



# International Lake of the Woods Basin Water Quality Plan of Study

Covering the Rainy-Lake of the Woods Watershed

Draft for Public Review and Comment  
July 22, 2014

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Kawishiwi River (A. Mast)



Steep Rock Mine (K.Saunders)



Pine and Curry Islands (K. Saunders)



Algae, Lake of the Woods (J. Taylor)

**Prepared by the Lake of the Woods Basin  
Water Quality Plan of Study Team**

## How to Provide Comments on the Draft Plan of Study

This Draft Plan of Study identifies the projects and activities needed to improve understanding of the ecosystem health of the Lake of the Woods Basin (the Basin) and support a balanced, international approach to water quality management in the Basin.

Individuals and organizations with an interest in the future of the Basin are invited to review and comment on the objectives, scope and projects presented in the draft plan. Following the 30-day public review and comment period, the Study Team will prepare a revised Plan of Study, taking into account all comments received, for approval of the International Joint Commission and submission to the governments of Canada and the United States.

Comments may be submitted to the Plan of Study Team on or before August 22, 2014 in any of the following ways:

1. *In-person*, during the public consultation meetings scheduled for:

- Warroad, MN, August 11
- International Falls, MN August 12
- Kenora, ON, August 13
- Ojibways of Onigaming First Nation, ON, August 13
- Atikokan, ON, August 14
- Red Lake, MN, August 14
- Ely, MN, August 15
- Rainy River, ON, August 15.

2. *Online*, at the Study's website: [ijc.org/en\\_/LWBWQPOS](http://ijc.org/en_/LWBWQPOS)

3. *In writing* to the Lake of the Woods Basin Water Quality Plan of Study Team:

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## **Acknowledgements**

In support of development of this Draft Plan of Study, the International Lake of the Woods Basin Water Quality Plan of Study Team wishes to acknowledge the following for their contributions:

- members of the International Rainy-Lake of the Woods Watershed Board, including the Board's Community Advisory Group and the Industry Advisory Group;
- members of the International Multi-Agency Arrangement Work Group and Technical Advisory Committee;
- authors of the Rainy-Lake of the Woods 2014 State of the Basin Report;
- staff with government agencies and non-governmental organizations in Canada and the United States;
- representatives from Tribes, First Nations and Métis communities in the Basin;
- participants at the Plan of Study Workshop held March 11-12, 2014, at the Rainy River Community College in International Falls, MN, and the follow-up webinar held on March 20, 2014;
- workshop leads and Basin experts who function as extended members of the Plan of Study Team; and,
- the many individuals who have taken the initiative over the past few months to contact the Study Team directly to provide information and express their views.

As the Draft Plan of Study is now available for public comment until August 22, 2014, the Study Team anticipates elaborating on this list of acknowledgements in its Final Plan of Study submission to the International Joint Commission, expected in October 2014.

Lake of the Woods Basin Water Quality Plan of Study Team

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## Executive Summary

### About the Draft Plan of Study

This Draft Plan of Study identifies the projects and activities needed to improve understanding of the ecosystem health of the Lake of the Woods Basin (the Basin) and support a balanced, international approach to water quality management in the Basin.

The draft plan has been prepared by the Lake of the Woods Basin Water Quality Plan of Study Team, at the direction of the International Joint Commission (the IJC). The IJC instructed the Study Team to undertake a Plan of Study to:

- identify needed scientific research to understand the underlying causes of current water quality concerns and establish what remedial actions might be most appropriate to addressing the priority issues;
- provide an analysis of what work is being done in these areas, its timing, as well as what work is still needed;
- assess the costs of any actions and the role of governments and the public in this regard; and,
- provide a basis for the IJC to report to the governments of Canada and the United States on recommended actions.

Individuals and organizations with an interest in the future of the Basin are invited to review and comment on the objectives, scope and projects presented in the draft plan. Following the public review and comment period, the Study Team will prepare a final Plan of Study, taking into account all comments received, for approval of the IJC and submission to the governments of Canada and the United States.

The Draft Plan of Study recognizes that watershed assessment and protection is at widely varying stages throughout the Basin, and that working towards Basin-wide solutions requires common goals and a balanced, binational commitment to management. The Plan also recognizes the importance of adaptive management in an ever-changing Basin.

The Draft Plan of Study builds upon considerable cooperative work and planning that has been undertaken in the Basin in recent years. This includes the ongoing assessment and reporting work of the International Rainy-Lake of the Woods Watershed Board, and the work of the International Multi-Agency Arrangement Work Group, which works to foster trans-jurisdictional coordination and collaboration on science and management activities to enhance and restore water quality in the Lake of the Woods Watershed. In addition, the recently released *Lake of the Woods and Rainy River State of the Basin Report* provides a comprehensive review of environmental conditions and existing data for this Basin, including key ecosystem concerns, the gaps in knowledge to better understand those concerns, and recommended approaches for addressing these gaps.

The preparation of this Draft Plan of Study has involved extensive engagement with public agencies in Canada and the United States, scientific and technical experts, First Nations, Métis and Tribes, and the general public. This engagement will continue throughout the remainder of the Plan of Study process.

## Addressing Priority Water Quality Concerns in the Lake of the Woods Basin

Straddling the international border between Canada and the United States, the Lake of the Woods Basin is an important natural, economic and recreational resource. Its drainage area covers about 69,750 km<sup>2</sup> (26,930 mi<sup>2</sup>), with nearly 60 percent located in Ontario and Manitoba and the balance in Minnesota. The area is approximately 400 km (240 mi) east-to-west and 260km (156 mi) north-to-south.

Over the past decade, attention has increasingly focused on the ecosystem health of the Basin and on the need for cooperative, binational action to address complex water quality challenges. Three such challenges are recognized as priorities:

- nutrient enrichment and harmful algal blooms;
- aquatic invasive species; and,
- surface and groundwater contamination, including heavy metals and other contaminants.

The IJC's Terms of Reference for the Plan of Study identified two other important factors, climate change and hydrology and hydrologic regulation, and several cross-cutting areas, including consideration of current organizational and institutional arrangements and programs and the importance of incorporating traditional and indigenous knowledge into the Study's analysis.

The Draft Plan of Study recommends 33 projects to address these water quality and organizational challenges. Table Ex-1 lists the projects under each of the five major themes. These projects would engage researchers from public agencies in Canada and the United States, universities, the private sector, and First Nations, Métis and Tribes.

Under each recommended project, the Draft Plan of Study outlines the objectives, description of work, organization and linkages to other projects, timing considerations, and a summary of project benefits. The final Plan of Study will include information on the estimated costs of the recommended projects.

### 1. Foundational Projects and Activities

This set of recommended projects and activities serve the needs of all three priority water quality challenges. They would help address knowledge and data gaps and establish monitoring systems and public engagement practices to sustain assessment and interest in the water quality and ecological condition of transboundary lakes and rivers. They are organized under two key study areas:

- projects to support the development of a comprehensive monitoring and data acquisition system that would cover critical aquatic and atmospheric parameters critical for understanding processes that result in impairment of water quality; and,
- projects to inform the public and engage First Nations, Tribes and Métis to gain a complementary perspective on water quality and water resources in the Basin that can inform scientific understanding of water quality issues and enhance appreciation of the intrinsic value of rivers and lakes.

### 2. Nutrient Enrichment and Harmful Algal Blooms

Over the past decade, harmful algal blooms, triggered by a variety of climatic, physical, chemical and biological factors, continue to occur in the Basin, particularly in the southern basin of Lake of the Woods and in other lakes upstream from Rainy River.

**Table Ex-1**  
**Lake of the Woods Basin Water Quality Plan of Study**  
**Recommended Projects**

Challenge	Recommended Projects
<b>1. Foundational Projects and Activities</b>	<ol style="list-style-type: none"> <li>1. Coordinated Implementation of a Tiered Monitoring Program for the Lake of the Woods Basin</li> <li>2. Review of Data Collection Programs and Monitoring in the Headwaters Regions of the Basin</li> <li>3. Assessment of Monitoring Networks for Meteorological Conditions and Atmospheric Deposition of Nutrients and Contaminants</li> <li>4. Development of Regional Climate Models for the Basin and Improved Public Education and Engagement on the Issue of Climate Change</li> <li>5. Development of a Lake of the Woods Basin Geospatial Mapping Framework</li> <li>6. Collection of Ecosystem Information and Discussions of Ecosystem Health with Indigenous Communities</li> <li>7. Enhancement of the IRLWWB Website as a Public Communications Tool</li> </ol>
<b>2. Nutrient Enrichment and Harmful Algal Blooms</b>	<ol style="list-style-type: none"> <li>8. Mass-Balance Models for Phosphorus and Nitrogen: Towards An Understanding of the Sources and Sinks of Nutrients in the Lake of the Woods Basin</li> <li>9. Application of Water Quality Models at Watershed and Basin-Wide Scales to Apportion Nutrient Sources and Run Scenarios</li> <li>10. Improved Understanding of Internal Loads and Hypoxia in the Lake of the Woods</li> <li>11. Application of the Phosphorus-Ferrous Conceptual Model to Lake of the Woods</li> <li>12. Assessment of Nutrient Subsidies from Shorelines Due to Erosion from High Water Levels in Lakes and High Flows in Rivers</li> <li>13. Development of Predictive Models of Algal Blooms Based on Hydrological Forcing, Wind Dynamics and Water Circulation</li> <li>14. Application of Satellite Imagery and Remote Sensing Tools to Map and Characterize Water Quality and Algal Blooms in Lake of the Woods with Application to other Transboundary Lakes in the Basin</li> <li>15. Development of Aquatic Food Web Models Focusing on How Zooplankton Communities and Trophic Structure Affect Production of Harmful Algal Blooms</li> </ol>

Challenge	Recommended Projects
	<p>16. Taxonomic Characterization of Algal Communities and Algal Toxins</p> <p>17. Public Health and Animal Welfare Risks Including Public Alerting Mechanisms</p>
<b>3. Aquatic Invasive Species (AIS)</b>	<p>18. Binational Aquatic Invasive Species Management Team for the Lake of the Woods Basin and Development of a Binational Prevention Strategy</p> <p>19. Rapid Evaluation and Implementation of Options to Manage Recent Zebra Mussel Infestation in Headwaters Areas in Minnesota</p> <p>20. Ecological Impact of the Spiny Waterflea in Infested Boundary Lakes</p> <p>21. Develop and Implement Adaptive Control Measures for Hybrid Cattail and Rusty Crayfish.</p> <p>22. Comprehensive Assessment of Potential Invasion Risks to and within the Lake of the Woods Basin</p> <p>23. Water Quality Risk Assessment for Zebra Mussels and Quagga Mussels</p> <p>24. Climate Risk Assessment for Aquatic Invasive Species</p>
<b>4. Surface and Groundwater Contamination</b>	<p>25. Assessment Report on Contaminants in Water, Aquatic Sediment, and Fish</p> <p>26. Spatial Survey of Contaminants of Emerging Concern</p> <p>27. Assess Vulnerability of Border Waters to Contamination from Mining, Agriculture and Petroleum Transport</p> <p>28. Annual Mining Effects Science Workshop</p>
<b>5. International Water Quality Management</b>	<p>29. Determine the Most Appropriate Working Relationship Between the International Multi-Agency Work Group and the International Rainy-Lake of the Woods Watershed Board</p> <p>30. Feasibility of Establishing a Binational Agreement on Water Quality and Ecosystem Health of the Lake of the Woods Basin</p> <p>31. Pilot Project to Apply and Adapt Minnesota's Watershed Assessment Process to Ontario Waters</p> <p>32. Feasibility of Establishing a Funding Program for Non-governmental Organizations to Promote Stewardship</p> <p>33. Binational Water Quality Management Framework for the Lake of the Woods Basin</p>

Harmful algal blooms can prevent recreational usage of lakes for sport-fishing, boating and swimming, alter population densities of commercial and subsistence fisheries, cause undesirable taste and odor of drinking water and compromise water treatment facilities, and sometimes release algal toxins. Toxins are of particular concern because they threaten drinking water supplies, human health and animal welfare.

The Draft Plan of Study identifies a series of projects designed to improve understanding of what contributes to the occurrence of these blooms, to provide a platform by which nutrient abatement and bloom control solutions can be developed and evaluated, and to disseminate information about water quality conditions and harmful algal blooms to the public for safer use of basin waters.

### **3. Aquatic Invasive Species**

Over the last 30 years, the Lake of the Woods Basin has been invaded by many non-native species that have disrupted communities in all trophic levels of the aquatic ecosystem, from algae up to fish. These invasive species include the hybrid cattail, spiny waterflea, rusty crayfish, and Rainbow Smelt. The spiny waterflea, an invasive predatory zooplankton, poses a particular challenge, as it preys upon other zooplankton, a common food sources for juvenile and small fish species. As well, zebra mussels have been reported in the headwater lakes of the Big Fork River, a tributary to the Rainy River.

There is considerable potential for these invasive species to expand their ranges in the Basin, carried downstream by rivers or inadvertently transported to other waterways by recreational boaters and other “human vectors.” These threats require assessment, rapid response and a coordinated prevention plan.

### **4. Surface and Groundwater Contamination**

The impacts of contaminants in the Basin have been greatly reduced through reductions of pollutant inputs into the Rainy River over the years. There are generally less contaminants entering the Basin than there would be in more densely populated and industrialized areas, such as areas in the Great Lakes watershed.

There are however, areas listed as federal contaminated sites, legacy contamination from past mining activity, atmospheric contamination of lakes and fish by mercury, and agricultural inputs in the central portions of the Basin. There also are concerns within the Basin over potential contamination from new mining activities including mining of low-grade metal sulfide ores in northeastern Minnesota, and gold mining in Canada. Finally, contaminants of emerging concern, which include personal care products, drugs, antibiotics, and other classes of synthetic organic chemicals, have been detected in lakes within Voyageurs National Park.

In response to these concerns, the Draft Plan of Study identifies the need for a more complete assessment of the various contaminant issues in the Basin. The goals are to improve the knowledge base about potential sources of contamination, assess vulnerability of water resources, and ensure protection measures are in place to minimize risks associated with contamination from various sources.

### **5. International Water Quality Management**

Projects under this theme seek to strengthen international water quality management in the Lake of the Woods Basin in both the short-term and into the future. Existing collaborations and partnerships among agencies and organizations in Canada and the United States have done exceptional work towards



understanding and addressing the priority issues outlined in this Draft Plan of Study. The recommended projects are designed to fill existing gaps in how water is managed across the border and assess the feasibility of adopting more formal mechanisms that will accelerate resolution of transboundary water quality issues and ensure ongoing public engagement consistent with the spirit of the IJC's International Watershed Initiative. The end-goal of these projects is the development and adoption of a Basin-wide International Water Quality Management Framework aimed at restoring and protecting water quality in the Lake of the Woods Basin.

## **Looking Ahead**

Effective management of water quality issues and their complex interactions with environmental, climatic, and human influences requires high quality information gleaned from monitoring, research, modelling, analysis, and public consultation. Furthermore, it requires an adaptive management framework where problems are addressed with the best information available and evaluated using sound science, and where approaches are adapted as new information is learned. Finally, it requires the will and the commitment of governments to dedicate the necessary short and long term funding and resources to share the responsibilities of managing water quality together across the border and to provide opportunities for public participation.

The projects and activities outlined in this Draft Plan of Study are recommended to fulfill clear objectives and direct the studies and analyses towards clear outcomes. These outcomes will be the basis for future development of international strategies to manage nutrients and reduce the severity of harmful algal blooms, prevent and control aquatic invasive species, and inventory and manage risks of possible surface and groundwater contamination. Together, these strategies will enable the development of a water quality management framework for the Lake of the Woods Basin. Working towards such a framework has many steps, starting with this Draft Plan of Study. Considerable work will need to be done to realize this long-term goal for the Basin.

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### Acronyms

The following is a list of common acronyms used in the Draft Plan of Study:

AIS	Aquatic invasive species
BMPs	Best (or beneficial) management practices
CI	Cyanobacterial index
GCMs	Global Circulation Models
HABs	Harmful algal blooms
HPAB	Health Professionals Advisory Board
HUC	Hydrologic unit code
IJC	International Joint Commission
ILWCB	International Lake of the Woods Control Board
IMA-TAC	International Multi-Agency Arrangement - Technical Advisory Committee
IRLWWB	International Rainy-Lake of the Woods Watershed Board
IWCP	International Watershed Coordination Program
LOWWSF	Lake of the Woods Water Sustainability Foundation
LWCB	Lake of the Woods Control Board
MDNR	Minnesota Department of Natural Resources
MNRF	Ontario Ministry of Natural Resources and Forestry
MPCA	Minnesota Pollution Control Agency
NWHU	Northwestern Health Unit
RCMs	Regional Climate Models
SOBR	State of the Basin Report
TMDL	Total maximum daily load
TN	Total nitrogen
TP	Total phosphorus
USGS	United States Geological Survey

# 1. Introduction to the Draft Plan of Study

This section summarizes the purpose and approach of the draft Lake of the Woods Water Quality Plan of Study.

## 1.1 Purpose and Organization

This Draft Plan of Study identifies the projects and activities needed to improve understanding of the ecosystem health of the Lake of the Woods Basin (the Basin) and support a balanced, international approach to water quality management in the Basin.

The draft plan has been prepared by the Lake of the Woods Basin Water Quality Plan of Study Team (the Study Team), at the direction of the International Joint Commission (the IJC). The IJC's Directive and Terms of Reference for the Study<sup>1</sup> instructed the Study Team to undertake a Plan of Study to:

- identify needed scientific research to understand the underlying causes of current water quality concerns and establish what remedial actions might be most appropriate to addressing the priority issues;
- provide an analysis of what work is being done in these areas, its timing, as well as what work is still needed;
- assess the costs of any actions and the role of governments and the public in this regard; and,
- provide a basis for the IJC to report to the governments of Canada and the United States on recommended actions.

Individuals and organizations with an interest in the future of the Basin are invited to review and comment on the objectives, scope and projects presented in the draft plan. Following the public review and comment period, the Study Team will prepare a revised Plan of Study, taking into account all comments received, for approval of the IJC.

The Draft Plan of Study recognizes that watershed assessment and protection is at widely varying stages throughout the Basin, and that working towards Basin-wide solutions requires common goals and a balanced, binational commitment to management. The Plan also recognizes the importance of adaptive management in an ever-changing Basin. The projects recommended here include immediate, short-term and long-term initiatives, all of which will help resource agencies and their partners fulfill their mandates, but will necessitate commitments from governments. Recognition of this in light of increasing pressures on budgets and resources is imperative for successful implementation of the Plan of Study projects and the long-term international goals.

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<sup>1</sup> Available at [http://ijc.org/en/\\_LWBWQPOS](http://ijc.org/en/_LWBWQPOS)

This section provides a brief context to the Plan of Study and outlines the overall approach taken by the Plan of Study team.

Section 2 provides a brief overview of the Lake of the Woods Basin, including land and water uses, key interests in the Basin and water quality challenges.

Section 3 presents the recommended projects and activities to respond to the current and emerging challenges to the ecosystem health of the Lake of the Woods Basin.

Section 4 concludes with a brief synthesis of the projects in the context of the overall goal of strengthened international management of water quality in the Lake of the Woods Basin.

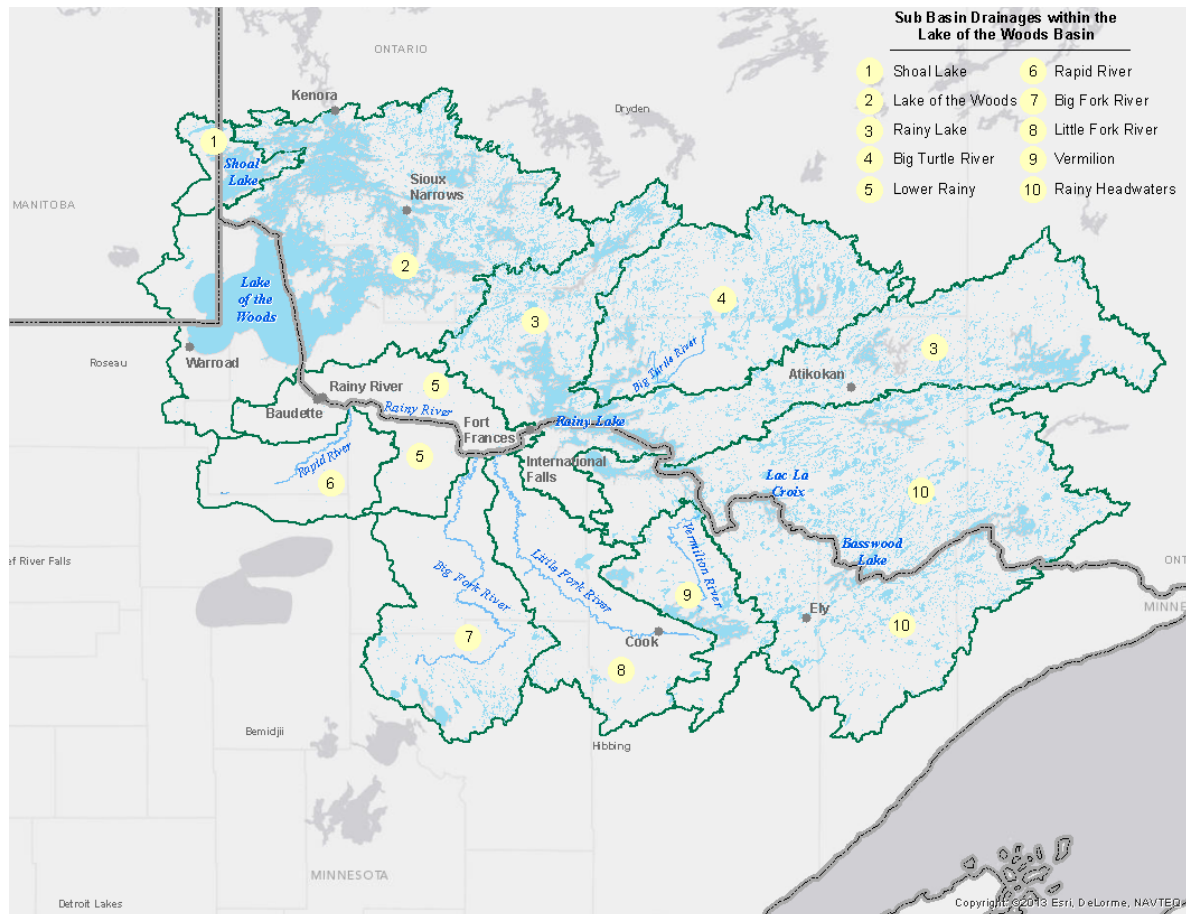
## **1.2 Background**

The Lake of the Woods Basin straddles the international border between Canada and the United States, (Figure 1). The Basin's drainage area, covering 10 major sub-basins, is about 69,750 km<sup>2</sup> (26,930 mi<sup>2</sup>) in area, with nearly 60 percent located mainly in Ontario with a small portion in Manitoba and the balance in Minnesota. It is approximately 400 km (240 mi) east-to-west and 260 km (156 mi) north-to-south.

