phosphorus loading to the St. Croix is accounted for, point sources contribute nearly 20 percent of current and future phosphorus loadings.

■ **Response of the St. Croix River Pools, Wisconsin and Minnesota, to Various Phosphorus-Loading Scenarios** (Dale Robertson and Bernard Lenz, United States Geological Survey, Appendix 9). Data collected from the above studies were used in a lake model (BATHTUB) to provide a better understanding of the sensitivity and anticipated trophic response of the St. Croix system to changes in phosphorus loading from point and nonpoint sources. As part of BATHTUB, the sources for nutrient loading into the basin were determined and can be found in Appendix 9. The modeling provided a tool to determine how changes in phosphorus loading would affect the trophic status of these pools. The pools in the lower reach of the St. Croix National Scenic Riverway, Wisconsin and Minnesota, and the adjoining Lake Mallalieu, are eutrophic based on high phosphorus loading. On the basis of the BATHTUB simulations, linear increases in phosphorus loading should cause the following changes in water quality in each of the pools: increases in phosphorus concentration; increases in chlorophyll *a* concentrations, increase in the frequency of algal blooms, a higher intensity of algal blooms; and slightly decreased water clarity. Water clarity will continue to be reduced by non-algal turbidity and high levels of dissolved organic carbon (tea-color) in the water.

- **Volunteer Monitoring on Lake St. Croix from 1999-2002** (Pamela Davis et al., St. Croix Basin Team, Minnesota-Wisconsin Boundary Area Commission, Metropolitan Council Environmental Services, Appendix 10). For four summers, water-quality monitoring information was provided by volunteers living around Lake St. Croix. This data was used to explore the relationship between users' perceptions of the physical appearance and recreational suitability of the water and chlorophyll *a* concentrations. This relationship established an assessment benchmark that provided a common point of reference for citizens and water-quality managers during the goal-setting phase of nutrient study. The volunteer monitoring analysis demonstrated that at six sites, frequent lake users/residents on Lake St. Croix perceived the lake was suitable for recreation and had fairly good water quality. The Secchi depth readings were relatively low (1.3 meters – 1.9 meters), yet the assessment was favorable. The tea-colored appearance of the water may hinder the ability to see algae or inhibit algal growth.

- **A Next Step: Soil and Water Assessment Tool (SWAT) Modeling for the St. Croix River Basin** (Jim Almendinger et al., St. Croix Watershed Research Station, Appendix 11). Computer modeling of watersheds is a tool that can assist water planners by calculating the nutrient and sediment loads by subwatershed. The TAPwaters program (Technical Assistance Program for Watersheds) established by the St. Croix Watershed Research Station will model subwatersheds as funding becomes available. SWAT modeling for the Willow River watershed in Wisconsin will be completed by June 2005. A funding request has been submitted for the Sunrise River watershed in Minnesota.



A glimpse of the River's past can also be seen on the landscape. A stone wall, a steel ring, a cabin or a metal bridge recalls earlier times.

Photo: Nile Fellows



Nutrient Goal Setting

The Nutrient Subcommittee Nutrient Goal-Setting Process

Through a series of discussions, the nutrient subcommittee determined recommended goal scenarios. For a complete review of the decision-making process, see Appendices 2, 3 and 4. Given the importance of the St. Croix National Scenic Riverway, the group included ecological factors as well as water-quality components in the goal-setting process. Four water-quality components were considered relevant to nutrient management:

- Algae (composition, concentrations and bloom frequency);
- Nutrients (phosphorus concentrations and annual loads);
- Water clarity; and
- Sediment accumulation rates.

Defining these water-quality components allowed the subcommittee to organize the analytical work compiled for the goal-setting process. Each component's specific attributes help describe the type of data used for goal setting. For example, the nutrient component of the water-quality condition was defined by the specific measurable attributes -- phosphorus concentrations and annual total phosphorus loads. To facilitate goal setting, the subcommittee further refined the measurable attributes by considering how sensitive each attribute was to the following three variables:

- Flow regime (high flow, low flow, average flow);
- Spatial scale (Lake St. Croix, tributaries, both); and
- Temporal scale (seasonal, annual, five-year, decadal, centennial).

Historical data were used to establish benchmark values for each measurable attribute. Three benchmark decades emerged from the historical data: 1990s (current conditions with modern water-quality monitoring programs); 1940s (population growth and post-WWII introduction of chemical fertilizers and synthetic laundry detergents containing phosphorus); and 1850s (pre-European settlement). Each of these benchmark decades provided unique values for each measurable attribute.

The subcommittee also created a 2020 benchmark to represent future trends in water-resource conditions in the St. Croix Basin. The 2020 benchmark represents a prediction of the water-resource status in Lake St. Croix, considering a 39-percent increase in population and no application of additional resource-management tools. To establish a recommended resource goal for the Lake St. Croix Basin, the subcommittee created a matrix of resource-management options. The following four management options were compared:

- No management action (resulting in conditions as predicted by the 2020 benchmark);
- Maintain water resource conditions at 1990 levels;
- Return nutrient, algae and water-clarity conditions to those which existed in the 1940s; and
- Return nutrient, algae and water-clarity conditions to pre-European settlement conditions.

The subcommittee determined that the third management option (circa 1940s) would be a reasonable goal in improving the water-resource conditions of Lake St. Croix. Reaching circa 1940s conditions will require a 20-percent reduction in total phosphorus loading to Lake St. Croix from current (1990s) conditions.

Water-resource managers must be aware that even attempting to maintain current water quality and ecological conditions in Lake St. Croix will require a reduction in phosphorus loading, given the current population forecast for 2020. The St. Croix Basin Team believes the no action scenario will result in significant degradation of the water resources in Lake St. Croix. Appendix 2 details the system indicators and five management scenarios in a matrix format. Appendix 3 details the sources of the data that were used to determine these levels, based on each management scenario. Appendix 4 demonstrates the numeric relationship between each system indicator and the five management scenarios.

Nutrient Management Implementation and Public Involvement

Coinciding with the beginning of research efforts, the St. Croix Basin Team sponsored annual conferences for sharing information, data and ideas. These conferences provide an opportunity for the public to interact with the St. Croix Basin organizations, agencies and others interested in resource management and protection of the St. Croix Basin.

Prior to 2004, the conferences focused on research and program presentations concerning the impact of excessive nutrient and sediment loading on the water resources of the St. Croix Basin. At the 2004 conference, a slightly different format was used to prepare for the implementation of the nutrient goals. The conference's main message to the public was that based on the projected population growth in the St. Croix River Basin, the water resources will continue to degrade under the current regulatory path.

In the morning session of the 2004 conference, the Basin Team presented the recommended 20-percent total phosphorus-reduction goal and the research upon which the nutrient goals were based. In afternoon discussion sessions, the participants expressed support for the recommended goals and suggested measures and actions to achieve them consistent with the value they place on protecting the scenic beauty, water quality, recreational opportunities and biological diversity of the waters in the St. Croix Basin. Appendix 12 details the outcome of these sessions.

The Next Step

The nutrient subcommittee members are working within their respective agencies and with local officials/organizations to determine how to incorporate the recommended goal into agency policies and programs, such as wastewater and stormwater permitting, as well as watershed planning and development practices at the local level. One local implementation procedure is focused on Project NEMO (Nonpoint Education for Municipal Officials). This educational program is directed towards those within local municipalities that make land-use decisions. It encourages incorporating the protection of natural resources into land-use planning. NEMO presentations have been made throughout Washington County, Minnesota, and in Osceola, Wisconsin, as a pilot program for western Wisconsin.

Finding effective and equitable ways to reduce the total phosphorus loading to the St. Croix River Basin by 20-percent will be the challenge for all. Accomplishing this goal will take dedicated effort by all citizens who work, live or recreate in the St. Croix Basin. As the nutrient subcommittee chair states – “The hard work starts now.”



Contrast the appearance of the St. Croix and Mississippi Rivers at the confluence in Prescott, Wisc. The opportunity to reduce the impact of nutrients and sediments on the St. Croix may be fleeting.