Over the past decade, attention has increasingly focused on the ecosystem health of the Basin and on the need for cooperative, binational action to address complex water quality challenges.

In 2010, the federal governments of Canada and the United States of America (the Governments) issued a Reference to the IJC to conduct a review of binational management of water quantity and quality in this Basin and make recommendations for improvement. To do this work, the IJC appointed the International Lake of the Woods and Rainy River Watershed Task Force (the Task Force) to prepare the review and recommendations. After extensive consultation with its Community Advisory Group, resource agencies, First Nations, Tribes, Métis and the general public, the Task Force submitted its report to the IJC in July 2011, identifying the main ecosystem health issues in the Basin together with observations of barriers to watershed-wide management based on regulatory and governance gaps across the international border. There was also recognition of the lack of indigenous representation at the IJC Board level.

The IJC submitted the Task Force's recommendations to the Governments in January 2012, along with suggested actions, such as the need to conduct a Water Quality Plan of Study to better understand the main water quality issues in the Basin. The Governments agreed and, in the summer of 2012, officially recognized the importance of having a sound understanding of water quality issues through a Water Quality Plan of Study, to inform subsequent actions by the Governments and by the International Rainy-Lake of the Woods Watershed Board (IRLWWB).



**Figure 1 - Major Sub-basins in the Lake of the Woods Basin**

The Governments also agreed with the need for indigenous representation and the need to structure IJC jurisdiction on a watershed basis. A number of improvements were addressed immediately, including:

- the amalgamation of the two previous IJC boards in the basin (the Rainy Lake Board of Control and the Rainy River Water Pollution Board) into the current IRLWWB with an expanded geographic jurisdiction based on the “basin” boundaries; and,
- the establishment of three seats on the new Board, one each for a Canadian First Nation member, a Canadian Métis member and a U.S. Tribal member.

This new board was given the mandate to monitor ecosystem health in the Basin. It was recognized that, given its new mandate, the Board would require a better understanding of the basin’s health.

The Draft Plan of Study builds upon considerable work that has been undertaken in the Basin in recent years. This work includes:

- The 2011 Task Force report, *Bi-national Management of Lake of the Woods and Rainy River Watershed*, which presented extensive information and analysis on the accomplishments around water

quality and quantity, responsibilities of agencies and organizations with water quality mandates, and binational management challenges;

- The recently released *Lake of the Woods and Rainy River State of the Basin Report, 2<sup>nd</sup> Edition* (SOBR) (Clark and Sellers, 2014), which provides a comprehensive review of environmental conditions and existing data for this Basin, including key ecosystem concerns, the gaps in knowledge to better understand those concerns, and recommended approaches for addressing these gaps;
- The draft *Five Year Workplan* of the International Multi-Agency Arrangement Work Group, which presents a thorough overview of completed, ongoing and proposed research on water quality on Lake of the Woods and immediate upstream waters. Driving much of this research is the Minnesota Pollution Control Agency's (MPCA) Total Maximum Daily Load Study for the U.S. portion of Lake of the Woods and the intensive watershed assessment work on other U.S. sub-basins to identify impairments; and,
- The *IJC's Rule Curve Review Studies for the Rainy and Namakan Chain of Lakes* (in progress), which includes projects providing key potential rule curve impact linkages to the Plan of Study.

## 1.3 Plan of Study Approach

This section provides a brief overview of the approach of the Plan of Study, including guiding principles, scope, key issues, organizational framework, timelines and interest group engagement.

### 1.3.1 Guiding Principles

The Lake of the Woods Basin Water Quality Plan of Study will adhere to the following principles:

- The Plan of Study will consider the needs of all the interests, including citizens and grass-roots advisory groups; Tribes, First Nations, and Métis communities; the business community; and governments in the Lake of the Woods Basin and, in doing so, will strive to provide a balanced, science-based Plan of Study.
- The Plan of Study process will be transparent, with opportunities for input and review by all interests.
- Citizen and indigenous knowledge will be given a voice in defining science needs for the Basin.
- The Plan of Study will strive for credible, peer-reviewed science using accepted methodologies.
- Potential resource management options that commit public (government) resources will be based on credible, peer-reviewed science.
- The Plan of Study will consider the most cost effective means to conduct recommended studies.
- The Plan of Study will strive to prioritize projects based on what is best for the Basin and propose options accordingly.

The Plan of Study is based on current knowledge and understanding. It is recommended that governments and stakeholders adopt an adaptive management approach for the course of the Study, adjusting plans, when appropriate, as new information comes to light.



### 1.3.2 Geographic Scope

The Draft Plan of Study recognizes the connectivity between the boundary waters and the entire upstream basin draining into those boundary waters and eventually feeding into Lake of the Woods. Therefore, the geographic scope of the Study, the Lake of the Woods Basin, refers to all land and water from the Rainy Headwaters in the east to the outlet where the system drains into the Winnipeg River in Kenora, ON to the northwest. Note that the Plan of Study also makes reference to the “Lake of the Woods sub-basin”, which is one of 10 sub-basins that constitute the larger Lake of the Woods Basin (Figure 1). Where the term “Lake of the Woods” is used on its own, this refers to the lake only.

The geographic scope of the Plan of Study draws from the IJC’s authorities under the *1909 Boundary Waters Treaty* (the Treaty) and the Directives issued by the IJC to the IRLWWB. Under the Treaty, the IJC may make recommendations to Governments with regards to water quality objectives for boundary waters in the Lake of the Woods Basin. These waters include Lake of the Woods, Rainy River, Rainy Lake and Namakan Lake, Sand Point, Little Vermilion, Lac La Croix, Crooked, Basswood, Sucker, Knife, Saganaga, Gunflint, and North Lakes. As a result, the scope of the Plan of Study focuses on the boundary waters of the Basin, though consideration for scientific analysis and/or activities has been given to upstream waters outside the defined boundary waters where there is justification to believe that activities upstream will affect receiving boundary waters, as is provided for in the IRLWWB Directives.

### 1.3.3 Key Issues

The scope of the Draft Plan of Study includes each of the priority issues and factors related to water quality specifically identified by the IJC in its report to January 2012 governments. These priority issues include:

- nutrient enrichment and harmful algal blooms;
- aquatic invasive species; and,
- surface and groundwater contamination, including heavy metals and other contaminants.

Other important factors identified as priorities by the IJC for understanding water quality include climate change and related development of indicators and adaptation measures, as well as hydrology and hydrologic regulation. These factors will be considered within the Plan of Study insofar as they relate directly to the priority issues.

The Terms of Reference for the Plan of Study identified several cross-cutting areas to be considered, including consideration of current organizational and institutional arrangements and programs, and the importance of incorporating traditional/indigenous knowledge into the Study’s analysis.

### 1.3.4 Organizational Framework

The Terms of Reference identifies a number of components to the Plan of Study including where significant deliverables are to be produced. The first five components of the Plan of Study were accomplished through the development of the SOBR Update and a series of targeted meetings, workshops and webinars with experts convened in early 2014. Specifically, these activities sought to accomplish the following objectives:

1. Identify existing research, data, regulatory and other relevant information available on the priority issues and factors.
2. Identify current activities and projects occurring in the watershed to address the priority issues and factors.
3. Identify key science and/or policy questions to be answered within the priority areas of concern and identify gaps in knowledge that, if filled, would provide answers to those key questions. As part of this component, it is critical to:
  - a. Develop an approach for engaging key scientists, resource managers, policy personnel, First Nations, Tribes, Métis, the public and the Board's CAG and IAG in this key component throughout the watershed. It is recommended that a technical session of experts (including traditional knowledge sharing) occur at the start of the process (for components 1-8) and a second technical session be held to review the output of the first session prior to finalizing a first draft; and,
  - b. Ensure that discussions around key science and/or policy questions not only focus on the priority issues and factors of concern themselves, but also on the gaps that may exist within the regulatory environment (e.g., land use regulation in unorganized territory, watershed planning capabilities, existing and/or differing standards).
4. Define the studies, research, and other activities necessary to fill the identified knowledge gaps and answer the key questions, including:
  - a. Articulating and recommending the methodology for conducting all studies and activities to be performed and level of detail anticipated for each;
  - b. Making recommendations for building upon existing monitoring programs to ensure long-term data are available to conduct the research, monitor trends and anticipate ecosystem pressures, as well as the effectiveness of activities and adaptive management strategies; and,
  - c. Identifying the sources of, or means of obtaining, needed information (scientific and historical/traditional knowledge).
5. Define and articulate the additional activities and projects necessary to address the priority issues and factors.

The remaining components have been or will be accomplished through further discussions with Basin experts, meetings with IJC Commissioners and advisors, public meetings and meetings with First Nations, Tribes and Métis and through the ongoing work of the Plan of Study Team:

6. Produce a preliminary draft version of the Plan of Study to be submitted for discussion at the International Rainy – Lake of the Woods Watershed Forum (IR-LW Watershed Forum) in March, 2014.
7. Recommend the agencies or organizations with the knowledge or expertise (scientific and activities and projects).
8. Establish the priority, duration and timing of each study or activity.
9. Estimate the human and financial resources, including expertise, required to conduct each individual study or activity:
  - a. Provide a selection of options that range from a full suite of recommended studies/activities and higher-end costing to scaled-down options with only priority studies and lesser cost; and
  - b. Identify potential funding sources available in both Canada and the U.S. to conduct this work and/or anticipated future funding constraints that could compromise the outcome of this study.

*Note: Costs have not yet been estimated for all projects, and are not included in this draft version of the Plan of Study.*

10. Produce a Draft Plan of Study to be submitted for comments to the IJC, the IRLWWB and its community and industry advisory groups at the April 2014 semi-annual meeting.
11. Produce a Final Draft Plan of Study to be made available in late July 2014 for a 30-day public comment period before the IRLWWB annual meeting.
12. Submit a Final Plan of Study to the IJC by October 2014.

### **1.3.5 Engagement of Basin Interests**

The preparation of this Draft Plan of Study has involved extensive engagement with public agencies in Canada and the United States, scientific and technical experts, First Nations, Métis and Tribes, and the general public. This engagement will continue throughout the remainder of the Plan of Study process.

In preparing the Draft Plan of Study, the Study team convened workshops and made presentations to Basin interests. Milestones to date include:

- IJC appoints Plan of Study co-chairs and issues terms of reference (January, 2014);
- Preliminary Plan of Study submitted to the IJC and IRLWWB (including the Community Advisory Group and the Industry Advisory Group) on February 28, 2014, in collaboration with

- selected scientists from the International Multi-Agency Arrangement Technical Advisory Committee and the State of the Basin Report (SOBR) Principal Investigator;
- Preliminary Plan of Study submitted for discussion and input at the Water Quality Plan of Study Expert Assessment Workshop on March 11-12, 2014 (prior to the Rainy-Lake of the Woods Watershed Forum March 12 - 13, 2014) and during a webinar on March 20, 2014;
  - Draft report submitted to the IJC, IRLWWB, Community Advisory Group and Industry Advisory Group on April 11, 2014 prior to Semi-annual meeting; discussion of contents at Plan of Study Team Appearance before Commissioners (April 30);
  - Presentations to City of Kenora (April 8), Métis Council of Kenora (May 12), Township of Sioux Narrows-Nestor Falls (June 3), Sioux Narrows Breakfast Club (June 17), Northwestern Ontario Municipal Association (June 18), Kenora Rotary Club (June 30), and Lake of the Woods District Property Owners Association (July 17);
  - Additional technical meetings with experts – IMA-TAC (May 27), Basin Experts (May 28, June 23), IMA-WG (June 10), AIS experts (June 12); and,
  - Discussions with IRLWWB (May 30).

Additional engagement activities are planned following the public release of the draft Plan of Study in July 2014. The Plan of Study Team has planned a series of nine meetings and two webinars throughout the Basin in mid-August 2014 to meet with technical experts, the IRLWWB, the community and industry advisory groups, the public, and indigenous communities to review the draft report and receive feedback prior to development of the final report. Public meetings are scheduled for: Warroad, MN (August 11), International Falls, MN (August 12), Kenora, ON (August 13), Ojibways of Onigaming First Nation, ON (August 13), Atikokan, ON (August 14), Red Lake, MN (August 14), Ely, MN (August 15) and Rainy River, ON (August 15).

In addition to the July 22 news release announcing the availability of the Draft Plan of Study, a notice announcing the series of August meetings was posted on community/municipal/ and Minnesota Soil and Water Conservation Districts websites and emailed to a large distribution list of individuals and groups within the Basin.

## **2. The Lake of the Woods Basin**

This section provides a brief overview of the Lake of the Woods Basin, including land and water uses, key interests in the Basin and water quality challenges.

### **2.1 Overview of Land and Water Uses**

The Lake of the Woods Basin is an area of great diversity in both geography and ecosystem health challenges. It is an important natural, economic and recreational resource. Its water resources are vital sources of drinking water for the City of Kenora, ON, the City of Winnipeg, MB (which draws drinking water from Shoal Lake), Canadian townships and unorganized territory, U.S. counties, First Nation, Métis and Tribal communities.

As noted in Figure 1, the Basin can be divided into 10 main sub-basins: Shoal Lake; Lake of the Woods; Big Turtle River - Rainy Lake; Rainy Lake; Rainy Headwaters; Vermillion River; Little Fork River; Big Fork River; Lower Rainy River; and Rapid River. In the upper sub-basins, the boundary area often referred to as the Quetico-Superior makes up a significant portion of the land mass and features boreal forest on shallow soils over bedrock. It is an area dominated by the presence of large national parks (Quetico, Voyageurs), the Superior National Forest and the Boundary Waters Canoe Area Wilderness (BWCAW). In 1978, logging was terminated in the BWCAW and motorboat usage was greatly decreased. Since 1978, land use in this protected area has been limited primarily to backcountry recreational use, and the BWCAW has become the most heavily used wilderness area in the United States. Visitor use has increased threefold since the early 1960s, and more than 100,000 people camp in the backcountry each year (Mast and Turk, 1999). Similarly, Ontario Parks statistics indicate that more than 75,000 visitors came to Quetico Provincial Park in 2010 (Ministry of Natural Resources, 2011).

The central and downstream sub-basins are a mix of boreal forest, bedrock, agricultural land and, in the southern Lake of the Woods region, extensive wetlands and sandy shorelines. Lake of the Woods, the largest lake in the Basin, covers an area of 3,850 km<sup>2</sup> (1,486 mi<sup>2</sup>), the northern portion being on Precambrian Shield and home to approximately 14,500 islands, while the southern shores of the lake are located on the prairie topography of the old Glacial Lake Agassiz lakebed. Rainy Lake is also of significant size at 932 km<sup>2</sup> (359 mi<sup>2</sup>).

Historical and current land uses in the Basin include agriculture, urbanization, forestry, mining and recreation. In and around the Rainy River and southern Lake of the Woods, forestry, recreation, tourism, and agriculture are the main land use activities, with a considerable portion of the region used for mixed farming or grazing. Agriculture covers 6.4 percent of the land portion of the Basin as cropland or cropland and shrubland/woodland. The Lower Rainy River and the Lake of the Woods sub-basins contain the highest proportion of cropland at approximately 10-15 percent of the land-only portion. Forestry and recreation dominate the land uses around Lake of the Woods.

Currently, mining operations on the Canadian side of the Basin are limited to exploration and development. There are new gold exploration properties located to the south (Rainy River) and to the east

of Lake of the Woods (Cameron Lake), as well as north of Atikokan, ON (Hammond Reef). Elsewhere in the Basin, other minerals have been mined, notably iron ore near Atikokan (the now-closed Steep Rock Mine that was in operation for 40 years) and in areas of Minnesota including Lake Vermilion, Ely, Tower-Soudan, and on the South Kawishiwi River. There are at least two active iron mine operations in Minnesota part of the Basin, as well as aggregate mining.

## 2.2 Key Interests in the Basin

The Basin's population is sparsely distributed and concentrated in a few cities, towns, townships, Counties, on First Nation, Métis and Tribal lands, and in seasonal residences around the shorelines of major lakes. As noted in DeSellas *et.al.*, (2009), population density ranges from approximately 0.15 to 1.79 people per km<sup>2</sup> for specific counties and districts in the Basin. Overall, the population is declining, though the populations of indigenous communities are growing. Although the population in the Basin proper is sparse, it burgeons during the summer tourist season. As well, more than 750,000 people rely on the waters of the Basin as a source of drinking water, including the City of Winnipeg, MB.

Comprehensive overviews of the many interests in the Basin, including those involved in water quality research and management, are available in both the SOBR (Clark and Sellers, 2014) and the 2011 Task Force Report. This section highlights some of those key participants and the partnerships that have developed leading up to the development of this Plan of Study.

### 2.2.1 International Partnerships

The past decade has seen an increase in collaborative research and communication between the U.S. and Canada, especially with regard to understanding what drives algal blooms on Lake of the Woods and caused the state of Minnesota to list the southern basin of Lake of the Woods as “impaired” for phosphorus and algae in 2008. Where there was a gap in IJC Board mandate in the Basin before, the establishment of the IRLWWB in 2013 now provides an international approach for collaborative surveillance of ecosystem health throughout the Basin. The work of the IRLWWB and the development of this Plan of Study can draw from the synergies in this Basin; the success of the implementation of the Plan of Study projects and the effectiveness of bi-national management planning will depend on the continuation of these synergies, which include:

- the partnership between the Lake of the Woods Water Sustainability Foundation (LOWWSF) and the IJC to fund the SOBR as a prelude to the Plan of Study has provided baseline information required to make informed decisions on gaps and future activities/research to better understand the priority issues.
- the Rainy-Lake of the Woods Watershed Forums, held since 2004, have provided the common ground where researchers share research findings, develop joint project plans and goals and discuss collaborative management options. The themes for the 2014 Forum mirrored the priority issues in this Plan of Study, ensuring that discussions were focused on the topics of greatest concern at this time. The Forum has become known as the hub for scientific knowledge in this Basin and, this year,

provided the most relevant venue for hosting the Plan of Study Expert Assessment Workshop on March 11 and 12 to seek input on the Draft Plan of Study.

- the commitment of the members of the International Multi-Agency Arrangement (IMA) (see 2.2.4, below) over the years to fund research projects within their workplan (in particular, the contributions from Minnesota), the contribution those projects now make to the robustness of the Plan of Study and the advisory role this IMA has played in developing the Plan of Study. The close ties between the objectives of the IMA and the outcome of the Plan of Study will undoubtedly identify studies and activities of benefit to the IMA and the IRLWWB in general as well as individual resource agencies with a mandate for water quality monitoring and management.
- the commitment of partners (currently the IJC, MPCA, LOWWSF, Province of Manitoba) to the provision of catalytic funding for the development of the International Watershed Coordination Program since October 2012; this program has enhanced the capacity within the Basin, through a dedicated Coordinator position, to provide secretariat support to this Plan of Study facilitate the workplan and actions of the IMA, and promote civic engagement activities across the border to build support for stewardship and watershed protection from the grassroots level.

## **2.2.2 International Rainy-Lake of the Woods Watershed Board**

Five years ago, there was an effort by citizen groups and local governments to encourage the IJC to create a water pollution board for Lake of the Woods and to create an ad hoc task force to coordinate complementary research and phosphorus management plans for Lake of the Woods. This goal has been considerably fulfilled and, in fact, expanded upon as a result of:

- the creation in 2013 of the IRLWWB (the name “watershed board” goes beyond the original call for a board for only Lake of the Woods); and,
- the ongoing collaborative work of the IMA (see 2.2.4).

The IRLWWB combines the former International Rainy Lake Board of Control and the International Rainy River Water Pollution Board. The Lake of the Woods Board of Control remains with its original mandate (see below).

The mandate of the IRLWWB is to:

- fulfill the obligations of the Rainy Lake convention to manage water levels on Rainy Lake and other boundary waters in the Rainy Lake watershed, and act as technical adviser to the Commission on this matter;
- report on existing water quality objectives in boundary waters;
- recommend new water quality and/or aquatic ecosystem health objectives in boundary waters, as required; and,
- establish and report on water quality and aquatic ecosystem health alert levels throughout the basin.

This Plan of Study identifies the research needs and activities required to support that mandate. The Board, as referenced in its Directive, has established a Community Advisory Group and an Industry Advisory Group to ensure that community members and industry representatives can provide input into Board activities and decisions and bring the perspectives of these groups to the Board table, via their co-chairs.

### **2.2.3 Lake of the Woods Water Sustainability Foundation**

The LOWWSF is a central player in the coordination of science and research in the Basin together with the timely dissemination of results between international researchers. Formed in 2005, the Foundation's goal is to support the long term viability of the Lake of the Woods basin by encouraging and providing financial support for research focused on understanding water quality issues in the basin and developing community and government policy support binationally for cooperative action to protect and sustain Lake of the Woods.

As noted, the Foundation, together with its partners, initiated the International Watershed Coordination Program, which has allowed for a mechanism to continue and enhance communication across the border, not only at the local level, but regionally and internationally. The Foundation also facilitates the Rainy-Lake of the Woods Watershed Forum each year in International Falls, MN, which allows extensive binational sharing of basin research and monitoring data relating to fisheries, wildlife, in-lake/river chemistry and biota, contaminants, external ecosystem drivers and historical reconstructions using paleoecology.

### **2.2.4 International Multi-Agency Arrangement**

Formed in 2009, the International Multi-Agency Arrangement (IMA) Work Group and its Technical Advisory Committee have moved forward a significant amount of research, especially on Lake of the Woods, have identified priority projects in need of funding and have developed a comprehensive five-year workplan to which all signatories may contribute. Signatories include the key federal and provincial resource agencies with mandates for water quality, including: Environment Canada; Lake of the Woods Water Sustainability Foundation; Minnesota Department of Natural Resources; Minnesota Pollution Control Agency; Ontario Ministry of the Environment and Climate Change; Ontario Ministry of Natural Resources; Manitoba Water Stewardship; Red Lake Band of Chippewa Indians; United States Environmental Protection Agency; and, Koochiching Soil and Water Conservation District.

The purpose of the IMA is “to foster trans-jurisdictional coordination and collaboration on science and/or management activities to enhance/restore water quality in the Lake of the Woods Watershed (with clarification in the IMA that this refers to the Lake of the Woods and Rainy River Basins together).” The IMA's 2014-2019 workplan includes ongoing and proposed projects that have been developed collaboratively among Canadian and United States partners to focus on understanding nutrients, algal blooms, erosion and management needs for the Lake of the Woods and Rainy River watershed (see section 2.3). The IMA also has begun discussions on the need to address aquatic invasive species in the



Basin and struck a subcommittee with representation from Minnesota, Ontario and Manitoba. While the IMA workplan has a vision to eventually incorporate the research needs in the upper basin, the majority of projects currently focus on Lake of the Woods (in particular, the southern portion of the lake) and the immediate upstream areas. The workplan also has a vision to incorporate management strategies for dealing with the issues identified through the research undertaken, but this phase of work has not yet been developed. It is worth noting that recruitment of new members is ongoing to ensure that the Basin is well represented by the interested groups working with a water quality mandate within its boundaries.

The initiatives of this workplan, together with the protection and implementation work of the resource agencies, municipalities and community groups, provide important insights into how issues are currently being managed and what is still needed for a more binational approach to water management.

### **2.2.5 Control Boards**

The Lake of the Woods Control Board (LWCB) is a Canadian board responsible for regulating the water levels of Lake of the Woods and Lac Seul, and the flows in the Winnipeg and English Rivers downstream of these lakes to their junction, for the benefit of all users and interests. It was established in 1919 and operates under Canadian federal and provincial legislation and a Canada-United States Treaty.

Distinct from the LWCB, the International Lake of the Woods Control Board (ILWCB) was established by a 1925 Canada-United States of America Treaty (Convention and Protocol for Regulating the Level of the Lake of the Woods). This Board approves the outflow from Lake of the Woods whenever the level of the lake rises above or falls below the elevations specified in the Treaty and regulated by the LWCB.

### **2.2.6 Local Governments, Organizations and Associations**

Local entities in the Basin play an important role in moving watershed management issues forward by way of their own planning and project initiatives. In Minnesota, for example, Soil and Water Conservation Districts are local units of government which direct natural resource management programs at the local level in conjunction with landowners and other units of government to carry out programs for conservation use and development of soil, water and related resources.

On the Canadian side of the border, local municipalities are playing a stewardship role through development and implementation of their Official Plans – documents that direct land use planning and stipulate environmental protection measures where necessary. The large tracts of unorganized land surrounding the municipalities are managed by provincial agencies (see section 2.3.2).

On both sides of the border, local lake associations play a significant role in supporting watershed protection programs, research, outreach and education. In Canada, the Lake of the Woods District Property Owners Association has more than 3,500 members and takes an active role in educating its members on stewardship through its educational website, its LakeSmart program, *Kids in the Wild*, and the work of its Environmental Committee.

In the U.S., organizations such as the Cook County Coalition of Lake Associations, the Friends of the Boundary Waters Area Wilderness, the binational Rainy Lake Conservancy, Minnesota Waters, and numerous lake associations promote conservation, water monitoring and protection and stewardship education at the grassroots level.

### **2.2.7 First Nations, Métis and Tribes**

The Canadian portion of the Lake of the Woods Basin lies within lands of the Anishinaabe Nation of Treaty 3. There are 28 communities that belong to Treaty 3, most of them within the Basin boundaries, including Buffalo Point First Nation in Manitoba.

Responsibility for environmental protection and management of natural resources is transitioning to First Nations. The Rainy River First Nation's Watershed Program and the Seine River First Nation water quality monitoring, as well as the resource management work of Grand Council Treaty 3, are examples of important water quality initiatives by First Nations within the Basin.

Local Métis Nation communities are organized by community councils, of which four are in and around the Lake of the Woods Basin from Kenora east to Atikokan. The Métis have harvesting rights to natural resources, including activities such as hunting and fishing within their traditional territory. They have a self-governed management regime that includes the responsibility to preserve and protect those resources for future generations and have traditional territory-based consultation protocols for any projects or actions which would impact their rights.

Tribes in the United States have sovereignty over their own trust resources and lands. Programs for fisheries monitoring and stocking, wildlife research and management planning are conducted by the Tribes and supported by the U.S. Department of Bureau of Indian Affairs. The Red Lake Band of Chippewa Indians and the Bois Fort Band have lands within the Basin boundaries; the Red Lake Band Department of Natural Resources has been an active member on the International Multi-Agency Arrangement and has contributed water quality monitoring data from the Northwest Angle and its tributaries to the MPCA's Total Maximum Daily Load study for Lake of the Woods.

## **2.3 Current Watershed Management in the Basin**

The 2014 SOBR provided a comprehensive, up-to-date account of the current and historical conditions in the Basin, and an overview of agencies and organizations assessing conditions and programs in place for monitoring, protecting and implementing management strategies. It included a focused discussion on the priority issues facing the Basin and identified gaps in research/knowledge and approaches to filling those gaps. The Task Force report reflected extensively on the policy and program inconsistencies across the border. Given these extensive overviews, only a brief summary of the watershed management conditions and challenges are provided here; gaps in knowledge of priority issues are summarized in Section 3.

The projects and activities suggested within this Plan of Study need to fulfill clear objectives and direct the analysis toward clear outcomes. It is recognized that there is a need for binational strategies to manage nutrients, aquatic invasive species and surface and groundwater contamination, all with an end goal of managing ecosystem health in the Basin. Working towards a binational water quality management framework has many steps, including this Plan of Study. Addressing current challenges in the Basin, be they scientific, policy or governance in nature, will continue the progress toward that objective.

### **2.3.1 Research and Monitoring**

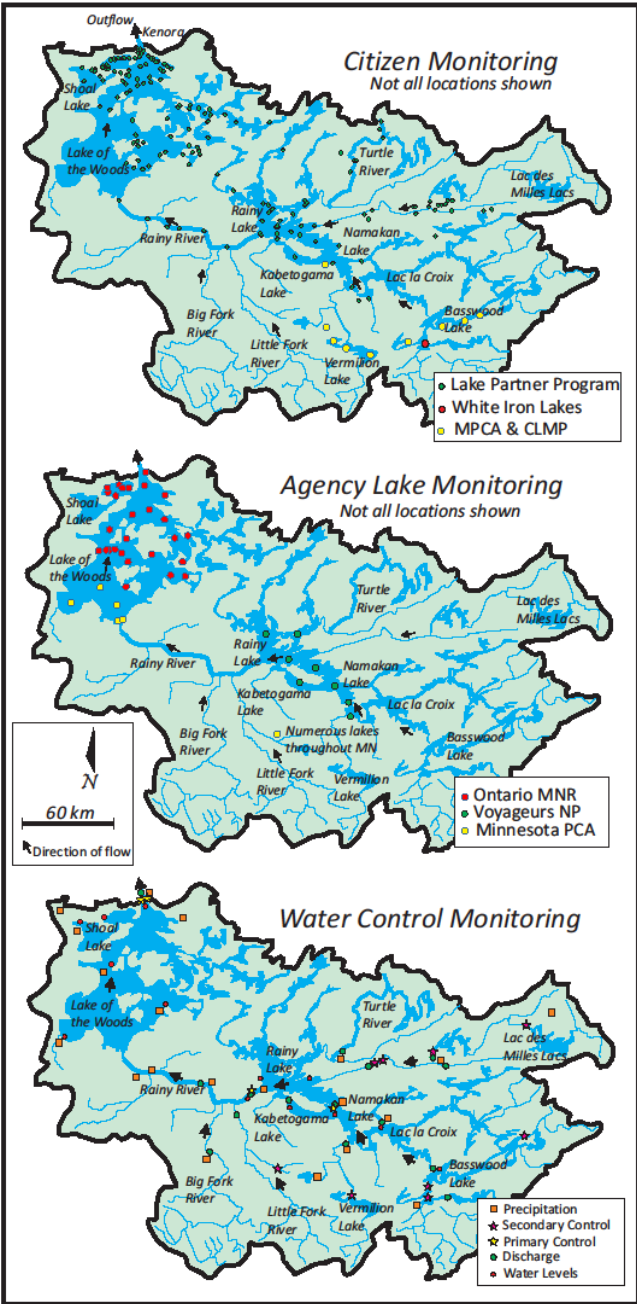
One of the greatest challenges to watershed management in this Basin is the limited availability of long-term, consistent data sets for the Basin as a whole, making the tracking of trends difficult. The past two decades, however, have produced a significant amount of project-specific data from a variety of sources (Figure 2) and, in some cases, coordinated monitoring with quality assurance/control protocols aligned across the border. As noted below, there are still considerable differences between the two countries in the amount of research and monitoring done and in programs to engage communities in restoration and protection.

#### **United States**

In the fall of 2008, Minnesota passed *The Clean Water, Land and Legacy Act*, an amendment to the state's constitution that created a three-eighths of a percent sales tax to fund, among other things, the protection and preservation of Minnesota's freshwater. The amendment has the potential to raise more than \$275 million a year, of which about one third, or \$85 million a year, will go toward protecting and preserving Minnesota's surface and ground water.

A total maximum daily load (TMDL) study is underway in Minnesota for the south end of Lake of the Woods in response to the portion of this water body in the United States being declared "impaired" for phosphorus and algae. Canada and Ontario are partnering on research initiatives and communicating with Minnesota to support the study, most notably through the initiation of monitoring of Canadian tributaries for concentrations of key water quality parameters and a lake and tributary sampling program by Environment Canada (see below). The data from Minnesota, Ontario and Canada have been used together in recent modelling efforts to assess nutrient loads to Lake of the Woods. Elsewhere in the Basin, the lower reach of the Little Fork River mainstream was added to the Impaired Waters List for turbidity in 2006.

Minnesota also employs, through the constitutional amendment, a major watershed approach to restore and protect water quality throughout the state. Under this approach, each of the watersheds in the Lake of the Woods Basin is being worked on over the next 10 years. The 2013 Big Fork River Watershed Monitoring and Assessment Report (Lueck *et al.*, 2013) noted that the most widespread impairment in both streams and lakes was mercury contamination, which limits the consumption of fish. Other impairments were due to natural causes. This report is an excellent example of the benefits of a basin approach to monitoring and illustrates the value of using volunteers in complex monitoring programs.



**Figure 2**  
**Scope of Monitoring in the Rainy-Lake of the Woods Basin**  
(Source: SOBR Overview, Clark and Sellers, 2014)

For the Rainy Headwaters, the MPCA's Major Watershed Restoration and Protection strategy begins in 2014, with plans to assess the Vermilion sub-basin beginning in 2015, the Rainy River/Rainy Lake sub-basin beginning in 2016, and the Black River, Rapid River and Baudette River sub-basins in 2017 (IRLBC/ IRRWPB-Fall 2012 Report-September 25, 2012). In 2011, the White Iron Chain of Lakes Association in partnership with the Soil and Water Conservation Districts implemented the Kawishiwi Watershed Protection Project, a three year project designed to develop a Watershed Management and Protection Plan. The program included lake and stream monitoring, and identification of protection and restoration needs along with the analysis of threats from aquatic invasive species and failing septic systems. The plan was completed in 2013.

## **Canada**

In February 2008, Environment Canada launched a \$17.7 million (Canadian) (over a four-year period) Lake Winnipeg Basin Initiative, which includes support for monitoring and research activities in Lake of the Woods (the lake) as well as on the Rainy River. The initiative was developed partly in response to Manitoba's request for federal support in meeting research, information and monitoring needs, and to facilitate governance and cooperation throughout the vast, trans-boundary Lake Winnipeg Basin. As of 2014, the initiative has been renewed for a further five years, though the renewal does not include continuation of the water quality monitoring work on Lake of the Woods.

Since 2009, the Ontario Ministry of the Environment and Climate Change has monitored 11 tributaries to Lake of the Woods and the Rainy River. The main objective is to contribute data to nutrient loading estimates. Three of the 11 tributaries are to the Rainy River: the LaVallee River, the Sturgeon River and the Pinewood River. Samples are analyzed for phosphorus, nitrogen, pH, alkalinity, specific conductance, total and dissolved solids, dissolved organic and inorganic carbon, and reactive silicate. Results to date have shown that concentrations in tributaries to the Rainy River are higher than they are in tributaries elsewhere around Lake of the Woods.

### **2.3.2 Governance and Policy Challenges**

In 2011, the Lake of the Woods and Rainy River Watershed Task Force observed that many organizations are monitoring water quality in the Basin, but there was no one entity with the role of overall coordination and reporting for the entire watershed, and there was no international governance mechanism in place to manage water quality throughout the watershed. The establishment of the IRLWWB and initiation of the International Watershed Coordination Program are important improvements in filling the coordination and reporting gap.

There remain vast differences in the regulatory regimes between the two countries, the funding funneled to water quality monitoring, and the programs in place for Basin monitoring and protection. The responsibility for regulation and management of LOW Basin resources lies with the 25+ agencies and organizations at the federal, state/provincial, and municipal level, together with Métis, First Nations and Tribes. This results in a diversity of approaches to water management, driven by very different legislative frameworks and policies and disjointed management.

## United States

In spring 2009, the Minnesota legislature took the first step in investing the money generated through the constitutional amendment, appropriating \$750,000 to the University of Minnesota's Water Resources Center to create a comprehensive, 25-year framework for the sustainable management of Minnesota's water resources.

There are several governmental structures and legislative initiatives in Minnesota that address water management issues in the watershed. For example, all lands are under well organized government oversight as part of counties, Soil and Water Conservation Districts cities, Tribal lands, parks, forests, and all are included in the new state-wide, comprehensive watershed planning process.

## Canada

In Ontario, the Ministry of the Environment and Climate Change's legislative authority to manage water comes primarily from the *Ontario Water Resources Act* and the *Environmental Protection Act*, which allows the province to regulate the volumes of water taken from any water body and the quality of any effluent discharged.

Regarding nutrient levels, Ontario's Provincial Water Quality Objective for phosphorus for lakes on the Precambrian Shield allows for a 50 percent increase in phosphorus concentration from a modelled baseline of water quality in the absence of human influence. The modelled objective is specific to each lake on the Shield, but it is only an objective with no legislative force. There is no similar program to Minnesota's Total Maximum Daily Load study for monitoring, mitigating and managing a water quality objective in current Ontario legislation. Water management plans exist in areas for flow and water level management and there are attempts to consider cumulative effects of industrial/municipal discharges.

Although there are several municipalities and numerous First Nation reserves on the Ontario side of the Basin, the majority of the land in the watershed is unorganized or unincorporated territory and is managed as Crown land by the Province. Crown land use is guided by policy and legislation of the Ontario Ministry of Natural Resources and Forestry (MNRF). With respect to water quality protection, MNRF reviews subdivision applications on waterbodies with an eye on protection of sensitive habitat and resource values while controlling activities on shorelands (public and private) through work permits under the *Public Lands Act*. MNRF routinely opposes development applications on lakes that have been identified as "at or over capacity" as per Ministry of Environment and Climate Change listings. In the unincorporated areas, private land planning applications, such as consents, subdivisions and condominiums, are reviewed by the Ministry of Municipal Affairs and Housing. This same ministry implements the Provincial Policy Statement, established to help guide development with environmental protection in mind and which all provincial ministries follow so as to promote consistency.

Within the Basin, MNRF established the Clearwater Bay Restricted Development Area Order and the Shoal Lake Restricted Area, both of which were established for the protection of water quality and the improvement of Lake Trout habitat.

### 3. Recommended Study Projects and Activities

This section outlines the recommended projects and activities and forms the core recommendations of the Draft Plan of Study to address the current and emerging challenges to the ecosystem health of the waters of the Lake of the Woods Basin. The 33 projects and activities presented here are grouped into five core areas or themes:

- Foundational projects and activities that serve the needs of the three priority ecosystem health issues;
- Nutrient enrichment and harmful algal blooms;
- Aquatic invasive species (AIS);
- Surface and groundwater contamination; and,
- Basin-wide International water management initiatives.

Each recommended project includes a statement of the project's *objective*; a *project description*; a summary of *methodology*; *organizations and key linkages*, which describes the institutions and organizations who would likely be involved with the project and the linkages of the recommended project to other work in the Basin or other recommended work in the Plan of Study; *timing*; and a summary of *project benefits*.

#### 3.1 Foundational Projects and Activities

This section covers recommended projects and activities that serve the needs of all three priority issues. Many of the projects and activities are derived from study recommendations made in both the SOBR (Clark and Sellers, 2014) and the IMA workplan for the Basin.

Foundational projects seek to address knowledge and data gaps and establish monitoring systems and public engagement practices to sustain assessment and interest in the water quality and ecological condition of transboundary lakes and rivers. They are organized under two key study areas: Monitoring in the Basin and Critical Sources of Information and Mapping, Communication Tools, and Public Information and Engagement. All seven projects are highly recommended.

##### 3.1.1 Monitoring in the Basin and Critical Sources of Information

Projects 1 through 4 form the basis of a comprehensive monitoring and data acquisition system that covers most of the critical aquatic and atmospheric parameters useful for understanding processes that result in impairment of water quality due to any of the priority issues. They are meant to build on existing monitoring and data acquisition infrastructure currently supported by agencies in the basin, identify deficiencies in monitoring networks and prioritize recommendations for new monitoring locations and measurement equipment, and establish frameworks for assessment of monitoring networks on a periodic basis and database management.

## **Project 1 Coordinated Implementation of a Tiered Monitoring Program for the Lake of the Woods Basin**

### *Objective*

Implementation of a core tiered monitoring program for the Lake of the Woods Basin that would provide data for the entire Basin as well as for individual sub-basins within the Basin and allow IMA agencies and partners the flexibility to expand or contract monitoring programs to meet budgeting realities.

### *Description*

The tiered monitoring program described here is based on the proposal submitted to the IMA-WG in October 2013 by the Core Monitoring Subcommittee of the IMA-TAC. Coordinated (Canada/U.S.) implementation of a tiered monitoring program for the Basin is a foundational project that serves the needs of all three priority issues as well as the cross-cutting thematic areas of climate change and hydrology. In the proposal, the Core Monitoring Subcommittee specified that the program should allow for seamless coverage from the Subregion/Basin scale down to the subwatershed scale, be statistically sound and accommodate new subject areas and special studies as necessary. It also recognized that a monitoring program would need to provide data for the following subject areas:

- nutrient enrichment and harmful algal blooms;
- aquatic invasive species (AIS);
- climate change;
- hydrology; and,
- surface and groundwater contamination.

The Draft Plan of Study wholly supports these concepts as a foundational need for this Basin and also suggests that additional tiers be implemented to ensure that monitoring is comprehensive on transboundary lakes. While monitoring in the Basin is fairly extensive, especially in Minnesota, there is a need to establish a set of strategic, long-term monitoring sites that utilizes existing sites where possible, allows for a more balanced monitoring system on both sides of the border and provides for consistent locations for sampling of priority issues parameters.

The approach is iterative and provides a viable framework that allows for:

- expansion or decrease in monitoring as budgets dictate;
- provision of data that are useful at the subwatershed, watershed and basin scale as necessary;
- determination of cumulative effects; and,
- determination of how effective projects are in meeting goals.

As stated in the proposal, this monitoring approach is similar to Minnesota's Watershed Approach which is based on Hydrologic Unit Code (HUC) 8 watersheds with annual load monitoring (HUC 8s and smaller) and every 10 years an intensive four-year study of individual HUC 8 watersheds that includes



monitoring (biological, chemical and physical), modelling and detailed protection/problem investigation and implementation planning at a subwatershed level. By establishing the core sites, sampling/monitoring of Canadian sub-basins becomes part of the strategic dataset.

The IJC's Harmonized Boundary Waters Dataset provides the details necessary to initially lay out the spatial scale and scope for the monitoring program. Watershed monitoring sites should provide data for a discrete area upstream of the site and, wherever possible, provide data about downstream effects. Watershed outlets or pour points at different spatial scales provide ready delineation of upstream areas and are often co-located with flow/discharge or water level gauges. To complete monitoring of the entire basin system, a core set of monitoring sites should also be established for Lake of the Woods itself and other large lakes along the border including, but not necessarily limited to, Gunflint Lake, Basswood Lake, Lac La Croix, Rainy Lake and Namakan Lake.

There are four tiers in the IMA-TAC proposed tiered monitoring program (note that geospatial descriptors follow USGS naming conventions):

- Tier 1 (River based) – Subregion/Basin scale: Permanent gauging combined with storm-event and calendar-based sampling at four key sites along the international border provides “big picture” water quality and ecological information for the Rainy Headwaters and Vermillion sub-basins, the Rainy Lake sub-basin, Big Turtle River and the Lower Rainy and its tributary sub-basins (Little Fork, Big Fork and Rapid River). Measurements and sampling should focus on hydrology, loading of pollutants, and biotic information relevant to nutrients and HABs, AIS, contaminants and climate change. Three of the four gauges are already in place: Gold Portage, International Falls, and Wheelers Point. A new gauge will be needed at the outlet of Namakan Lake. A fifth site at the outlet of Lake of the Woods towards the Ontario-Manitoba border would enable inclusion of the Lake of the Woods sub-basin, which would measure pollutant loads and other priority issues parameters from the entire Basin to the Winnipeg River. The data provided by all five of these gauges would provide water quality and loading data for all Rainy River watersheds and the Lake of the Woods Basin as well as parameter monitoring of the other priority issues.
- Tier 2 (River based) – Basin/Sub-basin Watershed scale: Permanent gauging along with storm-event and calendar-based sampling provides water quality and pollutant (nutrients, AIS, contaminants) information. Matching gauging should be established on the Canadian side to optimize coverage.
- Tier 3 (River based) – Watershed/Subwatershed scale: Permanent gauging and storm-event sampling at targeted smaller watersheds on both the United States and Canadian sides.
- Tier 4 – River-based Special Studies: Initiated by issues or problems identified in any of Tier 1, 2, or 3 monitoring activities, or identified by federal, provincial, state and local agencies, or residents and stakeholders. An example of a river-based special study might be bioassessment using benthic macroinvertebrates as diagnostics of specific stressors.