Photo: David Morrison, MPCA





References

- Davis, Pamela J., St. Croix Basin Water Resources Planning Team. 2001. *St. Croix Basin Water Resources Planning Status Report, 2001*. Contact Randy Ferrin, St. Croix National Scenic Riverway, National Park Service, phone 715-483-3284, email Randy_Ferrin@NPS.gov. The report can be found at www.pca.state.mn.us/water/basins/stcroix/index.html.
- Davis, Pamela J., St. Croix Basin Water Resources Planning Team. 2003. *St. Croix Basin Water Resources Planning Status Report, 2003*. Contact Randy Ferrin, St. Croix National Scenic Riverway, National Park Service, phone 715-483-3284, email Randy_Ferrin@NPS.gov. The report can be found at www.pca.state.mn.us/water/basins/stcroix/index.html.
- Fallon, James D., and Ryan P. McNellis. 2000. *Nutrients and Suspended Sediment in Snowmelt Runoff from Part of the Upper Mississippi River Basin, Minnesota and Wisconsin, 1997*. Water-Resources Investigations Report 00-4165. National Water-Quality Assessment Program. United States Department of the Interior. United States Geological Survey.
- Harris, H. Hallett., Robert B. Wenger, David S. DeVault. 1997. *The St. Croix National Scenic Riverway: An Assessment of Ecosystem Risks*. Based on a workshop sponsored by the McKnight Foundation and the University of Minnesota, USA, Center for Ecological Risk.
- Holmberg, Kerry, Jim Perry, Randy S. Ferrin, and David L. Sharrow. 1997. *Water Resources Management Plan St. Croix National Scenic Riverway Minnesota and Wisconsin*. Prepared for the St. Croix National Scenic Riverway National Park Service.
- Lenz, Bernard N., Dale M. Robertson, James Fallon, and Randy Ferrin. 2001. Revised 2003. *Nutrient and Suspended-Sediment Concentrations and Loads and Benthic-Invertebrate Data for Tributaries to the St. Croix River, Wisconsin and Minnesota, 1996-1999*. United States Geological Survey. Water-Resources Investigations Report 01-4162.
- Macbeth, Eric, and Pat Gostovich. 1998. *Volunteer Water Quality Monitoring of Lake Pepin and Spring Lake, 1994-96*. Minnesota-Wisconsin Boundary Area Commission. Final report for the Metropolitan Council Environmental Services, Mears Park Centre, 230 East Fifth Street, St. Paul, Minnesota, 55101-1634, USA.
- Robertson, Dale M., and Bernard Lenz. 2003. *Response of the St. Croix River Pools, Wisconsin and Minnesota, to Various Phosphorus-Loading Scenarios*. United States Geological Survey. Water-Resources Investigations Report 02-4181.
- Triplett, Laura D., Mark B. Edlund, and Daniel R. Engstrom. 2003. *A Whole-Basin Reconstruction of Sediment and Phosphorus Loading to Lake St. Croix*. St. Croix Watershed Research Station. Final project report to the Metropolitan Council Environmental Services at www.smm.org/SCWRS/.



Appendix 1. Participants in the St. Croix Nutrient Goal-Setting Process

Minnesota Pollution Control Agency (MPCA)

- Craig Affeldt
- John Hensel
- Frank Kohlasch
- Mark Tomasek

Wisconsin Department of Natural Resources (WDNR)

- Kathy Bartilson
- Patrick (Buzz) Sorge, Subcommittee chair
- Jim Cahow
- Pete Prusak

Minnesota Department of Natural Resources (DNR)

- Molly Shodeen

National Park Service (NPS)

- Randy Ferrin, Basin Team chair
- Brenda Moraska Lafrancois
- Marianna Young

Metropolitan Council Environmental Services (MCES)

- Kent Johnson

United States Geological Survey (USGS)

- Bernie Lenz
- Dale Robertson

St. Croix Watershed Research Station (Science Museum of Minnesota)

- Dan Engstrom
- Jim Almendinger
- Mark Edlund
- Laura Triplett (University of Minnesota)

Basin Team Coordinator

- Pam Davis

Basin Team Conference Coordinator

- Jim Harrison

Minnesota Department of Agriculture (MDA)

- Jerry Spetzman

University of Wisconsin, Extension (UW)

- John Haack
- Sheri Snowbank



*The nutrient subcommittee canoes the
St. Croix. Photo: John Hensel, MPCA*





Appendix 2

Nutrient Goal-Setting Scenarios Spreadsheet

Management setting		Nutrient Goal Setting Scenarios Spreadsheet					Nutrient conditions prior to European settlement
		~ 20% reduction in nutrient loading from 1990s conditions; suite of goals	If no action is taken; operate under current regulations, based on 39% population growth	To maintain these current conditions would require changes	Basin team recommended nutrient goal scenarios approximates these conditions except sediment accumulation		
Time periods categorizing nutrient conditions in Lake St. Croix							
General category	Measurable attribute	Recommended Nutrient Goal Scenarios	2020	Current (1990s)	1940s	Pre 1850	
Algae	Composition	Benthic dominance	n/a	30% benthic, 70% planktonic	60% benthic, 40% planktonic	80% benthic, 20% planktonic	
	Concentration	12	15	14	12 (12.6)	9 (8.4)	
	Bloom Frequency	6	9	7	6	1	
Nutrients	TP (µg/L)	40	56	50	40	30	
	TP (t/yr)	360	540	460	360	170	
Water Clarity	Secchi Transparency (m)	1.5	1.4	1.4	1.5	1.7	
	Accumulation Rate	47,200	59,000*	59,000	92,000	16,000	
Sediment Accumulation	Volume lost per century (%)	4	5	5	10	1	



Appendix 3

Nutrient Goal-Setting Scenarios Spreadsheet Data Sources

Nutrient Goal Setting Scenarios Spreadsheet Data Sources

Management setting			~ 20% reduction in nutrient loading from 1990s conditions; suite of goals	If no action is taken; operate under current regulations	To maintain these current conditions would require changes	Basin team recommended nutrient goal scenarios approximates these conditions except sediment accumulation	Nutrient conditions prior to European settlement
General category	Attribute	Measurable attribute	Time periods categorizing nutrient conditions in Lake St. Croix				
			Recommended Nutrient Goal Scenarios	2020	Current (1990s)	1940s	Pre 1850
Algae	Composition	benthic:planktonic ratio	Triplett, Edlund, and Engstrom core data	n/a	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data
	Concentration	May-September median surface Total Chlor a (µg/L)	Extracted from USGS bathtub model based on a 20% reduction in P load; reference 1940s conditions	Extracted from USGS Bathtub model based on % change in P load	Medians from combined lakewide Met Council and MPCA data, 1990s, May-Sept	Extracted from USGS Bathtub model based on % change in P load	Extracted from USGS Bathtub model based on % change in P load
	Bloom Frequency	Frequency (%) Total Chlor a >20 µg/L during May-September	Extracted from USGS bathtub model based on a 20% reduction in P load; reference 1940s conditions	Extracted from USGS Bathtub model based on % change in P load	Extracted from USGS Bathtub model based on % change in P load	Extracted from USGS Bathtub model based on % change in P load	Extracted from USGS Bathtub model based on % change in P load
Nutrients	TP (µg/L)	May-September median surface TP concentrations	Medians from combined lakewide Met Council and MPCA data, 1990s, May-Sept, reference 1940s conditions	Medians from combined lakewide Met Council and MPCA data, 1990s, May-Sept	Medians from combined lakewide Met Council and MPCA data, 1990s, May-Sept	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data
Management setting			~ 20% reduction in nutrient loading from 1990s conditions; suite of goals	If no action is taken; operate under current regulations	To maintain these current conditions would require changes	Basin team recommended nutrient goal scenarios approximate these conditions, except sediment accumulation	Nutrient conditions prior to European settlement
Nutrients	TP (t/yr)	Annual loads	Triplett, Edlund, and Engstrom core data (lakewide); reference to 1940s conditions	Triplett, Edlund, and Engstrom core data (lakewide); point source at 70 tons/yr based on MetCouncil population increase of ~39%, no technical improvements at WWTPs and mass cap at Stillwater; non point at 470 tons/yr= % increase from 1940s to 1990s (18.5%) and apply to 1990s	Triplett, Edlund, and Engstrom core data (lakewide) at 459 tons/yr; includes Edlund point source data at 52 tons/yr from USGS modeling report, non-point at 407 ton/yr by subtraction	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data
Water Clarity	Secchi Transparency (m)	May-September mean Secchi depths	Extracted from USGS Bathtub model based on 20% reduction in P load	Extracted from USGS Bathtub model based on % change in P load	Lakewide volunteer monitoring data, May-September, 1999-2002	Extracted from USGS Bathtub model based on % change in P load	Extracted from USGS Bathtub model based on % change in P load
Sediment Accumulation	Accumulation Rate	Annual by mass-basinwide (tons/yr)	Based on a 20% reduction in current loads and infilling rates	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data
		Volume lost per century (%)	Based on a 20% reduction in current loads and infilling rates	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data	Triplett, Edlund, and Engstrom core data



Appendix 4 The Nutrient Subcommittee Goal-Setting Process

Frank Kohlasch, Minnesota Pollution Control Agency

Through interactive decision making, the nutrient subcommittee determined recommended goal scenarios. During a day-long work session, each member of the committee developed his/her own list of four to five water resource goals based on Lake St. Croix (e.g., suppression of blue-green algae). As part of the St. Croix National Scenic Riverway, the group needed to include ecological factors as well as water-quality components in the goal-setting process.

The subcommittee condensed the individual lists of water resource goals into the following four ecological components relevant to nutrient management:

- Biology/ecology of the resource,
- Water clarity,
- Nutrients, and
- Sediment accumulation.

These ecological components allowed the subcommittee to organize the analytical work compiled for the goal-setting process.

Within each ecological component, the subcommittee described a condition of importance. Then, specific measurable attributes were identified to describe the type of data used for the goal setting. These measurable attributes will also serve as the future indicators for each ecological component. For example, under the ecological component

nutrients, total phosphorus was considered one of the measurable attributes used to describe the ecological condition.