The Wheelers Point gauge, listed under Tier 1 of the proposed monitoring program is considered particularly important by the IMA-TAC because it represents the terminus of the Rainy River and all upstream watersheds that discharge into the Lake of the Woods. Based on 2012 modelling, 89% of the water flowing into Lake of the Woods passes by Wheelers Point, along with 93% of the watershed phosphorus load. In a letter to the IJC (October 22, 2013), IRLWWB secretaries recommended that the

gauge (USGS Gage 05137500) be designated a gauge of binational significance and encouraged the IJC to commit to providing funding for its continued operation. Given the modest cost of operating this gauge (approximately \$16K/year), it is highly recommended that a long-term cost-sharing arrangement be established as a result of this Plan of Study.

In addition to the four tiers specified in the IMA-TAC proposal, a core monitoring system should be established for transboundary lakes in the basin (Tier 5). In the assessment of lake-based monitoring systems along the transboundary, complementary monitoring programs already in operation should be reviewed, including Minnesota's sampling of lakes above a certain size threshold two out every 10 years on a monthly basis, Voyageurs National Park's long-term biweekly program, and MNRF's lake sampling on a rotating basin. Environment Canada's recently terminated lake-based sampling should be reestablished.

- Tier 5 (Lake based) – Transboundary Lakes: A core set of monitoring sites for large lakes including, but not limited to, Lake of the Woods, Rainy Lake and Namakan Lake. For the Lake of the Woods, given its complex bathymetry, sites in multiple basins are necessary.
- Tier 6 – Lake-based Special Studies: Initiated by issues or problems identified in Tier 5 monitoring activities, or identified by federal, provincial, state and local agencies, or residents and stakeholders. From the NE-HABs set of projects, an example of a lake-based special study would be algal toxin monitoring in nearshore zones of lakes to enhance scientific understanding of algal species composition and to inform the public.

For river-based tiers 1 through 3 and lake-based tier 5, it is important that a common primary set of hydrologic, water quality and chemical parameters are measured to ensure continuity across the system. Similarly, any biological sampling that is undertaken must use the same field sampling techniques (for example, mesh size), lab-processing techniques (such as subsampling) and identification conventions. In addition to parameters that are routinely measured using multi-probe sondes, grab sampling or autosampling is essential to permit measurements of phosphorus fractions, nitrogen species, and suspended solids, among others through laboratory analyses. Measurements necessary under Special Studies tiers 4 and 6 will vary by issue, but may include specialized biotic assessments, scans of chemicals of emerging concern, among others.

### ***Organizations and Key Linkages***

The IMA consists of most of the federal, state and provincial agencies and organizations that have a role in adoption and implementation of this tiered monitoring program. Such a monitoring program is identified as an “unfunded high priority” in the IMA's five-year workplan. The IJC would also be included in the project through its geospatial data harmonization project. Given the nature of this Foundational Project, it directly and indirectly supports data needs of most projects listed under all three of the Priority Issues and several other Foundational Projects and Activities.

### ***Timing***

Initial funds are necessary to establish new monitoring stations. However, longer term support for operations is expected to be covered by the agencies. Due to differences in monitoring efforts currently underway on either side of the border, more new sites will be required on the Canadian side. Periodic reviews every five to 10 years will be necessary for optimal monitoring and cost-effectiveness.

### ***Project Benefits***

Establishment of this project will serve or contribute to the data needs of most projects listed under Priority Issues. Failure to support this tiered monitoring approach will compromise the acquisition of data needed to determine the status of a system, track trends over time and evaluate the effectiveness of remedial management actions.

## **Project 2 Review of Data Collection Programs and Monitoring in the Headwaters Regions of the Basin**

### ***Objective***

Improved capacity to detect water quality changes in the headwater systems that may influence the condition of transboundary lakes and rivers.

### ***Description***

A great deal of the monitoring of water quality in the Basin has focused on Lake of the Woods and immediately upstream, though in Minnesota, waters in the headwaters region have and will be monitored through the state's Intensive Watershed Monitoring Program. In the headwaters region, Intensive Watershed Monitoring is underway in the Rainy Headwaters sub-basin and will be done in the Vermilion sub-basin in 2015 and Rainy Lake sub-basin in 2016. Following from this, the state's Watershed Restoration and Protection Strategy will be applied to each sub-basin, based on what the data reveal around impairments and restoration needs. Lakes within Voyageurs National Park have been monitored for many years as part of the park's research initiatives and monitoring programs exist within the Superior National Forest, Quetico Park and within the Seine River system by Seine River First Nation. There are considerable headwaters data as part of the Kawishiwi Watershed Protection Project and citizen-based monitoring of a variety of lake associations elsewhere.

Data collection in the headwaters across the Basin serves at least two functions. First, it provides a means by which localized water quality issues can be readily identified. Secondly, it improves the understanding of how human activities in stream reaches and lakes can influence priority issues of transboundary waters.

### ***Methodology***

This project involves a review of data collection programs in headwaters regions, which should be accomplished through a survey of all agencies and organizations in the Basin for their current and planned monitoring and sampling activities. It should also involve a summit or workshop (possibly in conjunction with the annual Watershed Forum) to enable exchange of technical knowledge and development of a geospatially-referenced map of activities, and to affirm basin-wide involvement in the development of solutions for lakes and rivers along the transboundary. Such information would be made available through the IRLWWB website.

### ***Organizations and Key Linkages***

This project will involve all federal, state and provincial agencies, as well as any non-government organizations, First Nations, Tribes or Métis, that are collecting water quality data or information that may affect water quality.

### ***Timing***

The review of data collection programs should take less than a year, followed by a summit or workshop to bring participating agencies, organizations and individuals together.

### ***Project Benefits***

Headwaters data collection programs represent an early warning system for issues that may develop in transboundary lakes and rivers. They also serve the critical function of engaging all corners of the basin in a collective effort to improve water quality. This project complements the MPCA effort and efforts undertaken through the tiered monitoring program.

## **Project 3**

### **Assessment of Monitoring Networks for Meteorological Conditions and Atmospheric Deposition of Nutrients and Contaminants**

#### ***Objective***

Assessment of the robustness of current atmospheric monitoring networks for meteorological conditions and atmospheric deposition of nutrients and contaminants.

#### ***Description***

Aquatic ecosystems of the Lake of the Woods Basin are influenced by external forces that affect meteorological conditions and the deposition of pollutants from the atmosphere. This project complements the tiered monitoring program through the assessment of existing meteorological and atmospheric deposition monitoring stations and networks (see Clark and Sellers 2014 for tables of

existing stations) with the ultimate goal of having a representative core set of strategic, long-term monitoring stations in the Basin. New stations should be established in areas that will improve characterization of gradients across the Basin. Consideration should be given to one per each HUC 8 watershed; this should provide sufficient coverage to ensure that most storm track events will be caught by at least one gauge. Information gathered through these networks can be used to support numerous other projects identified in the Plan of Study involving hydrologic budgets, phosphorus budgets and mercury accumulation rates, among others.

For many nutrients and contaminants, the atmosphere is an important pathway for the importation of external sources. A significant fraction of phosphorus is derived from atmospheric sources, particularly in less-developed areas where point and non-point sources are relatively small (Hargan *et al.*, 2011). Though domestic rates of mercury emissions have decreased in Canada and the United States, there is strong evidence that most mercury is from overseas, the result of long-distance travel through global circulation. Of critical importance is the measurement of wet deposition during rain and snowfall and, if possible, dry deposition.

### ***Methodology***

Meteorological stations both on land and on water should be assessed for adequacy of coverage across the Basin to improve hydrologic budgets. Measurements of evaporation, humidity, wind speed, air temperature, and rainfall and snowfall amounts and accumulation rates, should be recorded at key locations in the Basin that represent different climatic and physiographic regions.

Where existing atmospheric monitoring stations are already in place, analysis of spatial and temporal coverage is possible to identify data deficiencies. To help with interpretation of data acquired through newer stations, retrospective comparisons may be possible through interpretation of recent and paleolimnological sediment cores.

### ***Organizations and Key Linkages***

This project will require participation of provincial, state and federal agencies to coordinate assessment of monitoring networks. Environment Canada operates a meteorological station in the northwestern section of the basin (standard meteorological and Canadian Air and Precipitation Monitoring Network [CAPMoN] site); it should be maintained and used as a reference and calibration station of other existing and planned stations.

### ***Timing***

Initial funds are necessary to establish new monitoring stations; however, longer term support for operations is expected to be covered by the agencies. Regular reviews every five to 10 years will be necessary for optimal monitoring and cost-effectiveness.

### ***Project Benefits***

Similar to implementation of the tiered monitoring program, meteorological and atmospheric deposition data are of critical importance for several projects under the Priority Issues that involve hydrologic and nutrient and contaminant budgets and models.

### **Project 4 Development of Regional Climate Models for the Basin and Improved Public Education and Engagement on the Issue of Climate Change**

#### ***Objective***

Sets of regional climate models that describe current climatic trends, including scenarios of temperature and precipitation regimes under climate change, and an informed public that can understand and adapt to climate change.

#### ***Description***

Climate change represents an overarching influence on natural processes and human activities throughout the basin. The latest Intergovernmental Panel on Climate Change report (IPCC, 2013) identifies fossil fuel consumption by human societies as the primary cause of global warming through excessive release of greenhouse gases and warming atmospheric temperatures.

Global Circulation Models (GCMs) simulate and forecast changes to temperature and precipitation regimes at a very large scale. Techniques exist to “down-scale” GCMs through integration of finer-scale meteorological data and generate Regional Climate Models (RCMs). To ensure that the influence of climate change is properly described and quantified for use in projects outlined in this Plan of Study, RCMs should be developed that reflect regional conditions. Once developed, the likely impacts of climate change (both apparent today and forecast for the future) should be made available to the public so that citizens can monitor how aspects of the basin, such as phenology, ice cover, water levels and temperature, and storm severity are changing and potentially affecting water quality and the priority issues identified in the Plan of Study.

This project involves several components:

- down-scaling of GCMs to RCMs specific to the Basin: regional interpretation of climate change will enable temperature and precipitation scenarios to be forecast;
- mapping and online availability of forecast changes to temperature and precipitation regimes as a result of RCMs;
- generation of a report that describes climate impacts on the priority issues in transboundary lakes and rivers and across the Basin;
- development of information tools for the public to assist with monitoring of water quality-related climate change impacts and with the selection of adaptation measures. Specific emphasis should be

on interactions with the appearance and dynamics of HABs and the identification of AIS and their distribution; and,

- development of policies resulting in citizen actions that promote awareness of human activities that contribute to climate change and adaptation practices.

### ***Organizations and Key Linkages***

Federal agencies such as the National Oceanic and Atmospheric Administration and Environment Canada, in conjunction with state and provincial agencies, should lead GCM to RCM down-scaling; the IRLWWB, the LOWWSF, the IJC and others in the basin should develop guidebooks and factsheets to expand understanding of climate change and encourage public interest and response. Climate change adaptation strategies currently in place by Ontario, Manitoba and Minnesota should be reviewed for inclusion in this project. Close collaboration and cross-referencing with the LWCB website would be beneficial to users.

Hydrologic models for Rainy Lake and Namakan Reservoir allow for investigation of water levels under different hydrologic regimes (1970 and 2000 Rule Curves; Thompson, 2013) and allow researchers to incorporate climate change through variable inflow datasets (variable inflow datasets to investigate climate change effects is proposed as part of IJC Review of 2000 Rule Curves).

Results of GCM to RCM downscaling are of direct benefit to several projects in this Plan of Study, especially those concerned with the improvement of hydrologic budgets and the forecasting of HABs.

### ***Timing***

It would take one to two years to prepare RCMs for the Basin and to include them in the Basin's geospatial mapping framework (see Project 5). Development of information tools and a reporting system should take approximately one year and then minimal funding would be necessary to manage datasets and share them via the Board's website.

### ***Project Benefits***

Climate change is increasingly recognized as a pervasive force that affects both water quantity and water quality. Priority issues identified in the Basin need to be served by climate models that are regionally-relevant. Public engagement in this cross-cutting issue is strengthened through knowledge about how climate change may affect lakes and rivers in the Basin and through a reporting process that takes advantage of public surveillance in the basin.

### **3.1.2 Mapping, Communication Tools, and Public Information and Engagement**

Projects 5 through 7 cover projects that are meant to directly engage or inform the public. The geospatial mapping project is meant to develop a framework that will serve geospatial needs for all stakeholders and the public at large. Data collected through projects 1 through 4 and many others in the rest of the Plan of Study can be visualized and interpreted through mapping tools. When made available through public websites, this complex information can be rendered accessible and useful for end-users. Information and data collected through collaborations with First Nations, Tribes and Métis provide a complementary perspective on water quality and water resources in the Basin that can inform scientific understanding of water quality issues and enhance appreciation of the intrinsic value of rivers and lakes.

#### **Project 5**

#### **Development of Lake of the Woods Basin Geospatial Mapping Framework**

##### *Objective*

To provide a common and sustainable geospatial platform upon which the IRLWWB, local non-governmental organizations, First Nations, Tribes, Métis, natural resources agencies and the public can access, supplement and steward geospatial data unique to the shared geography of the Basin. This platform will be created so as to be accessible via the current IRLWWB website.

This project is key to providing the IRLWWB with the tools it needs to monitor ecosystem health in the Basin – one geospatial reference location for the mapping of priority and emerging issues so that trends can be observed, new data can be added as it becomes available and information can be accessible when the Board is speaking to the public and partners. In addition, this project is meant to enhance community appreciation for the environmental resources of this binational basin via innovative GIS applications and tools while providing access to up to date scientific and social data unique to the Lake of the Woods Basin.

##### *Description*

In 2013, the IMA-TAC, along with the IJC, began to develop a draft Geospatial Strategic Plan, recognizing the need to develop a geospatial platform upon which the work of the IMA could be displayed and utilized by themselves, resource managers, the IRLWWB and others in the Basin. Other binational mapping initiatives in the Basin include Streamstats (online watershed delineation and hydrographic characterization through USGS) and SPARROW<sup>2</sup> water quality modelling through the IJC, USGS and NRC. The modelling efforts have primarily focused on the physical structure of landscapes, including digital elevations models), stream networks and watershed delineations, which comprise the fundamental hydrographic characteristics of the system. With the data-harmonized structure in place as created by the IJC, the development of the draft Geospatial Strategic Plan began as a way to start thinking about how best to map activities and findings in the Basin and to make them easily accessible. This project supports and builds upon the vision put forth in that draft plan. The geospatial platform and the

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<sup>2</sup> <http://water.usgs.gov/nawqa/sparrow/>



IRLWWB website will become the “home” to the information derived from the projects proposed in this Plan of Study, most notably the data generated from the strategic tiered monitoring program, as well as the information being collected by the IMA and others in the Basin.

Building upon the stated vision in the draft strategic plan, the key goals of this project are to:

- Bridge the institutional gaps that inhibit the creation, manipulation, visualization, and stewardship of geospatial data and sub sets of geospatial data unique to the Basin; mapping of information has been a challenge for the IMA and this provides the framework for referencing and comparing their work and the work of the other partners in the Basin;
- Deliver valued public service by ensuring responsiveness to communities in the Basin via accessible geospatial and geographic services;
- Evolve and enhance GIS applications and tools to support effective and efficient decision making; this will serve the needs of the IRLWWB and the IMA as they move forward in monitoring ecosystem health and working towards a binational management framework;
- Encourage local, regional, indigenous and federal engagement in the creation and visualization of geospatial data and media relating to the health and wellbeing of the ecosystem, thereby providing mechanisms for sharing information and enhancing communication.

### ***Methodology***

Some of the initial work required for this project has already been done. The first task of securing appropriate software and hardware has been achieved and is licensed to the LOWWSF (IMA member). The hiring of an individual to manage the geospatial activities listed below will be needed as well as ongoing funding to continually manage the mapping initiatives. Identification of pertinent base layers (datasets) and desired operational layers (datasets) would be the next steps.

There is a need for a wide variety of geospatial data layers to characterize the natural features of the Basin and human activities; some of this will be drawn from the current IMA project that is compiling Landsat data for the 1990 and 2010 time periods to develop land use maps of the entire Basin (to be complete June 2015). Accurate and updated land-use data are critical in the development of watershed loading models and nutrient budgets. Examples of natural features of particular importance for understanding water quality are vegetation cover, soils, surficial geology, and groundwater regions. Examples of human activities important for georeferencing are agricultural systems, municipal and industrial point sources, current and abandoned waste disposal facilities, road and rail transportation networks, and built-up areas. With the unprecedented flooding observed in 2014, another key geospatial data layer is flood extent according to variation in water levels.

The following focus areas are detailed to illustrate the utility of geospatial mapping.

### **Aquatic Invasive Species Mapping**

This component involves development of an international database and GIS layers to show distribution of aquatic invasive species in the Lake of the Woods Basin, and serve this information to resource managers

and the public via the worldwide web. This effort would also establish a monitoring and reporting system to provide resource managers with timely, updated information into the future.

Two web-accessible AIS inventories are already in place: the Early Detection and Distribution Mapping System<sup>3</sup> (covers Ontario and Manitoba; and the Nonindigenous Aquatic Species system covers invasive animal species (including aquatic invasive species such as zebra mussels) the continental United States<sup>4</sup>. This project would link these two systems to this Geospatial Mapping Project so that an internationally harmonized, web-viewable data base of AIS would be available to Basin managers and the public. This activity would necessarily encompass the entire Basin, as well as neighboring basins to support vulnerability assessments on an ongoing basis.

The project will consist of two main activities: (1) develop an automated system to pull data from national-scale data bases and integrate them with the international Geospatial Mapping project, so that AIS data can be accessed by the public and resource managers in a seamless manner, across the entire Lake of the Woods Basin and neighboring basins; and (2) develop a system for local (Lake of the Woods Basin) information to be uploaded into the respective national-scale data bases. The IMA has already discussed the idea of geospatially mapping signage for the prevention of AIS in the basin and to begin to record sightings of AIS on this platform through social media. It also has discussed the concept of developing a Basin geospatial narrative (a map service that provides an introduction to the geography and fundamental hydrodynamics of the basin). Both of these initiatives should be included in the scope of this Project as essential public involvement and outreach tools.

### **Potential Contaminant Sources Mapping**

This component will provide a publicly accessible, online, up-to-date map of mining (including historical, existing, approved, and permit-pending locations), cultivated agriculture, and petroleum transport activity to inform public and resource managers. Basin scientists saw the need to bring together known data of potential sources of contaminants into an integrated, harmonized GIS map product. There is concern within the Basin that future activities may have the potential to contaminate surface waters directly or indirectly via groundwater transport. Historical (closed), existing, and approved mines are important to map to give resource managers within the Basin a more accurate view of potential for mining-related contaminants that may affect water resources. Agricultural lands also need to be brought into the Basin's GIS. More detailed hydrogeologic mapping is needed where groundwater resources intersect potential areas of contamination; this information will directly support the vulnerability assessment project proposed (Project 27). Much of the information exists in state and provincial data bases; assembling the data and providing them publicly via the Basin's web-searchable GIS would provide a valuable information tool.

### ***Organizations and Key Linkages***

- Current partners in this initiative are the logical leads for this project: LOWWSF, IJC, and the IMA. A GIS specialist is needed to produce the deliverables.

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<sup>3</sup> <http://www.eddmaps.org/>

<sup>4</sup> NAS, <http://nas.er.usgs.gov/>

- Linkages to the EDDMaps system, and the U.S. NAS system.
- Partnerships among state and provincial agencies (MNRF, MDNR, Manitoba Conservation and Water Stewardship), university experts, IJC, Ontario Federation of Anglers and Hunters, Voyageurs National Park.
- Linkages to satellite imagery and remote-sensed data and algal bloom project #14.

### ***Timing***

Initial development: one year; requires ongoing effort to maintain data base.

### ***Project Benefits***

The benefits of this project are many – it is absolutely essential that a common geospatial platform be developed for this Basin so as to continue to display and analyze information on an international level, with data and information from both sides of the border displayed in one common place. The Plan of Study sees this as an excellent application of the IJCs data harmonization initiative and a logical next step for the work of the IRLWWB and the IMA and their partners. This will be a critical tool, providing the public and natural resource management agencies the ability to access up-to-date information on presence of AIS, contaminants and algal blooms, improving educational outreach efforts, and strengthening the capacity to adapt prevention and control strategies (for example, as AIS species spread to new locations).

## **Project 6**

### **Collection of Ecosystem Information and Discussions of Ecosystem Health with Indigenous Communities**

#### ***Objective***

Develop an inventory of existing ecosystem health data collected by First Nation, Métis and Tribal communities in the Basin and host an Elder Gathering to better understand indigenous views of priority issues.

#### ***Description***

The current conditions of the Basin have been described as they relate solely to the scientific data that have been collected by resource agencies, lake associations and local government organizations. This project aims to enhance the knowledge base of the Basin by developing an inventory of data and information being collected at First Nation, Tribe and Métis communities and organizations on the priority issues. Inclusion of this data with other information that will be collected as a result of Plan of Study projects or ongoing monitoring is important. In addition to this, this project will also support the enhancement of knowledge of this Basin through listening and learning from Elders.

### ***Methodology***

This project has two components. The first component is the inventory of data available through communities, Tribal Councils, Métis organizations, Tribes, Grand Council Treaty 3 and others to ensure ecosystem health data being collected are incorporated into the baseline knowledge for this Basin and that communities, in turn, are made aware of the scientific data and results to date being collected by others. Contact with communities and their representative councils and organizations will be done; the opportunity to include their work within the geospatial mapping project proposed will be discussed.

The second component of this project is based on listening and learning from aboriginal Elders regarding ecosystem health changes, bioindicators and ideas around environmental protection. It will involve the planning of an Elder Gathering and appropriate engagement with the Treaty 3 Women's Council. In traditional culture, women are the "water-keepers" and it is their responsibility to protect it, therefore this is a key group to work with on this project. Both components will provide for a database of observations, records and narratives to assist with interpretation of Plan of Study results and findings. Intellectual property rights will be respected and will remain vested in the community of origin.