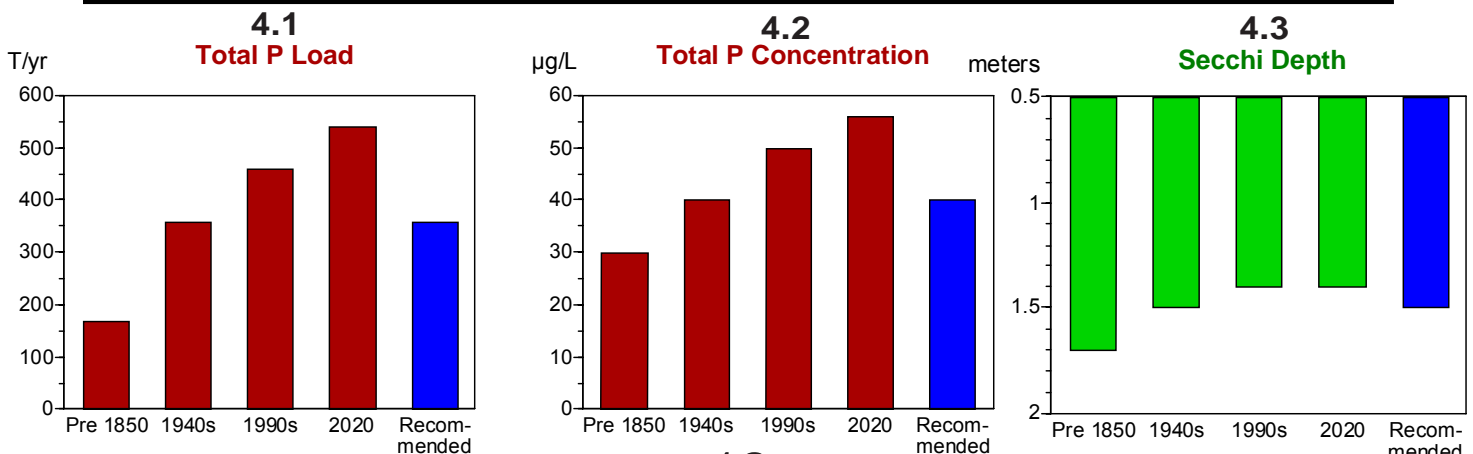
To facilitate goal setting, the subcommittee defined the measurable attributes by considering the sensitivities to the following three variables:

- Flow regime (high flow, low flow, average flow)
- Spatial scale (Lake St. Croix, tributaries, both)
- Temporal scale (seasonal, annual, five-year, decennial, centennial)

After reviewing historical data, the subcommittee determined average flow would be used for flow regime. Lake St. Croix was identified as the appropriate spatial scale because the lake acts as an integrator of nutrient and sediment inputs from all the tributaries. Monitoring frequency and data resolution of each measurable attribute determined the temporal scale.

An example of the definition of a measurable attribute is: May-September (growing season) median surface total phosphorus concentrations in Lake St. Croix. These definitions help ensure that future monitoring programs' data is comparable to current data.

Figures 4.1-4.6: Management scenarios of the six system ecological indicators



Once the categories and measurable attributes were defined for the system, the subcommittee used historical data to establish historical values for each measurable attribute. Three benchmarks emerged from the historical data. Each of these benchmark decades provided unique values for each measurable attribute.

- 1990s (current conditions with modern water-quality monitoring programs),
- 1940s (post-WWII introduction of chemical fertilizers) and
- 1850s (pre-European settlement).

The subcommittee also created a 2020 benchmark to indicate the future trajectory of the water resource conditions in the Lake St. Croix basin. The 2020 benchmark represents a prediction of the water resource status in Lake St. Croix considering a population growth of 39 percent and the application of no additional resource management tools. This forecast is important due to the management guidelines requirement for a National Scenic Riverway.

To establish a recommended resource goal for the Lake St. Croix basin, the subcommittee created a matrix of resource management options. The following four management options were compared:

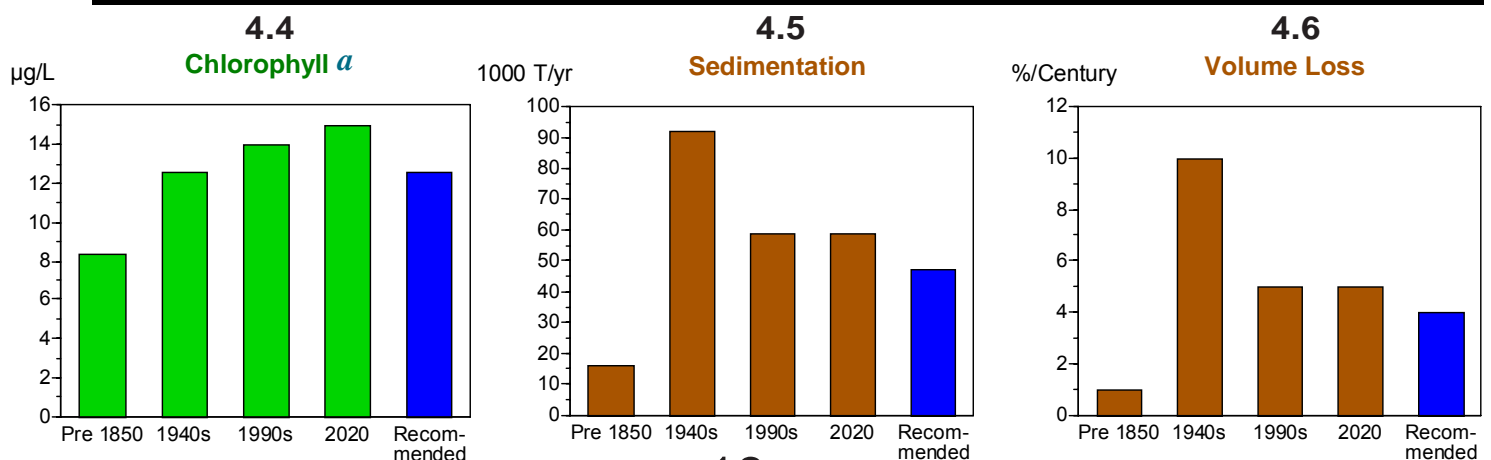
- No management action (resulting in conditions as predicted by the 2020 benchmark).
- Maintain water resource conditions at 1990s levels.
- Return nutrient, algae and water clarity to circa 1940s conditions.
- Return nutrient, algae and water clarity to pre-European settlement conditions.

The subcommittee determined that Management Option 3 (circa 1940s conditions) would be both achievable and successful in improving the water resource conditions of Lake St. Croix. Reaching circa 1940s conditions will require a 20-percent reduction in phosphorus loading to Lake St. Croix from current (1990s) conditions.

This goal was based on the 1940s period, which was after the major land-use changes occurring with European settlement in the late 1880s, but before the big peak in nutrients during the period 1950-1960 and before major changes in diatom communities and productivity occurred.

Using the 1940s condition as the goal will require a 20-percent reduction over current conditions. The only exception to this guideline is the sediment accumulation. The 1940s sediment accumulation data is higher than current conditions. The sediment goal of 47,200 tons/yr is a 20-percent reduction from current conditions.

Water resource managers must be aware that even attempting to maintain current conditions in Lake St. Croix will require a reduction in phosphorus loading from the current forecast for 2020. The subcommittee believes the “no action” scenario will result in significant degradation of the water resource in Lake St. Croix. Figures 4.1 through 4.6 demonstrate the numeric relationship between each system indicator and the five management scenarios. Appendix 2 details the system indicators and five management scenarios in a spreadsheet format. Appendix 3 details the source for the data that was used to determine these levels based on each management scenario.





Appendix 5

Insights from 25 Years of Water-Quality Monitoring: Trends and Patterns on the Lower St. Croix

B.M. Lafrancois¹, K. Johnson², M. Tomasek³

¹ National Park Service, ² Metropolitan Council Environmental Services, ³ Minnesota Pollution Control Agency

Introduction

The St. Croix River Basin drains 7,760 square miles in eastern Minnesota and western Wisconsin. Bogs, peatlands and forests predominate in the northern parts of the basin, with agricultural and urban land uses more prevalent to the south.

Loading of nutrients, such as nitrogen (N) and phosphorus (P), and sediment to the St. Croix is a continuing water-quality concern for water-management agencies and the public. Lake St. Croix, situated at the lower end of the St. Croix River, was formed naturally by a delta of the Mississippi River approximately 9,500 years ago and now serves as an important integrator site for water quality throughout the St. Croix Basin.

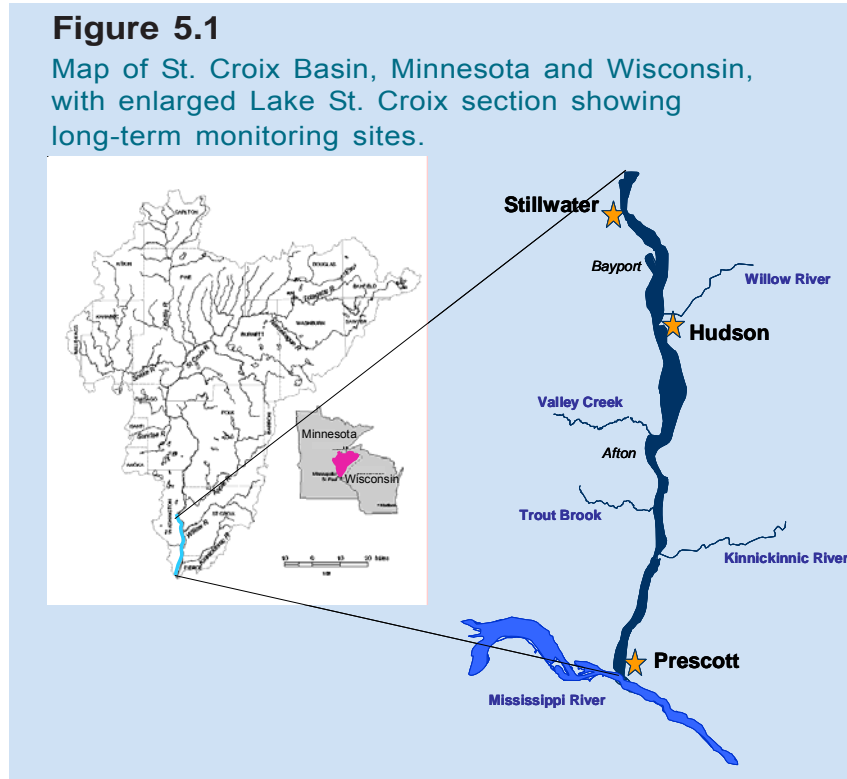
The Metropolitan Council Environmental Services and MPCA have regularly monitored water quality at three sites in Lake St. Croix since the 1970s. Long-term monitoring sites are located at Stillwater, Minn.; Hudson, Wisc.; and Prescott, Wisc. The St. Croix Basin Team’s nutrient technical subcommittee recently compiled and analyzed existing monitoring data from these three sites as part of the ongoing nutrient goal-setting process.

Data Analysis Objectives

- Investigate water-quality trends at Lake St. Croix monitoring sites since 1975.
- Characterize current water-quality conditions for use as a goal-setting benchmark.

Figure 5.1

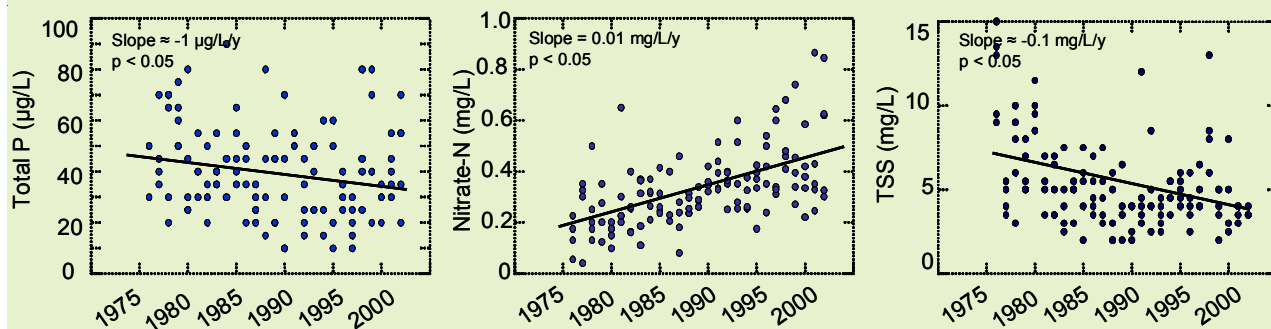
Map of St. Croix Basin, Minnesota and Wisconsin, with enlarged Lake St. Croix section showing long-term monitoring sites.



Methods

- Compiled monitoring data from two sources, Metropolitan Council Environmental Services and Minnesota Pollution Control Agency.
- Tested for trends in flow-adjusted water chemistry variables using Seasonal Kendall test.
- Characterized “current” water-quality conditions for the growing season months (May-September) using lake-wide median concentrations for the period of 1990-1999.
- Compared current conditions with reference conditions using EPA Ecoregion VII criteria.

Figure 5.2 Graphs of select water quality trends in Lake St. Croix, Prescott, 1976-2002.



Results

- Concentrations of most nutrient and sediment variables declined since 1975.
- Concentrations of some variables increased (nitrate and the ratio of dissolved inorganic N to Total P).
- Total P, total N and chlorophyll *a* levels exceed EPA nutrient criteria (reference conditions).
- Nutrient ratios suggest algae are likely P-limited and sensitive to increased P loads.

Conclusions

Small but statistically significant improvements in most nutrient and sediment levels have occurred since 1975. However, some nutrients have significantly increased, nutrient and sediment concentrations remain well above pre-European settlement levels, and future trajectories are uncertain due to increasing population growth and land-use change.



Photo: John Hensel



Lake St. Croix... formed naturally by a delta of the Mississippi River approximately 9,500 years ago... now serves as an important integrator site for water quality throughout the St. Croix Basin.

Table 5.1 Water-quality trends in Lake St. Croix, Prescott, 1976-2002.

Variable	Trend (1976-2002)	Current Condition (1990s)	"Reference" Condition
Total P (µg/L)	Down ↓	50	29
Phosphate (µg/L)	Down ↓	14	n/a
Ammonia (mg/L)	Down ↓	0.02	n/a
Total Kjeldahl N (mg/L)	Down ↓	0.64	n/a
Total N (mg/L)	↔	0.95	0.46
Nitrate (mg/L)	Up ↑	0.26	0.13
DIN:TP	Up ↑	6.7	(4.5-5.0)
Chlorophyll <i>a</i> (µg/L)	↔	14	9
TSS (mg/L)	Down ↓	7.0	n/a
Turbidity (NTU's)	Down ↓	3.2	0.84

Arrows denote direction of statistically significant ($p < 0.05$) trends in variables as determined from Seasonal Kendall trend tests. Current water-quality conditions were estimated as lake-wide median summer concentrations from 1990-1999. Reference conditions were derived from EPA Ecoregion VII, sub-ecoregion 51 nutrient criteria.



Appendix 6

Nutrient and Suspended Sediment Concentrations and Loading from Tributaries to the St. Croix River, Wisconsin and Minnesota, 1998-99

Bernard N. Lenz¹, Dale M. Robertson¹, James Fallon¹ and Randy Ferrin²

¹U.S. Geological Survey ²National Park Service

Nutrient and suspended-sediment data were collected on major tributaries to the St. Croix River from 1997-99 as part of three studies.

The first study, performed in 1997 as part of the U.S. Geological Survey's National Water-Quality Assessment Program, was a widespread synoptic survey of nutrient and suspended-sediment concentrations, loads and yields during snowmelt. Runoff from snowmelt in agricultural areas and areas with low permeability soils had significantly greater nutrient concentrations than forested areas, while differences in suspended-sediment loading were not detected.

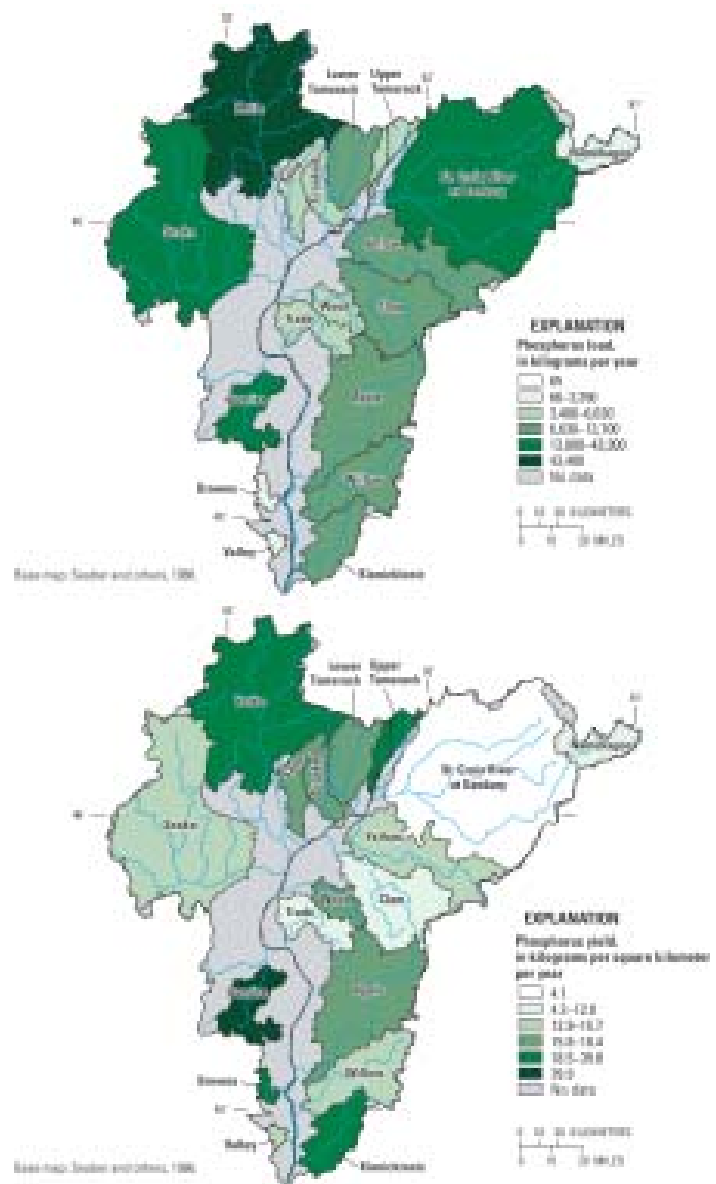
In 1998, synoptic samplings of 11 tributaries were conducted during snowmelt, base flow and storm-runoff periods. These studies showed that the Apple, Willow and Kinnickinnic Rivers were the major contributors of suspended sediments and nutrients during base flow and storm-runoff events. Nitrate concentrations were highest during base flow in the agricultural tributaries of the Kinnickinnic, Apple and Willow Rivers, possibly from ground-water recharge contributions.