The existence of ecosystem data within communities is not widely known, with the exception of the Red Lake Band who monitors water quality regularly in the Northwest Angle, Rainy River First Nation through their Watershed Program and Seine River First Nation's contaminants study, though there are examples of research and consultation in elsewhere along the transboundary (Tobias and Richmond, 2014).

### ***Organizations and Key Linkages***

First Nation communities in Treaty 3, Red Lake Band of Chippewa Indians, Bois Forte Band of Chippewa, Tribal Councils in basin, 1854 Treaty Authority, Grand Council Treaty 3, Métis Nation of Ontario and their local Councils.

### ***Timing***

The first component will take approximately two months.

### ***Project Benefits***

- Ensuring that the knowledge base of the Basin is comprehensive;
- Developing working relationships outside of the more traditional science community; and,
- Enhancing the knowledge of community members of the studies, science and data available to them and how their information can enhance this current knowledge.

## **Project 7 Enhancement of the IRLWWB Website as a Public Communications Tool**

### ***Objective***

To enhance the current IRLWWB website to better serve as a communications tool with the public.

### ***Description***

The current IRLWWB website is an excellent venue for communicating binational water quantity and quality issues with the public in both Canada and the U.S. With the amount of work currently occurring in the Basin and the additional work that will be generated as a result of both the Water Quality Plan of Study and the IJC's Rainy River Rule Curve Review, it is important to ensure that this information, along with other Basin initiatives that relate to ecosystem health, be easily accessible by the public.

This project involves a review of the current information on the IRLWWB website, development of a strategy for incorporating pertinent information on the Basin onto the website (for example, a review of information in SOBR, IMA workplan, Plan of Study projects that are implemented, links to resource agency websites) and integration of the geospatial database (Project #5) into an interactive map on the website. Suggested additions to the current website that may be of interest to the public include:

- Home Page – description of the watershed, details on what data the gauges shown on the map provide; listing of partners involved in binational water management; vision and mission of the Board, links to partner websites;
- Members Page – explanation of how Board was formed and importance of having local and designated members seats, map with distribution of membership (Board, community and industry advisory groups);
- Resources Page – links to more partners with indication of the type of work they do; interactive map with sub-basin level information; Board outreach plan; and,
- Links Page – add in other partners such as LOWWSF, Ontario Ministry of Environment and Climate Change (Lake of the Woods page), Environment Canada, MPCA, U.S. Environmental Protection Agency, and MNRF.

### ***Organizations and Key Linkages***

This project will be a partnership initiative of the IRLWWB and the IJC with input from a variety of resource agencies and organizations, indigenous communities and NGOs from which information will be highlighted or provided as a link. The development of the geospatial database in Project #5 will be housed on this website and the information then made accessible to the public. The IRLWWB is committed to ensuring it hears from and responds to the public and respond– the community and industry advisory groups are excellent venues for this, but this website will increase that ability significantly.

### ***Timing***

One year will be necessary to complete a study on website enhancement and interoperability. Ongoing financial and human resources will be required to ensure that the website is maintained and updated.

### ***Project Benefits***

An enhanced IRLWWB website would be the first comprehensive website for the public to gain access to basin-wide information on water quality.

## **3.2 Nutrients and Harmful Algal Blooms**

In temperate zone freshwater systems, phosphorus is generally considered to be the nutrient that limits primary production (aquatic plant growth) (Schindler, 2012). Time-series data of nutrient loads to Lake of the Woods show that phosphorus is decreasing. Yet, over the past decade, algal blooms, especially in the southern basin of the lake, continue to occur and may be increasing in severity. The trend is not limited to that lake, as algal blooms have been observed in many other lakes upstream from Rainy River. A wide variety of climatic, physical, chemical and biological factors are related to the genesis and onset of harmful algal blooms (HABs), their spatial extent and duration, and whether they produce algal toxins.

HABs are undesirable for many reasons: they can prevent recreational usage of lakes for sport-fishing, boating and swimming; alter population densities of commercial and subsistence fisheries; cause undesirable taste and odor of drinking water and compromise water treatment facilities; and sometimes release algal toxins. Over the past decade, a variety of toxins have been recorded in the basin, including Microcystin in Lake of the Woods, Aphanizomenon in Rainy Lake and *Oscillatoria rubescens* in lakes in the headwaters watershed. Toxins are of particular concern because they threaten drinking water supplies, human health and animal welfare.

The projects in this section are designed to improve understanding of what contributes to the occurrence of HABs, to provide a platform by which nutrient abatement and bloom control solutions can be developed and evaluated, and to disseminate information about water quality conditions and HABs to the public for safer use of basin waters. They cover most of the gaps identified in the Clark and Sellers (2014) SOBR that pertain to nutrient enrichment and HABs and build on many projects completed by Environment Canada listed in the IMA workplan. Given recent research into eutrophication in other transboundary systems, specific parallels are drawn between the approach adopted for the western basin of Lake Erie and Lake of the Woods.

### **3.2.1 Refine Existing Nutrient Budgets to Better Understand Sources and Sinks in the Basin**

Policy recommendations to decrease nutrient loads and reduce the frequency and severity of HABs rely on robust descriptions and models of lake and river systems. Through the IMA, a substantial amount of work has been done towards building nutrient budgets and mass-balance models for Lake of the Woods

and the Rainy River. However, Clark and Sellers (2014) and Pascoe *et al.* (2014) have identified several outstanding knowledge and data gaps that compromise a detailed and realistic accounting of phosphorus sources and sinks, not just in Lake of the Woods, but in several other transboundary lakes that also suffer from symptoms of eutrophication.

The nutrient budgets and mass balance models project serves as vehicle for linking datasets that can be used to map sources of nutrients and estimate loads to rivers and lakes. It is a keystone project that can be used towards the development of predictive models of HABs via an approach employed to address HABs and hypoxia in the western basin of Lake Erie. A similar approach is recommended for Lake of the Woods, whereby an index of HAB severity is developed from satellite imagery and related to phosphorus loads major tributaries (for example, Rainy River). Once stressor-response relationships are established, water quality objectives and load targets can be determined and policy recommendations devised accordingly. Phosphorus control solutions, through application of conservation practices through land use and land cover changes, implementation of best (or beneficial) management practices (BMPs) in urban, rural and agricultural lands, and remediation of algal blooms, can then be recommended and prioritized to combat eutrophication.

The second project builds on the first through the calibration of watershed-based and lake-based water quality models. It represents the primary vehicle by which the impacts of remediation policies, practices and actions can be forecast and evaluated against current or status quo conditions. In the process of developing these models, data gaps can be identified and research and monitoring efforts can be prioritized.

## **Project 8**

### **Mass-Balance Models for Phosphorus and Nitrogen: Towards An Understanding of the Sources and Sinks of Nutrients in the Lake of the Woods Basin**

#### ***Objective***

Mass-balance models that describe phosphorus and nitrogen budgets, loads, and concentration trends for Lake of the Woods and other transboundary lakes and in loads for the Rainy River and other tributaries.

#### ***Description***

Mass-balance modelling involves integration of inputs and outputs over defined periods of time. A budget is a way to quantify system compartments of the nutrients phosphorus and nitrogen within a lake and across its catchment. Budgets and mass-balance models depend on observational datasets to ensure that they, as realistically as possible, represent key components of a system and the rates by which nutrients move into and through the system. Studies of nutrient dynamics within Lake of the Woods (Hargan *et al.*, 2011; Anderson *et al.*, 2013) and in defined watersheds of the basin (MPCA) through accomplished IMA projects in the areas of load and mass-balance datasets, Rainy River load monitoring from 2010 and 2010, and load and lake mass-balance modelling for TMDL and lake-based models, and Minnesota's storm event-based watershed monitoring currently underway have already demonstrated the

utility of nutrient budgets and mass-balance models for improved understanding of nutrient sinks and sources.

In development of budgets for phosphorus and nitrogen, data gaps are likely to be encountered that hamper budget completeness. Such information will be useful in the assessment of monitoring network robustness. Within-lake budgets, especially for phosphorus, will depend on a greater understanding of internal loading (recycling of phosphorus from lake-bottom sediment back into the water column) as well as quantification of inputs from streams and rivers and the atmosphere (point and non-point sources). Total forms of phosphorus (TP) and nitrogen (TN) represent the most common measures of nutrients; however, special attention will also be dedicated to the feasibility and utility of budgets for dissolved or bioavailable phosphorus since they are the forms that most readily stimulate algal blooms. Paleolimnological work completed through the IMA should be considered as it will provide a picture of how loading rates and algal communities have changed over the recent past.

This project aims to build on these efforts by broadening the spatial extent of the budgets and models to include all remaining watersheds not covered by MPCA and others and to develop a basin-wide nutrient model. Once developed, phosphorus and nitrogen budgets can be used to set targets and objectives for concentrations in the water column of Lake of the Woods and other transboundary lakes and for annual or seasonal loads of nutrients entering the lakes. Targets and loads should be developed in consideration of approaches adopted in other systems confronted with eutrophication. For the western basin of Lake Erie, a cyanobacterial index (CI), a measure of algal bloom severity, is strongly related with discharge and phosphorus from key tributaries in the basin (Stumpf *et al.*, 2012; International Joint Commission, 2014; Scavia *et al.*, 2014). The resulting load-response curves can be used to set policies according to desirable levels of algal blooms compared to current conditions.

In addition, this project is important to the evaluation of the management action and conservation practices intended to reduce excessive nutrient loading to basin waters.

### ***Methodology***

This project has multiple components, some of which can be phased-in:

- Component 1: Development of nutrient budgets for watersheds in the basin not already covered through complementary efforts. For portions of the basin that have robust water quality data, such as watersheds in Minnesota, this will be more straightforward than for areas that are data-deficient, including some in northwestern Ontario. Estimates of historical P loads from Rainy River to Lake of the Woods and associated burial rates will be used to improve interpretation of budgets.
- Component 2: Development of lake-wide and basin-wide coupled mass-balance models that quantify nutrient sinks and sources. Models will consider annual periods, seasonal periods and storm events. This component should build on load and lake mass-balance modelling for Minnesota's TMDL program for impaired areas (for example, Big Traverse Bay) as described in the IMA workplan.
- Component 3: Development of relationships for transboundary lakes between indices of algal bloom severity, such as the CI and forcing factors such as discharge or phosphorus loads from key tributaries.



- Component 4: Recommending water quality objectives for nutrient concentrations in Lake of the Woods and other transboundary lakes and water quality load targets for the Rainy River and other major tributaries. Objectives and targets should focus on both total and dissolved reactive fractions of phosphorus, as well as other important parameters including nitrogen, suspended solids, among others. Objectives and targets should consider both mean annual and seasonal values, particularly due to the importance of the freshet or snowmelt period.
- Component 5: Phased-in aspect of the project involving stewardship and updating of the models on a periodic basis and as new sources of monitoring data and information are made available.
- Component 6: Focus on remedial actions and controls that can be implemented to reduce nutrient loads to lakes and rivers. It involves a review of conservation practices, best management practices for agricultural, urban and rural lands, their suitability for the Lake of the Woods Basin, and determination of knowledge and research gaps.

### ***Organizations and Key Linkages***

- The IMA, through its network of government agencies, is well-positioned to lead this project.
- It directly benefits from the Foundational Project 1 and, in addition to knowledge gained about nutrient dynamics in the basin, supports several other recommended projects under the nutrient enrichment-HABs priority.
- Minnesota's currently funded project, as described in the IMA "Storm-event based load monitoring", will be used to improve event-based phases of models. Similarly, results from the IMA accomplished project Estimating TP loads from Shoreline Erosion will be applied.
- Nutrient concentrations and loads should be geo-referenced to binational stream networks, under development through the IJC, and to land-use maps through IMA collaborations with University of Minnesota and University of Manitoba.
- Estimates of lake residence time and river discharge in quantification of nutrients will depend on hydrologic data as described in Project 13.
- Estimates of internal loading as a subsidy of phosphorus will depend on development of monitoring and measuring tools described in the Study Area "Better understanding of internal loads and in-lake processes".
- A paper titled, "Trophic state in Voyageurs National Park lakes before and after implementation of a revised water-level management plan" currently in press at the Journal of the American Water Resources Association provides nutrient and trophic status information for the Rainy Lake and Namakan Reservoir Lakes.

### ***Timing***

Phases one and two should each take approximately two years. Phase three through six would involve a longer term commitment to support analysis and interpretation of water quality datasets.

### ***Project Benefits***

As mass-balance models for phosphorus and nitrogen represent a robust approach to the quantification of nutrient loads and apportionment of sources, results of this project have critical importance in the development of management responses. Phases one and two are high priority as they are both essential to the development of a binational nutrient management strategy.

### **Project 9**

#### **Application of Water Quality Models at Watershed and Basin-Wide Scales to Apportion Nutrient Sources and Run Scenarios**

##### ***Objective***

Calibrate water quality models for specific watersheds and the Lake of the Woods basin as a whole that can be used to apportion nutrient sources and run management action and climate change scenarios.

##### ***Description***

Water quality models build on nutrient budgets. They can be used to identify knowledge and data gaps, answer questions about sources of nutrients, and evaluate scenarios that may involve climate change or nutrient abatement management actions. Successful calibration of water quality models depends on the availability of relevant datasets.

The state of Minnesota has already made great strides in the modelling of watersheds that comprise portions of the Lake of the Woods Basin through the application of Hydrological Simulation Program-Fortran (HSPF), which includes a routine that can provide preliminary mass-balance model evaluations. The current HSPF model under development (anticipated completion data of August 2015) includes the Canadian portion of the basin. Watershed modelling efforts recommended in this project complement the HSPF as well as the IJC's SPARROW application (anticipated completion date December 2014). Calibrated water quality models have several uses in the Lake of the Woods basin. First, they can be coupled to lake models (IMA workplan, and Clark and Sellers, 2014) as drivers of water quality, ecological condition and algal blooms (for example, Zhang *et al.*, 2013). Second, they can be used to evaluate hypotheses or policies of land use change, management actions or climate change to estimate their influence on nutrient concentrations and loads. Third, online mapping and decision support system tools of calibrated models afford opportunities for customization to suit local stakeholder needs and for public engagement through visualization of water quality and watershed attributes.

##### ***Methodology***

Given the water quality modelling activities already underway in the basin, the first activity in this project should be organization of a workshop or summit to exchange information and analytical tools, and to identify data gaps. In watersheds of the basin for which there is insufficient monitoring data to calibrate a

water quality model, regional binational modelling should be advanced to at least provide estimates of nutrient loads and concentrations that can be used to inform policy.

Where necessary, watershed attributes should be developed and harmonized across the basin to provide robust input data for the models. Such attributes or factors may include elevation models, stream networks, physiography, and land use/land cover maps, among others. A central archive and retrieval website for binational datasets would be of great benefit to model developers and interested organizations and residents of the basin. Land use/land cover maps, in particular, are useful for describing human activities in the basin and, when developed on a periodic basis, provide a picture of how the basin is changing over time (L. Olmanson, 2014, unpublished presentation to the IMA).

Calibrated models will be used to forecast changes in concentrations and loads of nutrients in lakes and rivers according to alterations (according to climate change scenarios) on temperature and precipitation regimes and policies and strategies involving BMP implementation. Calibrated models and their supporting datasets will be made available through technical (published) resources and online tools. With changes in human activities in the basin and the influence of climate change, models should be updated on a periodic basis as new monitoring information becomes available.

### ***Organizations and Key Linkages***

Binational work on water quality modelling will include partnerships or collaborations with MPCA, Environment Canada, USGS and the IJC.

### ***Timing***

Acquisition of datasets and calibration of water quality models usually takes approximately two years for complex systems. Multi-model integration and model stewardship represents an ongoing commitment.

### ***Project Benefits***

Water quality modelling represents a powerful tool for understanding nutrient dynamics in watersheds. Development and calibration of water quality models for key watersheds and for the entire international basin are both high priorities. Water quality models, built upon high-quality monitoring data and mass-balance budgets, are important for policy development as they afford opportunities to evaluate “what if?” scenarios according to changes in key model inputs, including physical drivers such as precipitation or human activities such as land use alteration.

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### 3.2.2 Better Understanding of Internal Loads and In-Lake Processes

A consistent message from Basin experts and highlighted in both the 2014 Clark and Sellers report and the IMA work plan is that there is insufficient knowledge about the role of internal loading in the development of algal blooms in the basin. Over 90 percent of the phosphorus entering Lake of the Woods comes from the Rainy River. As noted earlier, though the annual loads of phosphorus to Lake of the Woods have been decreasing from Rainy River, the frequency and severity of algal blooms has not and may, in fact, be increasing. The subsidy of phosphorus from lake-bottom sediments is thought to be particularly important in the Lake of the Woods Basin. However, improved methodologies for quantifying internal loads are needed and they need to be tailored to transboundary lakes in the basin. Once internal loads of phosphorus are estimated, a variety of other ecological questions can be addressed, such as the occurrence and extent of hypoxia and the impacts on lake trout habitat.

The second project in this section focuses on iron at the sediment-water interface as it may play a specific biogeochemical role in the release and availability of internally loaded phosphorus.

The third project addresses shoreline erosion and how it may affect phosphorus loads from nearshore areas of lakes. Hadash (2010) and Hargan *et al.* (2011) have estimated that less than 5 percent of the overall phosphorus load to Lake of the Woods came from shoreline properties and (Anderson *et al.*, 2013) estimated that just over 5 percent came from shoreline erosion. With shorelines, particularly along the southern shores of transboundary lakes, vulnerable to the combined forces of high winds and high water levels, there is a likelihood that the subsidy of phosphorus from shorelines will increase. Elevated water levels and high winds observed during the late spring and early summer of 2014 may be an indicator of future environmental conditions.

#### **Project 10**

#### **Improved Understanding of Internal Loads and Hypoxia in the Lake of the Woods**

##### *Objective*

Improved understanding of internal loads and hypoxia towards better prediction of HABs.

##### *Description*

This is a multi-component project that seeks to build on existing research projects that have focused on areas of internal loads and hypoxia. Internal loads are believed to be a major source of phosphorus to the water column and a factor in the development and duration of HABs in Lake of the Woods (especially Big Traverse Bay) as well as other transboundary lakes such as Kabetogama and eutrophic bays of Rainy Lake. With phosphorus loads from the Rainy River generally decreasing over the past 50 years, there is speculation that the accumulated reservoir in lake-bottom sediments is supplying phosphorus for algal growth. Recent work by Edlund *et al.* (2014) has shown that phosphorus is mobile in Lake of the Woods sediments, indicating the importance of remobilization. In addition, phosphorus derived from internal loads is primarily in a dissolved form, which is more bioavailable for uptake by primary producers. Other dynamics at play at the sediment-water interface include sediment resuspension, particularly in areas of

lakes prone to large open-water stretches (fetches). This project would develop methods to monitor, estimate and model internal loads. Such methods would need to be applicable not just during the open-water season, but also during winter to quantify under-ice dynamics. Complete year accounts of internal loading would be subjected to interpretation as a function of climate change scenarios from regional climate models that may affect lake stratification, thermal regimes and ice phenology.

Hypoxia is related to internal loads through oxygen depletion. An understanding of the drivers of hypoxia, which includes inputs of phosphorus, organic matter and nitrogen, will improve quantification of internal loading and provide insight into conditions that may impair ecological condition through HABs or fishkills. This project would develop relationships between oxygen consumption and physical drivers, such as temperature, water circulation and lake bathymetry, and sediment chemistry. Research should be carried out in concert with the other projects listed in this subsection and would involve a combination of field studies and geospatial modelling. Another output from this project would be a mapping application that shows the location, size and duration of hypoxic areas. This application could be combined with other applications, such as HAB extent, to assess overlaps in space and time.

Lake trout are emblematic of the Lake of the Woods Basin. Healthy lake trout populations are due to well-oxygenated waters and availability of habitat for spawning. A number of headwater lakes in the Basin have been identified as sensitive sentinel lakes, which are lakes that are representative of the most common aquatic environments. The approach was first adopted by the state of Minnesota; there are significant binational benefits to having it applied in Ontario, too. The project would involve summer surveys of sentinel lakes to quantify and characterize lake trout habitat and collection of sediment cores to reconstruct hypolimnetic oxygen concentrations and historical water quality. Indigenous knowledge would form an additional source of information on the history of lake trout populations. Information on lake trout habitat in sentinel lakes would then be interpreted in the context of hydrologic regulation and climate change to forecast changes to lake trout populations.

### ***Methodology***

- Component 1: Estimation of phosphorus loading from sediments would be improved by the development of better measurement techniques and enhancement of monitoring. A particular challenge that needs to be overcome through this component is consideration of seasonality. Winter conditions, specifically, under ice dynamics, may play a key role in setting up conditions for internal loads and hypoxia; however, this portion of the year is typically difficult to monitor and often overlooked.
- Component 2: Associated with monitoring of internal loads is mapping of internal load locations and extents of hypoxia. Both are temporally dynamic in that locations of internal loading and the spatial extent of hypoxia varies from year to year. For this reason, mapping layers need to be linked to bathymetry. Variation in water levels, as function of hydrologic regulation or weather-related flooding, should be incorporated into the model to improve utility under future conditions. Overall, vulnerability areas should be identified that may include specific zones of lakes and relatively protected bays.

- Component 3: Information derived from monitoring and mapping should be integrated into a modelling tool that could be used to predict internal loads and hypoxia and serve as a visualization tool of conditions that are likely to lead to the development of HABs.
- Component 4: Mapping and modelling tools developed to describe hypoxic areas should then be applied to a select set of sentinel lakes to predict impacts of hypoxic variation on lake trout habitat.

### ***Organizations and Key Linkages***

- Internal load data will be useful in the development of nutrient budgets, as described in Project 8, and predictive models of HABs, as described in Project 13.
- Field campaigns and cores collected through paleolimnological studies, as described in components of projects 4 and 16.
- A geospatial data layer of hypoxia will contribute to the suite of mapping tools that can describe the condition of Lake of the Woods and other transboundary lakes.
- Monitoring data sets and reports from Voyageurs National Park for Rainy Lake and Namakan Reservoir; numerous peer reviewed reports, including Christensen *et al.*, (2013).