Extensive sampling, consisting of continuous streamflow measurements and other testing, was conducted monthly and during high-flow events from Oct. 1, 1998 to Sept. 30, 1999. These data were used to compute annual water year 1999 (October 1998 to September 1999) nutrient and suspended-sediment loads and yields at the monitored sites. Relations between environmental factors and computed annual nutrient and suspended-sediment yields were used to predict loading from unmonitored portions of the basin.

The environmental factors found to best predict yields were soil characteristics (clay, permeability of soil and K factor from universal soil loss equation), basin slope and area, and the percentages of wetland and urban areas in the basins. Variability in 1999 rainfall intensity resulted

in annual yields from several northern, forested basins being higher than those from the southern, agricultural areas. The Sunrise River had the highest annual suspended-sediment and nutrient yields for 1999. Concentration and instantaneous loading rates varied as

Figure 6.1 Phosphorus loading and yield for the St. Croix Basin



much among various flow conditions at individual sampling locations as among tributaries during the three years of study.

To read the complete study, see **Lenz, B.N., Robertson, D.M., Fallon, J.D., and Ferrin, R., 2001**, Nutrient and suspended-sediment loads and benthic invertebrate data for tributaries to the St. Croix River, Wisconsin and Minnesota, 1997-99: *U.S. Geological Survey Water-Resources Investigations Report 01-4162*, 57 p.

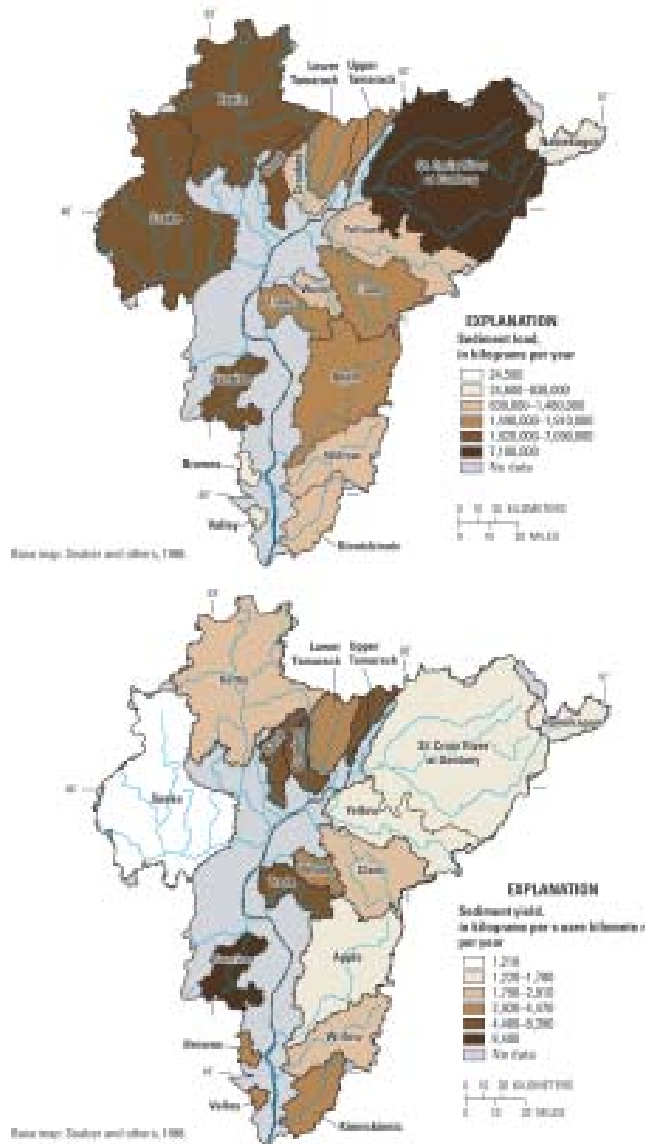


These studies showed that the Apple, Willow and Kinnickinnic Rivers were the major contributors of suspended sediments and nutrients during base flow and storm-runoff events.



Photo: Dave Morrison, MPCA

Figure 6.2 Sediment loading and yield for St. Croix Basin





Appendix 7

A Historical Reconstruction of Sediment and Phosphorus Loading to Lake St. Croix

Triplett, L.D.¹, Edlund, M.B.², Engstrom, D.R.²

¹ University of Minnesota, Department of Geology and Geophysics; ² St. Croix Watershed Research Station, Science Museum of Minnesota

Introduction

The lowermost 37 kilometers of the St. Croix River are naturally wider and deeper, creating what is called Lake St. Croix. The river current slows there, so sediment and other particles being carried by the water settle out to the bottom of the lake. The lake sediment thus contains information about the water quality of the lake; older sediments can tell us what the water quality was like before water monitoring began in the 1970s.

Methods

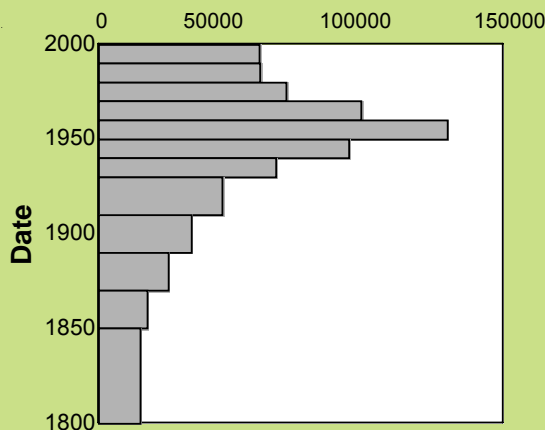
- Collected 24 sediment cores from Lake St. Croix
- Dated cores by ²¹⁰Pb, ¹³⁷Cs and ¹⁴C and calculated sediment accumulation rates for last 150+ years
- Reconstructed historical lakewater phosphorus (P) concentrations using diatom microfossils
- Measured the P trapped in the sediment
- Calculated whole-lake mass balance to determine loading of sediment and P to Lake St. Croix over the last 150 years

Sediment Results

Beginning in 1850, sediment accumulation increased to a peak in 1950-1960 of eight times background rates. The peak was driven largely by sediment

Figure 7.1

Sediment accumulation (t/yr)



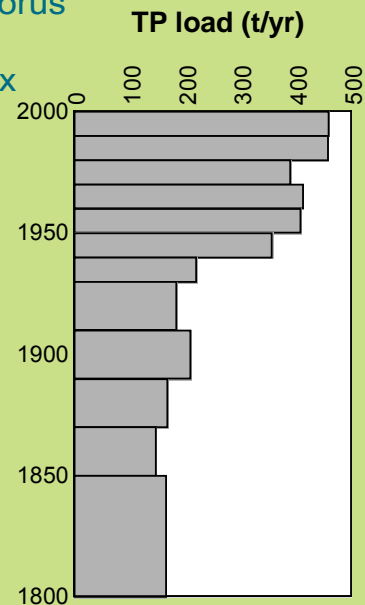
contributions from small side-valley tributaries flowing into the downstream half of the lake.

Phosphorus Results

Total P load to the lake increased sharply after 1940 and remains high, at around four times the pre-European settlement level.

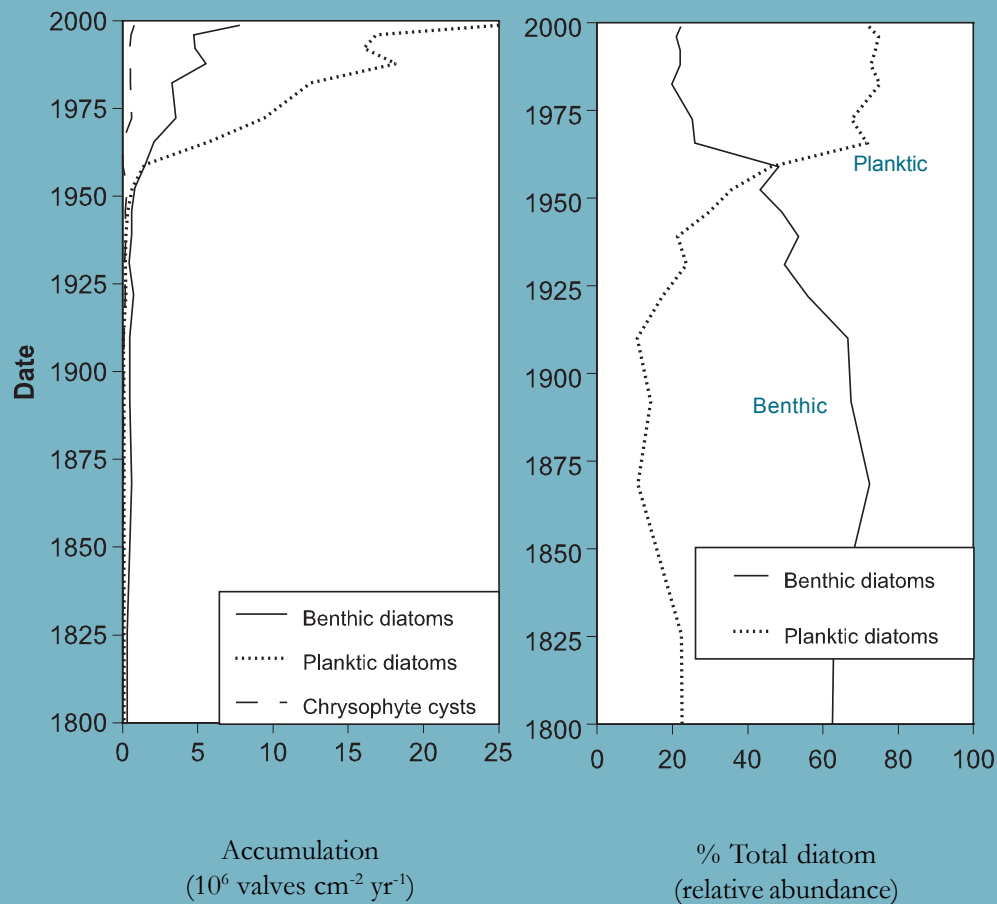
Figure 7.2

Total phosphorus load to Lake St. Croix



Diatom Results

- Since 1950, biogenic silica (bSi) accumulation has risen by 5 times. (Biogenic silica is a measure of the mass of diatoms in the system.)
- While lakewater P increased 2.5 times from 1850 to the present, bSi increased 5.5 times from pre-settlement levels. That is, one unit of P input sustains multiple generations of algal productivity.
- Since 1950, diatom accumulation in the sediment has increased 20- to 50-fold due to a shift to smaller species (includes all ecological groups).
- By 1950, planktic diatoms had surpassed benthic diatoms as the dominant ecological group in the lake.

Figure 7.3 Diatom accumulation and relative abundance

Summary

Lake St. Croix receives water and sediment from the entire St. Croix River Basin. The timing of peak sediment and P loading to Lake St. Croix shows that early settlement activities, such as logging and conversion of forest and prairie to agricultural land between 1850-1890, had only modest impacts on the lake.

By contrast, the mid-1900s brought major increases in sediment and P loading, suggesting that relatively recent activities in the watershed have caused the lake's current eutrophic condition. Diatom communities have changed drastically and all diatom groups have increased in abundance, likely in response to increased nutrient inputs. We do not know how these changes in algal productivity and ecology are affecting other organisms in the lake.



By contrast, the mid-1900s brought major increases in sediment and P loading, suggesting that relatively recent activities in the watershed have caused the lake's current eutrophic condition.



Appendix 8

Historical Trends in Phosphorus Loading to the St. Croix Drainage from Permitted Point-Source Discharges

Mark B. Edlund

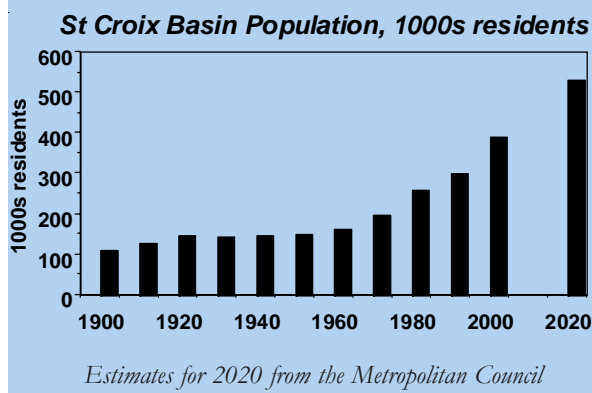
St. Croix Watershed Research Station, Science Museum of Minnesota

Background

Determining the timing and sources of historical nutrient loading to the St. Croix River is critical as we consider alternatives for managing nutrient inputs along the riverway. The reconstruction of historical phosphorus loading to Lake St. Croix using analysis of sediment cores indicates that significant increases in nutrient loading did not occur until after 1940.

Two major landscape changes have occurred concomitant with increases in nutrient loading: shifts in agriculture and increased urbanization. Whereas acreage in agricultural production has declined since the 1930s, changes in agricultural practices and increased availability of chemical fertilizers may have affected water quality. The current trend toward urbanization began after World War II and continues; southern counties in the St. Croix basin are some of the fastest growing in the region. Urbanization has resulted in widespread sewerage of communities in the basin since 1905, causing past and future concerns about nutrient contributions from point-source discharges.

Figure 8.1 St. Croix River Basin population 1900-2000



Project Scope

- Determine the historical contribution of point-source loadings to the St. Croix River.
- Identify the locations, operational histories and nutrient discharges from permitted point sources.
- Estimate future point and nonpoint loadings.

Methods

- Phosphorus loadings were estimated from compliance data, discharge volumes, demographics, per capita P production, industry type and wastewater technologies in use.
- Population growth estimates were used to calculate future point-source loadings. A linear model of 1940s-1990s nonpoint loading predicted future nonpoint quantities.

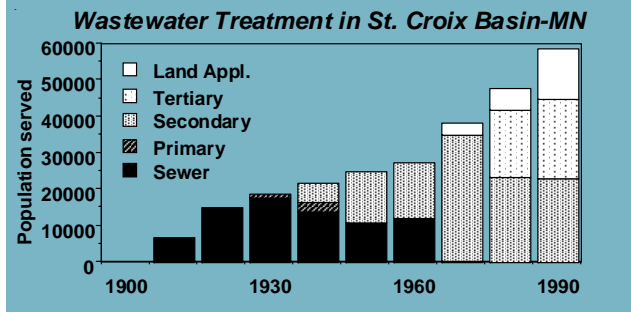
Results

- A population of about 150,000 that lived in the St. Croix Valley from 1920 to 1950 has increased to nearly 400,000 in 2000 (Fig. 1). More than 500,000 residents are predicted by 2020.
- More than 160 municipal and industrial permitted point-source dischargers have operated in the St. Croix Basin since 1905.
- Early wastewater facilities discharged untreated sewage. Technological advances had secondary treatment in many communities by the 1960s-1970s and much of the population served by tertiary treatment by the 1990s (Fig. 8.2).
- Peak nutrient discharges occurred in the 1960s-1970s. We estimated 1990s point-source loadings at 52 metric tons P per year. This represents about 11.3 percent of the total phosphorus loading (Fig. 8.3).
- Compared to estimated natural or background P loading to the St. Croix (166 tons/yr), point sources contribute nearly 20 percent of current and future phosphorus loadings.



Point sources contribute nearly 20% of current and future phosphorus loadings.

Figure 8.2 Minnesota population served by different municipal wastewater treatment technologies, 1900-1990.



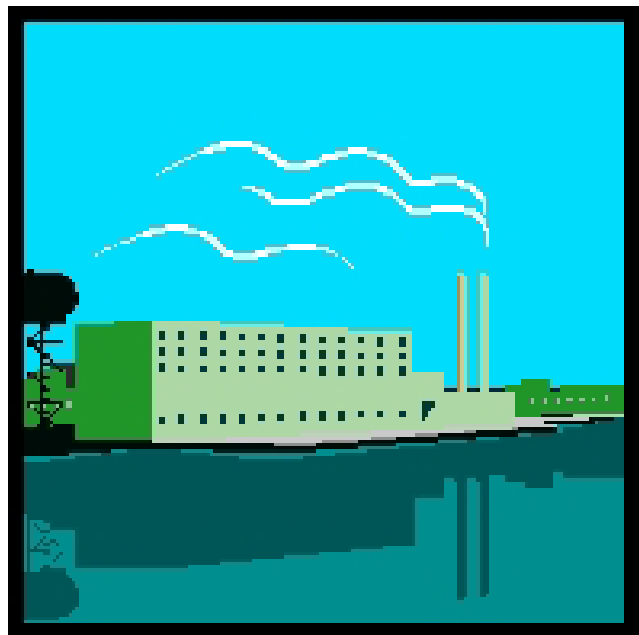
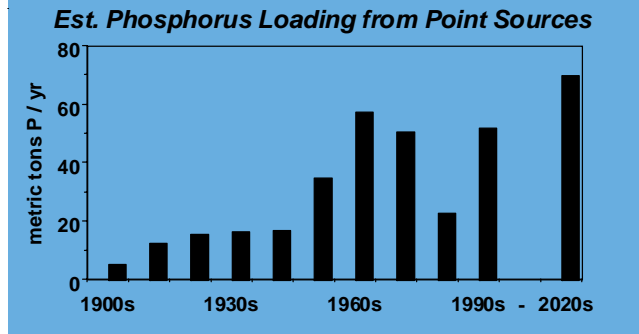
Conclusions

- Research shows point-source loadings are a significant nutrient contribution to the St. Croix, and without action they will increase in the future.
- Point sources should be considered in developing management alternatives to control nutrient inputs as we plan for the future of the St. Croix River.