### ***Timing***

Components 1, 2 and 4 of this project are research-oriented and should take two to three years to complete, though additional years may be necessary to characterize interannual variability. Component 3 will require a start-up period to ensure data are translated into mapping tools, and then an ongoing commitment to mapping support.

### ***Project Benefits***

There is some evidence that internal loads may play a relatively stronger role in the development of HABs in the Lake of the Woods and other transboundary lakes compared to other lakes suffering eutrophication, due to differences in physiography and land use on either side of the border and the complicated bathymetry of Lake of the Woods in particular. Progress on measuring, monitoring, and mapping internal loads and hypoxia will be essential for forecasting HABs and other biological attributes of the lakes, such as the distribution of lake trout populations and habitat. Support for this project will ensure that one of the largest gaps in Lake of the Woods limnology is addressed. Knowledge gained through this project will be applicable not just to other transboundary lakes in the Lake of the Woods Basin, but across North America.

## **Project 11**

### **Application of the Phosphorus-Ferrous Conceptual Model to Lake of the Woods**

#### ***Objective***

Determine whether anoxia and phosphorus-iron dynamics at the sediment-water interface are precursors to internal loading and the formation of algal blooms.

#### ***Description***

Recent research from a survey of Canadian lakes suggests that iron plays a specific role at the sediment-water interface that translates into a stimulation of algal blooms. In consideration of project #10, there appears to be a key gap in basic scientific understanding of lake biogeochemistry, particularly at the sediment-water interface that is compromising our capacity to predict HABs.

Molot *et al.* (2014) provided evidence from several Canadian lakes spanning a trophic gradient that, while phosphorus controls productivity, blue-green algal dominance of phytoplankton communities is dependent on access to ferrous iron in anoxic waters diffusing from anoxic sediments below. Experimental evidence from ELA (Molot *et al.*, 2010) showed that denial of access to ferrous iron prevents bloom formation even if productivity does not decrease. This suggests that bloom formation could be prevented in Lake of the Woods by maintaining oxidized sediments to prevent formation of ferrous iron. In turn, this could be accomplished by limiting anthropogenic inputs to the lake not only of phosphorus but also possibly organic carbon, organic nitrogen and ammonium, all of which lead to microbial consumption of dissolved oxygen. Indeed, the risk of bloom formation (Downing *et al.*, 2001) may be linked to the risk of anoxic sediment formation which increases as P loading increases.

#### ***Methodology***

This project would involve a combination of field and laboratory studies to:

- assess the development of anoxia and internal loading in affected and reference areas of the lake in relation to the timing of blooms;
- map surface sediments for organic carbon, organic nitrogen and ammonium;
- assess the potential of sediments to contribute ferrous iron should sediments become anoxic;
- measure sediment and water column nitrification and respiration rates; and,
- measure release rates of phosphorus and iron from incubating sediment cores.

Results would be used to develop a bloom susceptibility rating for different areas of the lake based on sediment geochemistry and be linked to monitoring and mapping of internal loads and hypoxia as described in Project 10.

### ***Organizations and Key Linkages***

- This project should be led by an academic institution in partnership with federal, state and provincial agencies.
- Evidence found in support of the phosphorus-ferrous model will inform development of predictive models of HABs, as described in Project 13.
- Results could be linked to phosphorus mass balances (section 3.2) to set effective phosphorus input targets once a dissolved oxygen model becomes available that predicts how sediments will respond to various phosphorus control scenarios. However, mass balances for other oxygen consuming substances may be necessary.

### ***Timing***

This is a research-oriented project that will require two to three years to complete.

### ***Project Benefits***

Though eutrophication afflicts many lakes along the transboundary between Canada and the United States, no two lake systems are identical. A greater understanding of the sediment-water biogeochemical dynamics may provide invaluable insight into specific mechanisms that may trigger algal blooms or sustain their occurrence.

## **Project 12**

### **Assessment of Nutrient Subsidies from Shorelines Due to Erosion from High Water Levels in Lakes and High Flows in Rivers**

#### ***Objective***

Quantify rates of phosphorus loss from existing properties and infrastructure and shoreline erosion to improve nutrient budgets and develop a shoreline vulnerability index that considers high water levels in lakes and high flows in rivers due to hydrologic regulation and altered circulation and wind patterns due to climate change.

#### ***Description***

The 2014 SOBR identified shoreline erosion as one of the main concerns facing the Basin, most significantly in the southern portion of Lake of the Woods along the Minnesota lakeshore and in the Buffalo Point area in Manitoba. Erosion was the focus of a detailed investigation on shoreline load contributions from Minnesota to sediment and nutrient budgets (Houston Engineering Inc., 2013).

Several other projects have been completed or are underway that address interactions between water level regulation and shoreline erosion. Phillips and Rasid (1996) provide a historical overview of erosion problems in Lake of the Woods that are associated with water level controls. The purpose of



that study was to contribute to the understanding of how sediment and nutrients move through and within the lake and to refine the characterization of how shoreline erosion along the U.S. side of the lake contributes to the lake's nutrient issues. It also refined the estimate of sediment and nutrient loads from the tributaries. Results from the study, when compared to the research done on nutrient budget for the lake (Hadash, 2010; Hargan *et al.*, 2011), indicate that TP loading to the lake from southern shoreline erosion may be a significant source of nutrients to the lake; results are on the order of loading from precipitation and local watershed inputs (estimated by Hargan, *et al.* at 105 and 89 tonnes/year, respectively). They are also an order of magnitude higher than TP loading from the Lake of the Woods watershed (estimated at about 15 tonnes/year).

In addition, the IJC on behalf of the IRLWWB is funding ongoing efforts to evaluate the performance of water level management strategies for Rainy and Namakan Lakes and Rainy River (Rule Curve Review).

As part of that review, a consultant was retained in 2013 to undertake site visits of shoreline properties on the Rainy, Namakan, Kabetogama, Sand Point, Little Vermilion, and Crane Lakes to help gather the necessary data to assess shoreline vulnerability due to high water levels. The project is expected to be completed in March 2015.

Where applicable, results from these studies will be interpreted for their potential influence on vulnerability of shorelines to erosion and sediment and nutrient loss rates. Many factors can affect rates of shoreline erosion. Some are within the control of structures in the basin through water level regulation, while others are not, such as alteration of wind and water circulation patterns due to climate change. The high water levels and flows experienced in the Basin during June and July of 2014 due to exceptionally high rainfall rates exacerbate current rates of erosion.

A challenge in this project will be to estimate changes in nutrient subsidies to rivers and lakes as a function of these factors and how they influence water quality and the occurrence of HABs.

### ***Methodology***

Given the work done in support of this area of research through the IMA "Estimating TP Loads from Shoreline Erosion", this project should focus on the following five components:

- Component 1: Incorporate measured TP loads from southern shores and estimates of TP loads from northern shores into nutrient budget models;
- Component 2: Add a nearshore sampling program (possibly through Project 1 river-based and lake-based special studies) to characterize the distribution and fate of phosphorus from eroded sediments;
- Component 3: Develop an assessment of erosion vulnerability index for shorelines and express it through a mapping tool that would show shoreline zones in a risk framework. The index should include hydrologic conditions such as those observed in 2014 and be used to model shoreline projections (alterations to shorelines) according to more recent trends in hydrologic variability and possibly frequency of extreme events. The index would then be used to estimate future changes to phosphorus loads from shorelines and assist with land-use planning;

- Component 4: Review protection strategies for erodible shorelines and initiative demonstration projects; and,
- Component 5: Interpret results of projects undertaken through the Rule Curve Review by relating them to risk of increased shoreline erosion.

### ***Organizations and Key Linkages***

Work in support of this project should be undertaken by agencies in collaboration with soil and water conservation districts and property owners/lake associations. Results of this project will directly benefit Project 8 on nutrient budgets and be incorporated into the geospatial mapping framework described in Project 5.

### ***Timing***

The project should take two to three years to ensure that adequate interannual variation is covered.

### ***Project Benefits***

Exceptionally high water levels in 2014 have dramatically increased the profile of the importance of water level regulation in efforts to mitigate catastrophic losses. An improved understanding of what factors are most important in determining rates of erosion informs the development of nutrient budgets and facilitates a key research link between water quantity issues and water quality issues.

## **3.2.3 Drivers of Harmful Algal Blooms and Development of Predictive Models and Tools**

The generation of a predictive model for the timing, spatial extent and duration of HABs represents an ambitious goal. The projects under this subheading involve identification of drivers or forcing factors that may result in HABs and characterization of HABs through satellite imagery and remote-sensed data to facilitate visualization and interpretation.

A component of the first two projects is application of the approach adopted for the western basin of Lake Erie involving development of relationships between a CI based on satellite imagery and phosphorus loads from a major contributing tributary. The return of severe HABs at Lake Erie and the response of governments, stakeholders and citizens in that basin provide an example of how to frame and address eutrophication in an international context.

The last project in this section addresses how food web variation may increase or decrease the likelihood of algal blooms. Ecological properties of trophic structure may exert control on processes such as grazing pressure on algae and may help explain why lakes behave differently. Similarly, the introduction and establishment of aquatic invasive species can have a major influence on food web dynamics, such as spiny waterflea on zooplankton communities and zebra and quagga mussels on nearshore habitats and communities (see section 3.3).

## **Project 13**

### **Development of Predictive Models of Algal Blooms Based on Hydrological Forcing, Wind Dynamics and Water Circulation**

#### *Objective*

Improved understanding of how hydrometeorological processes including hydrological forcing, wind dynamics and water circulation affect the onset, extent and duration of algal blooms.

#### *Description*

Prediction of the location, timing and extent of HABs in Lake of the Woods would be of great benefit to government agencies, regional stakeholders and residents of the watershed. However, the great variety of interacting factors suggests that undertaking multiple approaches is likely the best option for making sense of such a complex system. In addition to the biogeochemical processes referred to in this section, there are physical or hydrometeorological processes, such as hydrological forcing, wind patterns and dynamics and water circulation and flows, that influence the distribution of nutrients in water bodies and the dynamics of algal blooms (McCullough *et al.*, 2012; Zhang *et al.*, 2013).

#### *Methodology*

The project involves analysis of historical and contemporary hydrometeorological data to develop time-series of hydrological forcing, wind patterns and water circulation. In their absence, modelling data should be used. The key steps are:

- First, evidence from some other lakes suffering from eutrophication suggests that increases in loads alone are not sufficient to explain the recent proliferation of algal blooms, but that hydrological forcing as a result of increases in runoff is accelerating the transfer of phosphorus from land to receiving waters. This project involves relating phosphorus loads from Rainy River to estimates of runoff and discharge to separate the relative contributions of both factors.
- Second, changing wind patterns may have an impact on thermal stability with Lake of the Woods, which in turn may influence internal loading and algal abundance and composition. Environment Canada embarked on a study that involved development of a wind simulation, but wind data were only available for one season. Multiple years of data are needed to parameterize a model of wind patterns. Wind measurements would need to be coupled to simultaneous measurements of internal loading.
- Third, the circulation and flows of water within Lake of the Woods has an impact on the lateral and vertical transfer of nutrients and the spatial distribution of algal blooms. A circulation model for the lake exists (Zhang *et al.*, 2013; Pascoe *et al.*, 2014), but it needs further refinement. In addition, water level variation, as a function of hydrologic regulation or climate change, should be considered when developing and modelling water circulation through the system.
- All models should be made available through mapping tools and versions of the models should be applied to other transboundary lakes.

### ***Organizations and Key Linkages***

- Agencies that collect information on wind direction and speed and water movement through the Lake of the Woods and its basin should be involved.
- This project should be coordinated with other projects that focus on development and use of topographic DEMs and bathymetric maps.
- This project should be coordinated with other projects that focus on development and use of topographic DEMs and bathymetric maps. Detailed bathymetric mapping of select littoral zone locations in Rainy Lake and Namakan Reservoir is a planned study associated with the Rainy and Namakan Lakes Rule Curve studies, and will support development of a more precise digital elevation model for Rainy Lake and Namakan Reservoir which allows researchers to improve their data analyses by improved quantification of areas inundated and dried under various hydrologic regimes. This is important for nutrient loading (and HABS) as well as for production of methylmercury (contaminants). Creation of detailed digital elevation model (DEM) for the Rainy Lake and Namakan Reservoir area, as part of the habitat modelling project for these waterbodies, can be used in combination with the hydrologic models referenced above to investigate the relative influence of various hydrologic regimes (Rule Curves and state of nature) on nutrient loading, methylmercury production, and habitat for fish and wildlife.
- Consideration of changes in the physical forces of wind and water movement will be useful in understanding the causes of shoreline erosion.
- Characterization of the natural hydrology of the Rainy River and effects of 1970 and 2000 Rule Curves on Rainy River hydrology, which is now completed, allows for investigation of water levels under different hydrologic regimes (for example, 1970 and 2000 Rule Curves; Thompson, 2013). This may also allow improved estimates of Rainy River flow (and by extension loading) to Lake of the Woods under various hydrologic scenarios.

### ***Timing***

This project should take two to three years.

### ***Project Benefits***

Given the complexity of the topography and bathymetry of Lake of the Woods and its basin, the influence of physical forces such as wind and water circulation may play a disproportionate role in algal bloom formation. This project addresses the knowledge gaps surrounding how the complex bathymetry of Lake of the Woods and topography of the basin and how wind dynamics are changing as a result of climate change and contributing to shoreline erosion.

## **Project 14**

### **Application of Satellite Imagery and Remote Sensing Tools to Map and Characterize Water Quality and Algal Blooms in Lake of the Woods with Application to other Transboundary Lakes in the Basin**

#### ***Objective***

Use satellite imagery and remote sensing tools to develop mapping and interpretation tools of water quality and harmful algal blooms and to develop an index of bloom severity.

#### ***Description***

Research in the Lake of the Woods basin using satellite imagery and remote sensing data has shown a promising capacity to describe algal bloom timing, extent and severity. This project would build on and accelerate research into algal bloom characterization (Binding *et al.*, 2011a; Binding *et al.*, 2011b; Pascoe *et al.*, 2014) and develop relationships between imagery attributes and putative predictors of algal blooms. These predictors may include descriptors of water quality based on satellite imagery and remote sensing data, but also field-based measures of water temperature, dissolved oxygen profiles, turbidity, concentrations of chlorophyll, and rates of inflow and phosphorus loads into lakes, among others. In addition, images and interactive maps can serve as powerful tools for public education and awareness, as specifically noted in the IMA workplan.

The experience of understanding HABs in the western basin of Lake Erie suggests that predictive relationships of algal bloom spatial extent and duration can be developed using key forcing variables such as discharge or phosphorus loads from major tributaries (International Joint Commission, 2014). Satellite imagery collected through this project should be evaluated for interpretation as a CI (as described in Stumpf *et al.*, 2012; Michalak *et al.*, 2013) which can then be used towards setting phosphorus load targets and objectives for algal bloom frequency and severity.

#### ***Methodology***

There are numerous satellite-based and remotely-sensed images and datasets available. Due to the complex geomorphology and bathymetry of the Lake of the Woods, the data limitation for this project is observational data that can be used to validate images and datasets and calibrate models. Significant data collection will be required for this project. Selection of specific zones, bays or regions of Lake of the Woods and other transboundary lakes prone to water quality issues and HABs in particular may be necessary for expedient development of mapping and interpretation tools. This project has four complementary components:

- First, there is a need to develop real-time monitoring of transboundary systems during the open-water season, which focuses on current algal conditions. Satellite imagery would focus on chlorophyll and

other-related spectra and particulate conditions. One example worth considering is the bimonthly updates from NOAA Lake Erie Harmful Algal Bloom Update.<sup>5</sup>

- Second, a remote sensing tool needs to be developed that can map algal distribution, quantify abundance and characterize species composition. Following protocols developed by the USGS, satellite imagery should be validated and calibrated against fixed-station data. Such a tool would be important for public education and awareness.
- Third, imagery and spatial datasets generated through this project should be assessed for suitability as an index of algal bloom extent and duration, such as the CI developed for the western basin of Lake Erie.
- Fourth, a remote sensing tool that can be used to assess spatial patterns in water clarity should be developed from LandSat and posted through online tools such as Google Earth. This component could build on water clarity information from MNRF available for more than 100 lakes in the Ontario portion of the Basin through its Broad-scale Monitoring Program in relevant Fisheries Management Zones. Similar to the tool for mapping attributes of algae, this tool would also serve an important function for publication and awareness.

### ***Organizations and Key Linkages***

- Agencies and organizations referred to in the IMA should form the core group for this project.
- Geospatial data products developed through this project would be accessible and made available through the Foundational geospatial mapping project.

### ***Timing***

Research in support of this project should take two to three years, as it will mainly focus on processing imagery and data. A longer timeframe maybe required to capture interannual variability.

### ***Project Benefits***

Satellite-imagery and remote-sensed data serve scientific demands for quantifying the spatial scale and character of water quality issues and public information needs through the linking of imagery to mapping tools. Support for this project will leverage interpretation from a wide variety of other satellite imagery and remote-sense data projects elsewhere in North America (for example, Lake Erie and Lake Winnipeg) that can be applied to Lake of the Woods.

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<sup>5</sup> <http://www2.nccos.noaa.gov/coast/lakeerie/bulletin/>.

## **Project 15**

### **Development of Aquatic Food Web Models Focusing on How Zooplankton Communities and Trophic Structure Affect Production of Harmful Algal Blooms**

#### ***Objective***

Understand and quantify the role of zooplankton communities and aquatic trophic structure in the development of HABs.

#### ***Description***

Trophic interactions in aquatic ecosystems can exert a strong influence on energy flow. Algal population growth and community structure are controlled by the availability of bioavailable nutrients and by grazing pressure, primarily by invertebrates called zooplankton. In most lakes, aquatic community structure is relatively stable, meaning that the composition and abundance of organisms at different trophic levels (that is, primary producers, such as algae and macrophytes; herbivores, such as zooplankton; consumers, such as forage fish; and top-level predators, such salmonids) are relatively unchanged from year to year. It is a testament to the resilience of most natural communities that they persist in this way.

This project is focused on understanding and quantifying how alteration to components of transboundary lake food webs may influence the occurrence and severity of HABs. One of the major perturbations to aquatic food webs in the basin is the introduction of the aquatic invasive species spiny waterflea. It may affect algal growth and biomass through alteration of herbivorous zooplankton communities (Yan *et al.*, 2002; Barbiero and Tuchman, 2004). Trophic structure as a whole may also affect the likelihood that algal blooms occur through phenomena called trophic cascades (Carpenter and Kitchell, 1996). Another major perturbation to aquatic food webs can occur as a result of invasion of zebra mussels. Though zebra mussel habitat is primarily along shorelines, their filtration capacity has been observed to dramatically alter water clarity and distribution of nutrients across the nearshore zone to the open water zone (Hecky *et al.*, 2004). With the complex bathymetry and density of islands that exist in the Lake of the Woods in particular, there is the potential for widespread infestation.

#### ***Methodology***

This project relies on coordinated biotic sampling in selected parts of the Lake of the Woods and across a series of transboundary lakes. Construction of food web models should include identification of predatory-prey relationships through field observations and gut contents analyses, as well as through the application of stable isotope analyses. Food web models should then be interpreted and, if possible, coupled to other models developed through the Plan of Study to develop a more comprehensive picture of what factors may control HABs.

For studies involving zebra mussels, strong linkages should be established with activities listed under the AIS priority issue.

### ***Organizations and Key Linkages***

- Selection of study locations should follow the Foundational tiered monitoring program (see Project 1), particularly the river-based and lake-based special studies.
- This project should be operated as a partnership between agencies in the Basin, which can assist with monitoring and sampling, and key academic institutions, which can assist with analyses and interpretation.
- Other Plan of Study projects addressing the spiny waterflea should be linked, as well (see section 3.3).

### ***Timing***

As a field-based research project, a minimum of three years should be undertaken for biotic monitoring and sampling.

### ***Project Benefits***

A greater understanding of biotic factors in transboundary lakes will improve predictive models of HABs, help quantify the influence of spiny waterflea on water quality and the occurrence of HABs, and increase the public's appreciation of ecological interactions and biological community structure.

## **3.2.4 Improved Understanding of Risks Associated with Toxic Algae and Enhancement of Public Education**

One of the more hazardous by-products of HABs is the potential release of algal toxins. There is limited knowledge about the taxonomy of algal species in HABs and even less about algal toxins. The first project under this group involves a synoptic survey of nearshore waters and targeted sampling of algal blooms to improve understanding of specific risks in the Lake of the Woods Basin transboundary lakes and rivers. This information will be useful for generation of accurate public health advisories regarding water uses.

The second project focuses on a review of public health and animal welfare risks as a result of algal toxins. It builds on previous work in the Basin by the IJC's Health Professionals Advisory Board (HPAB) and involves development of communication tools such as websites, social media alerts and traditional print media to inform the public of current conditions.



## **Project 16**

### **Taxonomic Characterization of Algal Communities and Algal Toxins**

#### ***Objective***

Detailed characterization of algal communities and algal toxins to provide the public with accurate and up-to-date information about water quality conditions in transboundary lakes that experience HABs.

#### ***Description***

HABs are undesirable in the Basin because they impair water quality, ecological condition and human uses of water resources. HABs can also lead to the release of algal toxins that threaten the human health and animal welfare (such as pets and livestock).

There is insufficient understanding of the composition and structure of phytoplankton communities in both offshore and nearshore zones of Lake of the Woods and other transboundary lakes (Kotak and Zurawell, 2007). Over the past decade, there have been several reports of cyanobacterial bloom toxins, including Microcystin in Lake of the Woods (Chen *et al.*, 2009; Orihel *et al.*, 2012), a report of Aphanizomenon in Rainy Lake, and reports of *Oscillatoria rubescens* in several headwaters watershed lakes.

Paleolimnological analyses, as expected from the IMA project Southern Basins Paleolimnology Project, will be used to provide historical context for contemporary observations.

#### ***Methodology***

This project would involve a series of monitoring programs and sampling would occur during the open-water season over three years to capture within-season and inter-annual variation. Samples would be collected from the pelagic (open-water) zone and from a fixed depth to collect algae settling out of the water column. It would also involve identification of algal toxins (for example, Microcystin).