Acknowledgments

We thank the nutrient subcommittee of the Basin Team for their assistance, and Pam Davis, Dan Engstrom, Mark Tomasek, Kathy Bartilson, Craig Affeldt, Randy Ferrin, Gail Mills, Bernie Lenz, Kent Johnson, Pete Prusak, Greg Johnson and Brenda Moraska Lafrancois for providing data. This project was funded by the National Park Service.

Figure 8.3 Estimated phosphorus discharges (tons/yr) from permitted point sources, Minnesota and Wisconsin, 1900s-2020s





Appendix 9

Response of the St. Croix River Pools, Wisconsin and Minnesota, to Various Phosphorus-Loading Scenarios

*Dale M. Robertson and Bernard N. Lenz
U.S. Geological Survey, WRD, Wisconsin District*

The pools in the lower reach of the St. Croix National Scenic Riverway, Wisconsin and Minnesota, and the adjoining Lake Mallalieu, are eutrophic because of high phosphorus loading. To determine how changes in phosphorus loading would affect the trophic status of these pools, the water-quality model, BATHTUB, was used to simulate existing (1999) water quality and simulate the water quality with various phosphorus-loading scenarios.

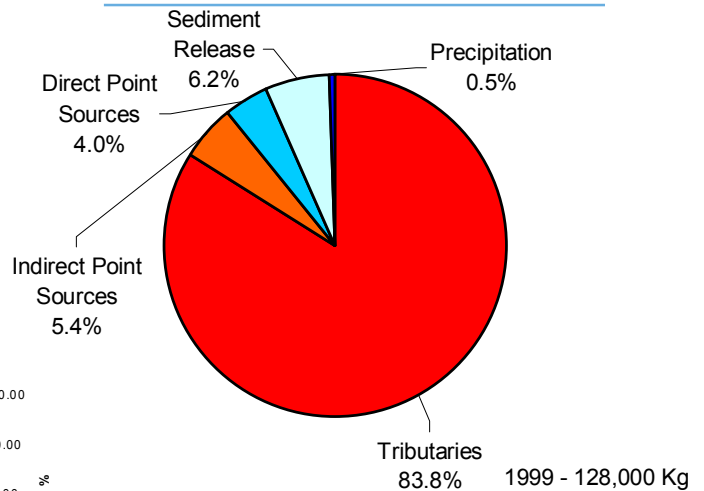
To determine if water quality in the pools responds differently during different flow regimes, sensitivity and scenario evaluations were performed not only for 1999, but also for a simulated period with relatively low flows throughout the basin (using flow data from 1988) and for a simulated period with relatively high flows throughout the basin (using flow data from 1996).

On the basis of the BATHTUB simulations, linear increases in phosphorus loading should cause the following changes in water quality in each of the pools: linear increases in phosphorus concentrations, although at a smaller rate than the increase in loading; non-linear

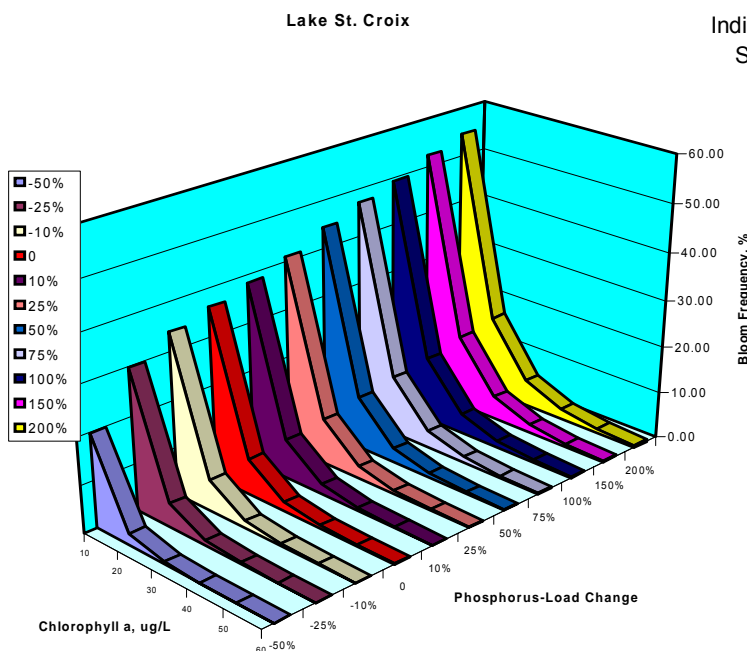
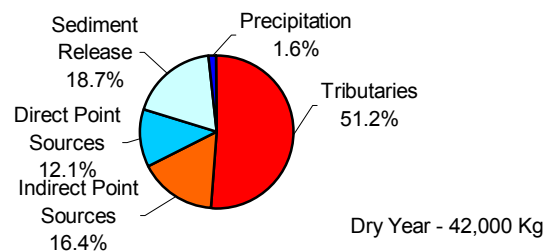
increases in chlorophyll *a* concentrations, with a smaller relative response with higher phosphorus loading; increase in the frequency of algal blooms, with a higher frequency of intense algal blooms; and slightly decreased water clarity.

The response in water quality to changes in the phosphorus loading should be relatively similar for all three flow regimes. Reducing phosphorus loading by about 50 percent would be necessary for the Lake St. Croix pools to be classified as mesotrophic with respect to phosphorus and chlorophyll *a* concentrations, whereas a larger reduction in phosphorus loading would be needed for Lake Mallalieu to be classified as mesotrophic. Even with reductions, water clarity will remain low because of the high non-algal turbidity and stained water in the pools.

1999



Dry Year





Appendix 10

Volunteer Monitoring on Lake St. Croix from 1999-2002

P.J. Davis¹, B. Malick², K. Johnson³

¹*St. Croix Basin Water Resources Planning Team, ²Minnesota-Wisconsin Boundary Area Commission,*

³*Metropolitan Council Environmental Services*

Background

Through a scoping session of interested citizens and agency personnel, nutrient and sediment loading was determined as the top issue affecting water quality in the St. Croix River. To address this issue, the St. Croix Basin Water Resources Planning Team formed a nutrient technical subcommittee in 1997 (nutrient subcommittee) with personnel from the Minnesota Pollution Control Agency, Metropolitan Council Environmental Services, National Park Service, St. Croix Watershed Research Station/Science Museum of Minnesota, United States Geological Survey, and Wisconsin Department of Natural Resources.

In 1998, the nutrient subcommittee secured funding and personnel to support a plan for monitoring, modeling, goal setting, and yearly conferences for public interaction. This report describes the volunteer monitoring component of the nutrient study.

Adopting a model from a recent study completed on Lake Pepin in Minnesota and Wisconsin (Macbeth and Gostovich 1998), citizen monitoring was organized to provide additional data and citizen perceptions of the water quality on Lake St. Croix, a riverine lake identified as a sink for the St. Croix Watershed. The objectives of the study were:

- To develop citizen involvement in water-quality protection to increase the level of stewardship in the St. Croix Basin.
- To explore the relationship between users' perceptions of the physical appearance and recreational suitability of the water, and chlorophyll *a* concentrations.

The physical appearance/chlorophyll *a* relationship established an assessment benchmark that provided a common point of reference for citizens and water-quality managers during the goal-setting phase of the nutrient study.

Methods

Volunteers monitored six sites on Lake St. Croix from 1999 – 2002 during the summer season. The variables monitored were total phosphorus, viable chlorophyll *a*, physical condition rating, recreational suitability rating and Secchi depth. Water samples were collected at the same time the physical assessment was made.

Results

The results showed total phosphorus concentrations varied between 52 ug/l downstream to 79 ug/l midstream. Viable chlorophyll *a* concentrations varied between 13.8 downstream and 23.9 upstream. Physical condition ratings were between 1 and 2. Recreational suitability ratings were between 1 and 2. Secchi depth measurements varied between 1.3 and 1.9 meters (see Table 10.1, next page).

Conclusions

The volunteer monitoring analysis demonstrated that at six sites, frequent lake users/residents on Lake St. Croix perceived that the lake was suitable for recreation and had fairly good water quality. The Secchi readings were lower, yet the assessment was favorable. The tea-colored appearance of the water may hinder the ability to see algae or inhibit algal growth.



NPS Photo



Volunteer water-quality monitors see surprising results (and local wildlife) while helping to assess the condition of the environment.

Table 10.1 Comparative Analysis Lake St. Croix Volunteer Monitoring Program, 1999 - 2002

		Total phosphorus ug/l	Viable chlorophyll a ug/l	Physical condition rating *1-5	Recreational suitability rating **1-5	Secchi depth meters
Site	River mile	MEAN	MEAN	MEAN	MEAN	MEAN
SCU 1	21.5	75	23.9	2	2	1.3
SCU 2	20.5	75	21.3	2	2	1.4
SCM 3	16.5	77	16.9	1	2	1.4
SCM 4	15.8	79	18.1	2	1	1.4
SCM 5	14.5	70	16.3	1	1	1.8
SCL 6	11.5	52	13.8	2	2	1.9

***Physical Condition Rating Scale**

- 1 = crystal clear
- 2 = not quite clear, a little algae present/ visible
- 3 = definite algal green, yellow, or brown color apparent
- 4 = high algal levels with limited clarity and/or mild odor apparent
- 5 = severely high algal levels with one or more: massive floating scums, strong foul odor.

****Recreational Suitability Rating**

- 1 = beautiful, could not be better
- 2 = very minor aesthetic problems, excellent for swimming and boating
- 3 = swimming and aesthetic enjoyment slightly impaired because of algae level
- 4 = desire to swim and levels of enjoyment substantially reduced because of algae level
- 5 = swimming and aesthetic enjoyment of the water nearly impossible because of algae



Frequent lake users/residents on Lake St. Croix perceived the lake was suitable for recreation and had fairly good water quality.





Appendix 11

A Next Step: Soil and Water Assessment Tool (SWAT) Modeling for the St. Croix River Basin

J.E. Almendinger¹, M. Murphy², M. Young³, and the Nutrient Subcommittee of the St. Croix Basin Water Resources Planning Team

¹ St. Croix Watershed Research Station, Science Museum of Minnesota, ² University of Minnesota, ³ National Park Service

Introduction

As demonstrated in previous presentations, the St. Croix is a resource of unquestionable natural and recreational value, and yet it has been significantly affected by nutrient and sediment loads, particularly from non-point sources. Especially in the rapidly developing lower part of the basin, such pressures on the St. Croix will escalate in the next few decades.

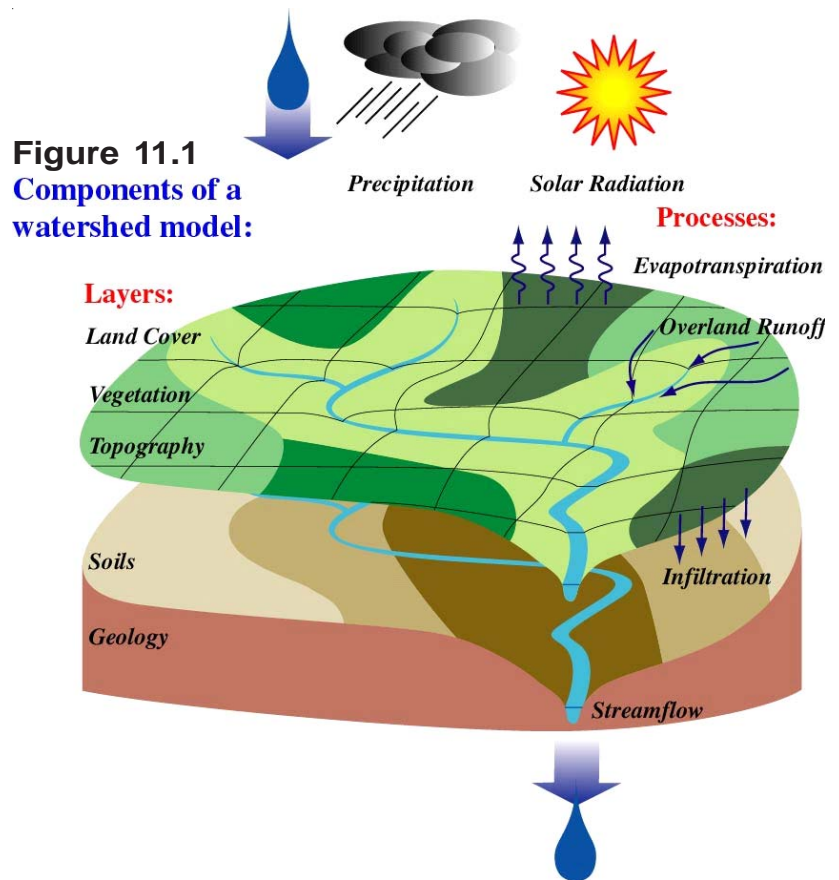
Without planning by watershed managers to design mitigation strategies for these pressures, the St. Croix will become progressively more degraded. We have only to look at other nearby major river systems to see the consequences of failing to plan.

Basin Planning and Modeling

Basin planning has a long and troubled history in the USA. Federal efforts at large-basin planning were formalized in 1965 with the Water Resources Planning Act, but were derailed by funding cuts in 1980. Consequently the burden of basin planning has fallen to the states.

Both Minnesota and Wisconsin recognize the value of basin-wide planning that may provide guidance to, but not replace, local water plans. Basin planners have a daunting task: they need intimate knowledge of how the watershed functions; they need to know that proposed mitigation strategies have a chance of succeeding; and they need to know how to distribute the cost of mitigation equitably among stakeholders.

Computer modeling of watersheds is one tool that can help address these needs and communicate the results effectively to stakeholders (Figure 11.1). A watershed model is a simplification of the actual



hydrologic cycle, with the essential features and processes programmed into a computer. Topography, cover type, land use and soil data are entered to set up the physical framework of the watershed.

Then climate data are put into the model, which then calculates the fate of incident precipitation. The “land phase” of the model calculates whether the precipitation is rain or snow, how much infiltrates, how much evaporates or is transpired, and how much runs off as overland flow.

The model also calculates the nutrient and sediment load carried by the water as it moves across the landscape or through the soil. Water reaches designated channels by both surface and subsurface flow, at which time the “water phase” of the model routes the water with its load of sediment and nutrients downstream.

TAPwaters and SWAT

To make such watershed modeling tools available for basin planning and local watershed management, the St. Croix Watershed Research Station has established TAPwaters, the Technical Assistance Program for Watersheds. Objectives of the TAPwaters project are:

- To model at least one subwatershed in the St. Croix Basin and test selected best-management practice scenarios for effectiveness in reducing non-point source pollution, and
- To construct a coarse-resolution model of the entire St. Croix Basin to provide regional context for local remediation efforts.

To perform this modeling, the TAPwaters center has chosen to start with the Soil and Water Assessment Tool (SWAT). SWAT is a modeling program developed by the USDA’s Agricultural Research Service and has state-of-the-art routines for calculating non-point source pollution loads from agricultural landscapes. In addition, SWAT has recently included routines for urban landscapes as well. The Willow River watershed in Wisconsin has been chosen by the Basin Team as the initial modeling project for the TAPwaters team.

Acknowledgments

Funding during 2003-06 for part of the TAPwaters project was recommended by the Legislative Commission on Minnesota Resources from Minnesota Future Resources Fund. Matching funds are being provided by the Wisconsin Department of Natural Resources.



Basin planners have a daunting task: they need intimate knowledge of how the watershed functions; they need to know that proposed mitigation strategies have a chance of succeeding; and they need to know how to distribute the cost of mitigation equitably among stakeholders.



Appendix 12

Results from the 5th Annual Conference *Protecting the St. Croix: Reducing and Managing Nutrients and Sediments*

February 12, 2004

The following lists the agency/organization/interest for the 94 participants in the conference.

- Consultants (9)
- Municipal officials (15)
- Industry representatives (4)
- Water resource agency staff (36)
- County resource staff (7)
- Researchers/educators (15)
- Lake and river associations (8)

Three questions were presented in the morning sessions to allow the participants an opportunity to contemplate these questions while the research was presented. During the afternoon breakout sessions, the questions were addressed individually, and then shared within small groups. The questions, as stated in the 2004 workshop, are listed below. The number of participants that listed the response is in parentheses.

Your breakout group moderator will ask you write down on a piece of paper the attribute or characteristic you value the most regarding the water resources of the St. Croix River Basin; then he or she will ask you to introduce yourself by name and title, affiliation or interest to the other members of the breakout group, and to tell which quality you chose.

Responses to Question #1: **Most Valued Characteristic of the St. Croix Basin**

- i. Natural Scenic Beauty (19)
- ii. Water Quality (15)
- iii. Recreational Opportunities (13)
- iv. Biological Diversity/Habitat (18)
- v. Valuable Ag. Production (2)
- vi. Stable Water Levels (1)

Reflecting on the conference message above and on your stated values regarding the water resources of the St. Croix River Basin, what is your reaction to the recommended nutrient management scenario?

Responses to Question #2: **Overall Reactions to Recommended Scenario**

- i. No Control (0)
- ii. Hold at Same Level (11)
- iii. 20% Proposal (34)
- iv. Greater than 20% (4)
- v. Additional comments in regards to question #2
 - Work to make sure the public understands the risks/costs and are involved
 - Keep the message simple
 - Everyone needs to cooperate to make this work

(continued on next page)

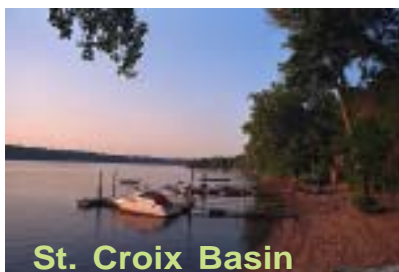
- What will be the impacts on development in the basin?
- Concerned about the cost vs. benefits
- Must focus on non-point sources
- Based on sound science

What measures or actions do you think are realistic and achievable in terms of a nutrient management scenario that responds to the conference message?



Responses to Question #3: **Achievable Actions**

- Controlling non-point
- Education
- Local enforcement/regulations
- Incentive-based programs
- Political changes
- Focus on achievable activities
- More studies
- Nutrient trading
- Find funding to back up programs
- Update BMPs
- Ban “P” dishwashing detergent
- Fertilizer restrictions
- Federal support
- Land-use planning
- Maintain hydrology of basin



St. Croix Basin
Phosphorus-Based
Water-Quality Goals

August 2004

wq-b6-01