In addition, the project would greatly benefit from *in situ* continuous sensor measurements of chlorophyll-*a* and blue-green pigments. The project would start with a pilot study to develop and test sampling strategies, processing techniques and methods of toxin analysis. Relationships would be developed between algal communities and water quality parameters and satellite imagery.

#### ***Organizations and Key Linkages***

- This project should be supported through partnerships agencies, academic institutions and other specialized organizations that can identify algal species and toxins.
- Information collected through this project on algal toxins will be useful for other Plan of Study projects involving review of public health implications of HABs, as being carried out by the IJC's HPAB, and public education.

- Characterization of algal communities will be cross-validated with satellite imagery and remote-sensed data.

### ***Timing***

This project should span two to three years, depending on availability of sample material during algal blooms. Specialized services may be necessary for sampling processing.

### ***Project Benefits***

Accurate characterization of algal bloom communities and the specific toxins that may result is critical for dissemination of accurate information to the public about water access and use.

## **Project 17 Public Health and Animal Welfare Risks Including Public Alerting Mechanisms**

### ***Objective***

To assess the risks of HABs to public health and animal welfare and develop communication tools to alert the public of possible risks.

This project will support efforts by government agencies, stakeholders and non-government organizations to keep the public informed about when and where HABs occur and the associated composition of algal toxins. It would entail building on the biotic monitoring plan by also encouraging monitoring of algal toxins along nearshore zones and in drinking water supplies. It would also form the basis of a HAB and algal toxin early warning system that could be linked to other geospatial applications in the basin (see Project 5).

### ***Description***

When HABs occur, there is an increased risk that algal toxins may be released, putting human health and animal welfare at risk.

This project has two components. The first is to determine the risks associated with occurrences of microcystin and other toxins such as anatoxins by conducting a literature review and producing a discussion paper.

The second component is to develop an effective communication tool to notify the public of the risks, based on enhancing current communication efforts in both Canada and the United States.

## **Methodology**

The first component of the project involves development of a discussion paper that would draw from existing algal toxin data from the Basin and would include a review of toxicity incidents to humans and animals, worldwide. It would document types of toxins, exposure routes, toxicity and conduct a risk assessment. The discussion paper could then be used as a foundation for the development of the near-shore monitoring program framework for algal toxins in the Lake of the Woods watershed (Project 1). It also could feed into the IJC's HPAB update of the Health of Rainy-Lake of the Woods report that may be addressing/suggesting the analysis of water samples collected at beaches for microcystins in addition to the regular analyses for *Escherichia coli*.

The second component is needed to ensure that communication of HABs and algal toxins reaches the general public, medical community (doctors, veterinarians), government agencies and others in the Basin. The geography of this Basin makes it difficult to reach the communities that can be affected and different communication tools will work better for different communities. A concerted effort needs to be placed on communicating health risks, as well as previous and new results of algal toxin monitoring. A communications strategy needs to be developed and should include:

- review of provincial/state communication tools for HABs;
- identification of target audiences;
- messaging; and,
- types of communications media (for example, pamphlets/fact sheets, posting on websites, newspaper articles, face book, regular update in the Lake of the Woods State of the Basin Report).

This project would involve an inventory of actions taken within each jurisdiction regarding alerting the public of HABs. In Ontario, the Ontario Ministry of the Environment and Climate Change and the Northwestern Health Unit (NWHU) have partnered in the past to produce posters with information on blue-green algae, the need to avoid them if seen and numbers to call if the blooms are spotted. However, there is no ongoing information on algae blooms offered on the websites of either the Ministry or the NWHU website<sup>6</sup>, though beach closure notifications (as they relate to *E. coli*) are noted on the NWHU website. Regular monitoring of microcystins does not occur as a part of the weekly beach sampling program done by the NWHU. The Ontario government recommends contacting their Spills Action Centre if an algae bloom is seen. In Minnesota, the Department of Environmental Health website has information on microcystins for the public to read, as does the MPCA website.

## **Organizations and Key Linkages**

Linkages to: NWHU, Minnesota Department of Environmental Health, MPCA, Ontario Ministry of the Environment and Climate Change, indigenous communities, Grand Council Treaty 3.

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<sup>6</sup> [www.nwhu.on.ca](http://www.nwhu.on.ca)

Working with the IJC, provincial/state/federal government agencies and other experts, a draft communication plan would be developed. Based on the communication plan, communication products/avenues of communication would be subsequently implemented.

### ***Project Benefits***

Understanding the risks associated with HABs and how to avoid contact with blooms should help to decrease the exposure of humans and animals to these blooms. The project also will help alert the public to the fact that there are agencies responsible for responding to blooms. In addition, a reliable and reputable alerting system will help the public appreciate risks associated with HABs; which will avoid unnecessary alarm in lakefront communities and economic hardship to the tourism sector dependent on lake-based activities.

## **3.3 Aquatic Invasive Species**

The Lake of the Woods Basin has been invaded by many non-native species that have disrupted communities in all trophic levels of the aquatic ecosystem, from algae up to fish. (Clark and Sellers, 2014). There is potential for further invasions in the Basin. Aquatic invasive species (AIS) include species that are not indigenous to the Lake of the Woods Basin, and some fish species (for example, bass, walleye, black crappie) that may naturally occur in some basin waters, but which have been transported into basin lakes in which they were not historically present.

Several non-native flora and fauna have invaded the Basin over the last 30 years. The hybrid cattail (*Typha xglauca*), spiny waterflea (*Bythotrephes longimanus*), water flea (*Eubosmina coregoni*), rusty crayfish (*Orconectes rusticus*), papershell crayfish (*Orconectes immunis*), clearwater crayfish (*Orconectes propinquus*) and Rainbow Smelt (*Osmerus mordax*) are among the confirmed invaders in parts of Lake of the Woods and the Rainy River (Clark and Sellers, 2014).

The MDNR reports that zebra mussels are now (as of 2013) in headwaters of the Big Fork River, a tributary to the Rainy River (Clark and Sellers, 2014; Minnesota Department of Natural Resources, 2014). Given the potential for spreading of zebra mussels toward boundary waters, this issue is of high importance for immediate response.

There is considerable potential for invasive species distribution both downstream or by human vectors such as movement of boats and live bait. There is also possibility of range expansion by the zebra mussel (*Dreissena polymorpha*) and range expansions in the benthic diatom *Didymosphenia geminata*. These threats require assessment and active, adaptive management (Clark and Sellers, 2014).

The spiny waterflea is an invasive predatory zooplankton. Spiny waterflea prey upon other zooplankton, including *Daphnia spp.*, which are common food sources for juvenile and small native fish. In lakes in south-central Ontario on the Precambrian Shield, they have been implicated in the decline in some species of zooplankton and the alteration of zooplankton communities (Yan *et al.*, 2001; Boudreau and Yan, 2003; Jacques *et al.*, 2005; Strecker *et al.*, 2006).

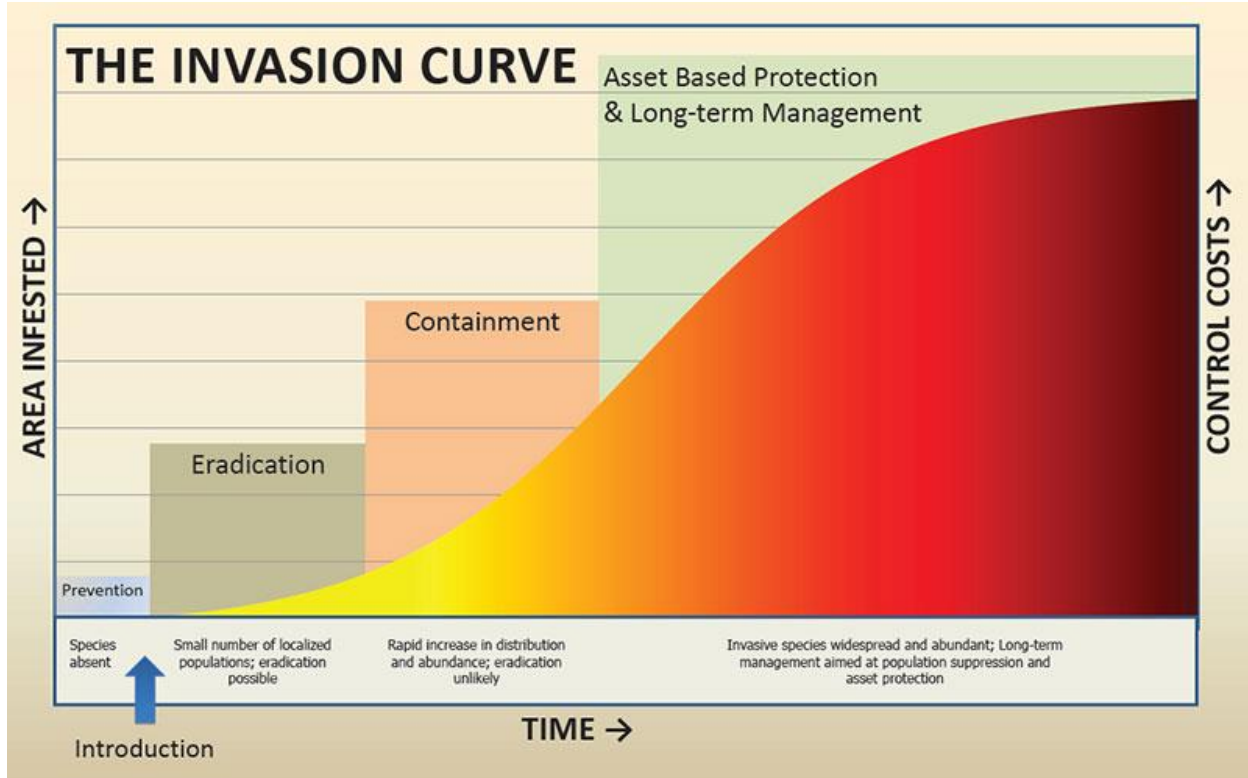
The spiny waterflea was first observed in Saganagons Lake, near the southeastern boundary of Quetico Provincial Park in 2003, in the South Arm of Rainy Lake in August 2006, in Namakan Lake during September 2006, and in the Rainy River below the Fort Frances dam during the spring 2007 (Rob and Van den Broeck, 2007). By late summer of 2007, the spiny waterflea was detected in Wheeler's Point at the outflow of the Rainy River to Lake of the Woods. It has since been found in other portions of Lake of the Woods, including Zippel Bay to Zippel Creek and the Big Fork, Little Fork, and Warroad, and Baudette Rivers (Minnesota Department of Natural Resources, 2014) and in Ontario waters along the eastern shore northwards to Morson and Miles Bay (Mosindy, 2010). SWF were immediately incorporated into diets of Cisco, Yellow Perch, Black Crappies and juvenile Walleye. SWF spread quickly throughout Lake of the Woods and by 2009 they were found in Whitefish Bay and in Shoal Lake by 2011 (Mosindy, 2013). Other basin waterbodies known to have infestations of SWF include Lake Kabetogama, Sand Point Lake, Crane Lake, Little Vermilion Lake, Burntside Lake, Lake Vermilion, Fall Lake, and the Shagawa River.

As a result of the invasion in Lake of the Woods, the MDNR (Baudette Office) and OMNRF (Fort Frances Office) increased their zooplankton sampling effort in the Rainy River and the southern basin of Lake of the Woods with the intent of tracking and detecting potential shifts in the zooplankton community (T. Heinrich, MDNR, Baudette, MN, Pers. Comm.; J. Vandembroek, OMNR, Fort Frances, ON, Pers. Comm.). As a result of the invasion in Rainy Lake and the five lakes of Namakan Reservoir, Voyageurs National Park and the MDNR are monitoring zooplankton communities throughout each open water season to track changes in zooplankton communities of these lakes (Pers. Comm.; R. Maki, Voyageurs National Park).

Spiny waterflea invasions likely have resulted in large changes to zooplankton communities in border lakes within Voyageurs National Park (Hobmeier *et al.*, 2013), with dominance shifting towards copepods and larger bodied or gelatinous cladoceran species, while overall zooplankton biomass was reduced by 40 to 60 percent. Most cladoceran species showed severely decreased populations and changing seasonal abundances, suggesting a gradual and accumulative effect of spiny waterflea. Importantly, Hobmeier *et al.* (2013) noted that spiny waterflea also seem to have important non-consumptive effects on native competitor species such as *Leptodora kindtii* and predaceous copepods. Jodie Hirsch (MDNR; St. Paul office) presented a summary of the shifts in zooplankton communities in Lake of the Woods, Rainy Lake, and the five Namakan Reservoir lakes at the 2014 Lake of the Woods Basin Water Quality Forum. The changes are substantial and follow similar patterns among the lakes. Although it is difficult to assign cause to the above-noted changes in aquatic foodwebs, it is likely that spiny waterflea will result in substantial disruptions to ecosystems that it invades. These disruptions potentially include limiting fish production and limiting consumption of algae which may exacerbate harmful algal blooms.

### 3.3.1 Comprehensive Aquatic Invasive Species Prevention Strategy

Large-scale ecological and economic disruptions often occur when invasive species enter water bodies (Ricciardi, 2001; Pimentel *et al.*, 2005). Because the most cost-effective approach to management of invasive species is preventing them from invading ecosystems (Figure 3), the highest priorities for the Basin are to develop and implement effective prevention strategies and improve upon existing strategies. Manitoba, Ontario and Minnesota each have their own prevention initiatives, legislation, and strategies and these will need to be coordinated so as to be most effective for the Basin.



**Figure 3**  
**The Invasion Curve**

The invasion curve conceptual diagram suggests that prevention costs are small, compared with management of invasions after they occur; and that cost progressively increase as the area of infestation increases and invasive species become widespread and abundant.

(Figure and concepts from LeRoy Rodgers, South Florida Water Management District, <http://www.naisn.org/generalinformation.html>)

In 2013, an Aquatic Invasive Species Subcommittee of the IMA-TAC was struck to begin this effort. However, the subcommittee has not yet been able to advance its goals and objectives. The subcommittee drew up a draft mission statement and plan for cooperative prevention among the three jurisdictions. This provides a good starting point, but there needs to be resources and capacity for this group to be successful. The project in this section outlines a mechanism for developing a coordinated, comprehensive prevention strategy for the Basin and the more specific pieces required to better understand the threats and options for implementation.

## **Project 18**

### **Binational Aquatic Invasive Species Management Team for the Lake of the Woods Basin and Development of a Binational Prevention Strategy**

#### *Objective*

1. Strengthen the leadership and capacity of the IMA-TAC AIS Subcommittee to become the Binational Management Team; and,
2. Establish the mission of the Team to be:
  - the development of a binational strategy (program) to prevent AIS in the Basin and, where possible, to contain or eradicate, AIS already in the Basin; and,
  - develop a bi-national public engagement and education campaign.

#### *Description*

This activity will ensure that membership on the IMA-TAC Subcommittee is supported with representation from Ontario, Manitoba and Minnesota and that the resources are provided to develop a coordinated, multi-jurisdictional framework to improve efforts to prevent the introduction of aquatic invasive species from nearby basins. The level of effort varies considerably between the jurisdictions and it will be important to balance these efforts more. Minnesota has an extensive prevention strategy and Ontario and Manitoba have already worked alongside AIS leaders in Minnesota to develop and enhance their own programs. Manitoba has a well-defined border inspection program that has proven to be effective. Ontario implements its invasive species program through the Ontario Federation of Anglers and Hunters and, at times, has partnered locally with the local Lake of the Woods and District Property Owners Association to ensure a student is monitoring and undertaking outreach activities on the topic. In the past few years, the association has provided this service independently.

While the framework will largely be developed and implemented with input from resource agencies with this mandate in the Basin, it is important that it be done in partnership with indigenous communities and the general public and provide for educational opportunities on prevention.

The prevention framework should include:

- Harmonization and implementation of regulations and actions, across borders and political jurisdictions, aimed at prevention of the intentional and unintentional spread of invasive species. For example, consistent approaches to managing spread of bait, bait water, and invasive species on

aquatic equipment and gear are needed; common messaging and signage throughout the Basin is another example.

- An emphasis on managing the pathways or vectors through which AIS enter or move within the Basin, and managing those vectors to prevent the spread of all invasive species, rather than a species by species strategy (for example, see page 25 of Rosenberg *et al.*, 2010). Building on the inspection programs in place within the three jurisdictions and handling them cooperatively, especially at provincial and federal borders will be important.
- Ongoing research, review, and adaptive management of current actions related to AIS prevention (monitoring, regulations, educational activities, civic engagement, and other preventative measures), to assess efficacy of approaches.
- Develop a Rapid Response Plan for the most ecologically and economically threatening species.

With regard to the Public Engagement and Education component, civic engagement for many ecosystem stewardship activities is underway as part of the International Watershed Coordination Program as well as through the current AIS prevention strategies in each jurisdiction. Basin scientists and stakeholders have expressed a need to expand efforts to engage and educate the public on a number of interrelated issues regarding aquatic invasive species. This needs to be done more consistently on both sides of the border. These efforts include: information on the ecological, aesthetic, and economic damage caused by invasive species in the Basin; threats if regionally important AIS invade the Lake of the Woods Basin; best practices for reducing or preventing further spread of invasive species into and within the Basin; and, engaging the public in the flow of information, including the links to data bases and decision support systems.

Developing effective outreach materials and strategies was deemed a high priority by Basin experts. One example of a useful education/outreach activity could be development of a “10 most unwanted species” information campaign (brochure, web site, media campaign) highlighting species of high risk for introduction or spread within the Basin and including information on prevention.

### **Methodology**

This project will build upon the AIS prevention efforts and public engagement/education campaigns underway by agencies and organizations in Minnesota, Manitoba, and Ontario. It would complement and strengthen ongoing activities, and therefore strengthen AIS prevention efforts across the entire Lake of the Woods Basin.

Due to the ongoing threat of AIS infestation, particularly in light of expanding ranges of many AIS in the region, this will necessarily be a long-term, sustained effort, and is a high priority for the Basin. This is a major effort that requires commitment and support from local, state, provincial, and federal agencies, as well as non-government organizations.

A useful model to consider for adaptation to the Lake of the Woods Basin is the framework developed for the Lake Huron/Lake Erie Corridor as a pilot project for international basins (Donahue, 2012). It addresses the following key objectives: early detection and reporting process; rapid risk assessment methodology; decision making and response protocol; prompt, efficient and effective response actions;



and, continuous plan assessment and adaptive management. Although a primary objective of the plan is rapid response, numerous aspects of the plan establish a sound framework for binational management of AIS, including monitoring, research, prevention, rapid response, and ongoing adaptive management.

The framework would be facilitated by annual meetings of the binational team, timed in conjunction with the annual Rainy-Lake of the Woods Watershed Forum.

### ***Organizations and Key Linkages***

This project will draw from strategies being developed elsewhere (for example, Donahue, 2012; Ontario Ministry of Natural Resources, 2012; Lake Superior Binational Program, 2014) and will build upon the work already started by the AIS Subcommittee of the IMA-TAC. Partnering with the IRLWWB will be important to ensure the information flow to the Board is seamless for its work in monitoring ecosystem health.

Key linkages should be made with: the MDNR Invasive Species Program; Ontario Federation of Anglers and Hunters Invading Species Awareness Program<sup>7</sup>; Ontario's Invasive Plant Council; lake associations throughout the Basin; Minnesota Sea Grant; Voyageurs National Park; MNRF (Lake of the Woods Fisheries Assessment Unit, regional MNRF science staff); U.S. Fish and Wildlife Service; the Great Lakes Aquatic Nuisance Species Panel<sup>8</sup>; and other agencies and independent experts.

The work should connect with ongoing focused research, such as that done by at Lakehead University on models to predict angler movement based on fish population characteristics and access points. Outreach messages will draw from existing economic impact studies of AIS invasion; Partnerships should be established between government agencies, universities, and local watershed organizations, IJC/IRLWWB, existing outreach programs of Ontario Federation of Anglers and Hunters, Minnesota Sea Grant, Manitoba Conservation and Water Stewardship. This topic was identified as a major role of the IJC in the Basin. The overarching structure through the IJC and the IRLWWB is in place to develop and implement a comprehensive approach by all jurisdictions in the Basin.

### ***Timing***

Immediate start and ongoing effort.

### ***Project Benefits***

The benefit of this effort is to increase the robustness of prevention programs and rapid response efforts to contain and eradicate new infestations, when they occur.

Ecosystem services provided by lakes and rivers in the Basin are substantial, and include recreational and subsistence fishing and wild rice harvesting, as well as other recreational uses. Many people choose to live in or travel to the Basin because of these ecosystem services, and as such, they are a major economic

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<sup>7</sup> [www.invadingspecies.com](http://www.invadingspecies.com)

<sup>8</sup> <http://glc.org/projects/invasive/panel/>

driver in the Basin and can be a main vector for spread of AIS. There is widespread recognition that AIS can cause considerable loss of economic value of ecosystem services (Lovell and Stone, 2005) and that prevention efforts are the most effective—and most cost-effective—management option with respect to AIS<sup>9</sup>. Once species become established in an area, they are exceedingly difficult and costly to control, and often result in large-scale ecological and economic disruption.

### **3.3.2 Assessing and Controlling Impacts of Aquatic Invasive Species**

The most cost-effective and highest priority work related to invasive species is focused on preventing the introduction of additional invasive species. However, to protect and maintain natural resources and prevent economic harm, it is critically important to assess the impacts of and assess methods for controlling established populations of invasive species

Questions remain regarding the extent of demonstrated impacts of a variety of species in the Basin and future anticipated impacts. Better understanding of impacts is important to allow resource managers to avoid collapses in populations of economically vital gamefish populations as well as in populations of culturally important resources such as wild rice. This understanding is also important so that preventive measures may be placed into a cost-benefits construct; that is, to ensure that appropriate resources are allocated to prevent potentially costly spread of AIS into currently uninfested waters.

AIS such as the spiny waterflea, rusty crayfish, rainbow smelt, and hybrid cattail already have caused some ecological disruptions and have the potential to cause substantial additional ecological disruptions in boundary waters. There is a need to better understand these disruptions, their impact on economically and culturally important resources, and, where possible, to control AIS to minimize damage.

#### **Project 19 Rapid Evaluation and Implementation of Options to Manage Recent Zebra Mussel Infestation in Headwaters Areas in Minnesota**

##### *Objective*

- Contain or eradicate (if possible) zebra mussels from new invasion fronts in Lake of the Woods Basin; and,
- Prevent further introductions of zebra mussels from nearby waters.

##### *Description:*

In 2013, zebra mussels were reported in Sand Lake, Little Sand Lake, and the Bowstring River in Itasca County, MN (Minnesota Department of Natural Resources, 2014). These water bodies are all in the same sub-basin, and drain into the Big Fork River, a tributary to the Rainy River—the border river that flows into Lake of the Woods. Zebra mussels are also reported to be in waters of adjacent river basins, very near the Lake of the Woods Basin. These include Lake Winnibigoshish (Itasca County, Minnesota) and

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<sup>9</sup> See <http://www.naisn.org/generalinformation.html>

Gilbert Pit Lake (a former mine pit) in St. Louis County, MN (Minnesota Department of Natural Resources, 2014).

Given the potential for large-scale ecological disruption in border waters, including Rainy River and Lake of the Woods, which are downstream, high priority should be given for immediate action to prevent further spread of zebra mussels within the basin; reduce or eradicate zebra mussels from currently infested lakes; and prevent further introductions of zebra mussels from nearby waters.

### ***Methodology***

This project should include several complementary activities:

- vulnerability assessment for spread of zebra mussels in the Bowstring / Big Fork River sub-basin;
- assessment of containment or eradication options from Sand, Little Sand Lakes and Bowstring River.
- immediate ramp-up of inspections, enforcement actions, and related strategies to prevent further unintentional spread of zebra mussels within, or into the Lake of the Woods Basin by movement of boats or other means.

### ***Organizations and Key Linkages***

This would be a multi-investigator, multi-institutional study, with partnerships between MDNR, Itasca County (MN), Minnesota's Aquatic Invasive Species Prevention Aid grants<sup>10</sup>, conservation groups, and other agencies.

### ***Timing***

Immediate start, ongoing management.

### ***Project Benefits***

Successful containment or eradication (if possible) of zebra mussels from the headwaters would protect Basin waters, including border waters (Rainy River and Lake of the Woods) from costly, ecologically destructive infestations.

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<sup>10</sup> [http://www.dnr.state.mn.us/grants/aquatic\\_invasive/aq\\_inv\\_prevention\\_public\\_awareness.html](http://www.dnr.state.mn.us/grants/aquatic_invasive/aq_inv_prevention_public_awareness.html)

## **Project 20**

### **Ecological Impact of the Spiny Waterflea in Infested Boundary Lakes**

#### *Objective*

Characterize ecological disruptions that have resulted from spiny waterflea infestation in large boundary lakes, including effects on gamefish production.

#### *Description*

Basin scientists called for a comprehensive analysis and assessment of the ecological impacts of spiny waterflea in the Lake of the Woods Basin. They identified a need to better understand the effects of spiny waterflea on energy flow, fish recruitment and possibly phytoplankton dynamics in Lake of the Woods, Rainy Lake, and Namakan Reservoir and other lakes in the Basin. Substantial changes in lake ecology are caused by the spiny waterflea (Yan *et al.*, 2001; Rennie *et al.*, 2011; Yan *et al.*, 2011). There is evidence that native zooplankton populations have been reduced by as much as 40 percent in Lake of the Woods and that native zooplankton biomass has been reduced by 40 to 60 percent in Rainy Lake and the Namakan Reservoir (Hobmeier *et al.*, 2013), likely as a result of the spiny waterflea invasion. Based on the substantial reductions in zooplankton biomass measured in these lakes after the invasion, resource managers and researchers expect to see a decrease in fish production in these lakes (based on a decrease in energy flow and possibly due to a developmental bottleneck for young of the year fish). Such a decrease in zooplankton abundance may disrupt aquatic food webs in two important ways: First, abundance of important game fish species (including walleye, lake trout and northern pike) may be limited due to reduced biomass lower in the food web. Secondly, the algal blooms may be exacerbated because fewer zooplankton are consuming algae. Yet researchers lack quantified estimates of these effects in the Basin.

For this project, the highest priority water bodies to be assessed include Lake of the Woods, Rainy Lake, and Namakan Reservoir ecosystems, particularly because these lakes have zooplankton data pre- and post-invasion. The focus will be on assessing the effects of an established population of spiny waterflea on energy flow and developmental bottlenecks affecting gamefish populations in these three waterbodies. Due to pronounced decreases in biomass of lower trophic level prey in these lakes, fisheries managers and Voyageurs National Park would benefit from this assessment in order to manage for sustainable gamefish populations, including the economically vital walleye populations. This project came out as the top priority study of the AIS breakout session at the March, 2014 expert workshop.

It is anticipated that there would be a great increase in return of past research and monitoring investments on Lake of the Woods, Rainy Lake, and Namakan Reservoir by using a combination of existing pre and post spiny waterflea invasion zooplankton data (identifications, densities, biomass) and new data collected through this Plan of Study study on linkages in energy flow to assess whether fish production is being affected through a decrease in forage biomass and/or through a developmental bottleneck for young fish that are unable to efficiently consume spiny waterflea (Kerfoot *et al.*, 2011; LeDuc, 2012) and fail to develop due to a lack of available zooplankton forage.

This project would use existing and new data from Lake of the Woods, Rainy Lake, and the Namakan Reservoir Lakes. It would implement modelling to assist in adaptive management of fishery resources in the watershed and make use of stable isotopes to track food web linkages. The project would benefit from ongoing assessment and modelling work being performed by the MDNR, the USGS, and universities on other large lakes in Minnesota (especially on Mille Lacs, where current efforts are focused on the effects of spiny waterflea and zebra mussels on the walleye population). Consideration would also be given to reference lakes from other datasets, for example, the MDNR's Shallow Lakes Program<sup>11</sup> and Sustaining Lakes In a Changing Environment program<sup>12</sup>.

### ***Methodology***

Multi-investigator analysis of existing and new data; reporting of results in a peer-reviewed scientific report or paper.

### ***Organizations and Key Linkages***

This would be a multi-investigator, multi-institutional study, with partnerships between National Park Service, MDNR, MNRF, the University of Manitoba, and the USGS.

The US National Park Service, the Minnesota Department of Natural Resources, and Michigan Technological University are collaborating on a study of spiny water flea effects on four units of the US National Park Service, including Voyageurs National Park. This research has shown major effects of the exotic species spiny water flea on native zooplankton of these lakes (Kerfoot *et al.*, 2011), and provides a foundation for a Lake of the Woods study.

### ***Timing***

Immediate start, three-year project.

### ***Project Benefits***

Given the implications for both fishery production and algal blooms, an improved understanding of the effects of spiny waterflea is critical to improved management of these two natural resource concerns. If fish production is being limited due to ecological disruption caused by spiny waterflea (among other causes), then management options could be considered in a timely fashion. For example, reducing catch limits for certain fish on infested lakes could prevent the collapse of populations of prized game fish species and expensive fish-population restoration efforts. The information produced by this project will be useful when assessing potential future disruptions in other lakes in the Basin.

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<sup>11</sup> <http://www.dnr.state.mn.us/wildlife/shallowlakes/index.html>

<sup>12</sup> <http://www.dnr.state.mn.us/fisheries/slice/index.html>

## **Project 21**

### **Develop and Implement Adaptive Control Measures for Hybrid Cattail and Rusty Crayfish.**

#### ***Objective***

Eradicate or control invasive hybrid cattail and rusty crayfish populations from Basin waters, especially in native wild rice habitat.

#### ***Description***

Hybrid (non-native) cattails have invaded some waters in the Basin, and are displacing native wild rice plants, an important plant species to Basin residents, particularly the First Nations and Native American communities.

Rusty crayfish occupy similar habitats, and have disrupted aquatic ecosystems. There is an identified need to:

- corroborate the impact of hybrid cattail and rusty crayfish on aquatic vegetation, including wild rice;
- assess effects of changes in water level, growing season relative to climate change; and,
- develop measures to control the abundance or spread of these species, and restore desired ecologic functions, particularly wild rice production and fisheries.

Although eradication of either species in infested waters is thought to be difficult, it is important to attempt to control their distribution to prevent further spread of these species.

#### ***Methodology***

A multi-phased approach is envisioned. A pilot project is ongoing (supported by the International Watershed Initiative (IWI) funding of the IJC) that is attempting to eradicate hybrid cattails and re-establish wild rice in selected infested waters in First Nations territories in Ontario. However, given that complete eradication is extremely difficult, subsequent phases should focus on assessing the effectiveness of pilot management efforts, and continue adaptive management strategies to control hybrid cattails. Next, methods for controlling rusty crayfish need to be examined and, where feasible, piloted in infested portions of the Basin.

#### ***Organizations and Key Linkages***

This activity closely relates to an IWI-approved study (that is evaluating control strategies for invasive hybrid cattails).

Linkages will be needed with the Seine River First Nation, 1854 Treaty Authority, Treaty 3 and other First Nations/tribes, USFS, Experimental Lakes Area scientists.

### ***Timing***

The need for control and adaptive management will be ongoing.

### ***Project Benefits***

Efforts to control hybrid cattail and rusty crayfish offer two potential benefits.

- Restoration (or partial restoration) of impaired wild rice production areas will benefit individuals that rely on wild-harvested wild rice for subsistence, cultural, and economic benefits. This will particularly benefit the Native American and First Nations communities; and,
- The slowing or prevention of further spreading of these species to currently uninfested waters.

## **3.3.3 Aquatic Invasive Species Vulnerability Assessments**

Assessing vulnerability of waters within the Basin is an important component to developing effective prevention strategies and, in fact, can play a role in the prioritization of introduction prevention efforts; this was done in California for dreissenid introduction (Claudi and Prescott, 2011).

Consideration of how vulnerable boundary lakes are to new infestations of AIS is important. Zebra mussels, for example, have already infested several waters within the Basin, and are in adjacent basins. Also, boundary lakes that are currently infested by AIS need to be considered as potential sources of AIS to upstream lakes and tributary streams. Does water chemistry preclude a large-scale invasion? How is vulnerability impacted by climate change and what are the effects of climate on AIS habitat barriers?

### **Project 22**

#### **Comprehensive Assessment of Potential Invasion Risks to and within the Lake of the Woods Basin**

##### ***Objective***

Assess risks of invasion from nearby basins and spread of AIS from current infestations within the Lake of the Woods Basin.

##### ***Description***

A comprehensive assessment of invasion risks is critically important to developing an effective binational prevention strategy (see Project 18). This assessment would include the following components:

- Assessment of the distribution of AIS within the Lake of the Woods Basin (closely tied to inventory and mapping projects, described above), and neighboring basins. The analysis will cover current state of knowledge of key species of concern and include information on history (timing) of infestation; routes of entry into the Basin; information related to ecological and economic disruptions;

- Assessment of vulnerability of the Lake of the Woods Basin waters to infestation of AIS, which includes the following two sub-components:
  - identification of invasion vectors, or routes of entry, both for current infestations and for potential infestations from neighboring basins; and,
  - assessment of habitat suitability; suitable habitat would allow newly introduced species to become established within Basin waters, and lead to an infestation;
- Assessment of likely ecological and economic disruptions that would result from infestation;
- Assessment of management options in-place, and options needed to prevent further introductions into, or spreading of AIS within the Basin; and,
- Assessment of adequacy of current monitoring programs to document AIS infestations, to inform management decisions and prevention efforts.

The components of this activity are complementary. Zebra mussels, which have invaded many natural waters in the midcontinent, are a useful example. Tracking their migration within the region is important to increase prevention measures once their introduction becomes likely due to close proximity or frequent movement of boats from infested waters to the area of interest. Understanding how zebra mussels are transported (for example, by recreational boats) is important in developing prevention strategies. Assessing suitability of habitat is important to establish whether (or where) zebra mussels could survive. Some waters in the basin may be unsuitable habitat for zebra mussels due to low calcium concentrations, whereas other waters may be suitable. Therefore, a complete assessment of invasion risk for zebra mussels includes understanding its presence regionally, understanding routes of invasion, and assessing whether water bodies are capable of supporting a viable population.

Mapping the information on potential vectors of AIS invasion and vulnerability of water bodies to various invasive species will aid resource managers in more effectively understanding, managing and communicating the threats.

### ***Methodology***

A group of experts will prepare a report or scientific paper describing current state of knowledge of AIS infestations in neighboring basins, invasion vectors, and likely disruptions that would result from key AIS infestations. For example, MDNR researchers have performed a water quality suitability analysis for zebra mussels for many northern Minnesota lakes. The experts group will communicate with the Binational AIS Management Team proposed in Project 18.

### ***Organizations and Key Linkages***

Incorporate into Basin Geospatial mapping project. Partnerships between State and Provincial agencies (Ontario Federation of Anglers and Hunters; Manitoba Conservation and Water Stewardship, MNRF, MDNR), Voyageurs National Park, university experts and IJC.

Linkage to Water-quality risk assessment for AIS (Project 23) and climate risk assessment for AIS (Project 24).



### ***Timing***

Develop framework: 2 years; this activity should be periodically updated.

### ***Project Benefits:***

A state-of-the-science analysis of the risks of infestation of AIS from nearby basins, or further spreading within the Basin, will improve the ability to prevent and/or control the spread of these species into the Lake of the Woods Basin.

## **Project 23**

### **Water Quality Risk Assessment for Zebra Mussels and Quagga Mussels**

#### ***Objective***

Assess which basin waters have suitable water chemistry to allow dreissenid mussels (zebra mussels, quagga mussels) and other high-risk AIS to survive.

#### ***Description***

Basin experts expressed a need for an assessment of water-quality suitability of lakes and rivers within the basin for the establishment of zebra mussels and quagga mussels, two species of invasive dreissenid mussel. Adult zebra mussels do not survive in waters with low calcium (less than 8 milligrams per liter), low pH (less than 7), low alkalinity (less than 30 milligrams per liter as calcium carbonate), and low-conductivity (<30  $\mu\text{S}/\text{cm}$ ) (Mackie and Claudi, 2010). Waters with constituents slightly above these levels (8-15 mg/L calcium; pH 7.0-7.8; alkalinity 30-55 mg/L as calcium carbonate; and conductivity of 30-60  $\mu\text{S}/\text{cm}$ ) may be marginally suitable for survival of adult zebra mussels, but hold little potential for larval development and are, therefore, unlikely to become infested on a large scale. Additional water-chemistry and temperature requirements for these species have also been compiled (Mackie and Claudi, 2010).

An assessment of suitability of water chemistry for zebra mussel and quagga mussel infestations against such criteria (Mackie and Claudi, 2010) would help Basin managers focus control strategies on water bodies at risk for infestation.

Although many lakes in the Basin have calcium, pH, and/or alkalinity levels that currently are too low to support zebra mussels, there is concern that conditions could change and make water chemistry suitable for infestation. For example, calcium chloride in runoff from road salt could elevate calcium levels in some locations. Also, lake-water pH and alkalinity are recovering from historical acid rain pollution. Although the recovery is generally thought to be beneficial, lakes that might reach pH above 7.8 may become susceptible to zebra mussel infestation if other habitat suitability requirements also are met.

For the above reasons, it is critically important to:

- assess existing water-quality data (both chemical and physical measures) in relation to suitability (survivability) for AIS infestation;
- examine trends in water quality data that may indicate lakes and rivers that are not currently suitable but soon be as water quality changes; and,
- examine forcing functions (for example, calcium chloride road salt use) that may be managed to prevent reaching a tipping point in AIS survivability in certain waters in the Basin.

Two large-scale risk assessments have been done, but given the 2013 entry of zebra mussels into the Lake of the Woods Basin, it is critically important to provide an updated, spatially detailed assessment for the Lake of the Woods Basin. A Canada-wide risk assessment for dreissenid mussels (zebra mussels; quagga mussels) was conducted by Therriault *et al.* (2013). This assessment considers probability of invasion to be a function of probability of arrival (that is, accidental introduction of an AIS into a water body) and probability of survival (that is, whether water quality and habitat conditions are suitable for survival of the species). This analysis found that while the probability of arrival was high for both zebra mussel and quagga mussel in Lake of the Woods Basin (eastern Lake Winnipeg drainage), the probability of survival (and hence invasion) was low. However, Therriault *et al.*, (2013) provide the following caution:

*Given the spatial scale of this assessment (i.e., sub-drainages) and limited site-specific data, we did not determine explicitly the probability of secondary spread within each sub-drainage. The rapid expansion of these species across North America and Europe indicates that human-mediated activities are highly likely to re-distribute dreissenids within sub-drainages after their initial arrival. Further, by employing the 75th percentile in available calcium concentrations per sub-drainage this approach suggests within sub-drainages multiple locations of suitable habitats exist for secondary survival.*

An earlier risk assessment for the Province of Ontario indicates that the invasion into the southern portion of Lake of the Woods was “very probable” based on water chemistry, although much of the rest of the Ontario portion of the Basin was of “unlikely” probability for invasion (Neary and Leach, 1992).

This study would build on the national scale and Ontario-wide work of described above, and provide a more spatially detailed analysis for the Lake of the Woods Basin, using data from state, provincial, and federal agencies, as well as from Indian Tribes, First Nations and Métis communities. The goal is to identify specific water bodies within the Basin that are at risk for invasion; and quantify the risk (low, medium, and high) so that prevention efforts can be targeted accordingly.

### **Methodology**

Publish a peer-reviewed report or paper on suitability of water chemistry for certain high-risk AIS such as zebra mussels, using existing water-quality data sets. The paper would include assessment of water bodies where data are not complete or sufficient to assess vulnerability to dreissenid infestation.

### ***Organizations and Key Linkages***

University or agency research project. Participants to include the U.S. National Park Service, USGS, MPCA, Ontario, and Manitoba water-quality monitoring data sets. This activity would inform the Comprehensive Assessment, described above (Project 22).

### ***Timing***

immediate start; 1 year for completion.

### ***Project Benefits***

This project will allow better understanding of vulnerability of waters within the Basin to infestation of zebra and quagga mussels species, and will therefore allow more focused strategies to prevent further spread of these invasive mussels within or into the Basin.

## **Project 24 Climate Risk Assessment for Aquatic Invasive Species**

### ***Objective***

Produce a climate-based risk assessment for key AIS that are likely to invade the Lake of the Woods Basin.

### ***Description***

Develop a prioritized list of AIS that are known to be present within the region (but not yet in the Lake of the Woods Basin), that are known to be of high adverse economic impact, and for which survivability in the Basin is currently limited by temperature or other climate-related parameters, including dissolved oxygen (which is partly controlled in lakes by temperature regimes and eutrophication).

Develop models to predict climate-drive changes in border waters, and assess the effects of these changes on survivability of key AIS species. This activity should consider various modelled climate change scenarios considered likely by the generally accepted climate models. This would form the necessary information on which to base the comprehensive strategy to prevent AIS invasion of these lakes.

A comparable analysis, using climate change scenarios, has been done for lake thermal and dissolved oxygen regimes to assess potential changes in cold-water fish habitat and warm-water fish habitat under warming scenarios (Stefan *et al.*, 2001), and to assess changes in fish habitat in U.S. streams (Mohseni *et al.*, 2003).

### ***Methodology:***

Research study and peer-reviewed paper, by experts on AIS and lake-modelling.

***Organizations and Key Linkages:***

University researchers; agency AIS experts. This activity would inform future Comprehensive Assessments, described above (Project 22).

***Timing***

Start in years 3-5.

***Project Benefits***

Improved understanding of the vulnerability of Basin waters to new introductions of AIS will aid in developing and adapting management plans.

### **3.4 Surface and Groundwater Contamination, including Heavy Metals and other Contaminants**

The impacts of contaminants in the LOW Basin have been greatly reduced through reductions of pollutant inputs into the Rainy River over the years. There are generally less contaminants entering the Basin than there would be in more densely populated and industrialized areas, such as areas in the Great Lakes watershed. There are however, areas listed as Federal contaminated sites, legacy contamination from historic mining activity, atmospheric contamination of lakes and fish by mercury, agricultural inputs in the central portions of the Basin, and the potential for mining activities to increase in the Basin (Clark and Sellers, 2014). Contaminants of emerging concern (CECs, which include personal care products, drugs, antibiotics, and other classes of synthetic organic chemicals) have been detected in both the heavily used (for example, Kabetogama) and remote lakes within Voyageurs National Park. In addition to direct input through inflows, aerial deposition of some of these compounds is suspected. Among other negative effects, these compounds can disrupt reproduction of aquatic organisms.

The level of threat varies among contaminants and among water bodies. A more thorough evaluation of monitoring data than has been completed to date is necessary to assess of threats from contaminants, and to assess robustness of existing monitoring data and programs. The State of the Basin Report points to the lack of a complete inventory of contaminants in the Basin, and indicates that “more detailed review of the potential for contaminants to enter groundwater from diffuse and point sources in the basin is required” (Clark and Sellers, 2014).

### **3.4.1 Inventory of Surface and Groundwater Contamination Issues and Prioritization of Threats to Ecosystems and Human Health**

Although numerous studies and monitoring programs may have collected data on contaminants in the LOW Basin, this information has not been rigorously summarized. While the State of the Basin Report (Clark and Sellers, 2014) provides an overview of contaminant issues within the Basin, it recognizes "...there is not a complete inventory that can be examined." Therefore, Basin experts agreed on the need for a more complete assessment of the various contaminant issues in the Basin, including detailed assessments of contaminant concentrations against established levels of concern; compilation of information on contaminant data collected by various monitoring efforts; and compilation of information on potential new contamination sources from proposed mining, petroleum transport, and other activities.

#### **Project 25 Assessment Report on Contaminants in Water, Aquatic Sediment, and Fish**

##### *Objective*

Summarize state of knowledge on contaminants in the Lake of the Woods Basin.

##### *Description*

This project would provide for a binationally coordinated assessment of contaminants in water and fish. The assessment should:

- review existing data on contaminants in the Basin, summarizing published reports and papers, and publicly accessible agency data bases;
- compare contaminant concentrations to available levels of concern, including water quality standards, human-health-based screening levels or advisory levels, and levels of ecotoxicological concern;
- prioritize the different contaminants based on prevalence, exceedances of established levels of concern, and other indicators of the severity of threat;
- assess adequacy of current monitoring efforts for priority contaminants; and,
- assess trends over past 10 to 30 years in concentrations of priority contaminants in surface water and sediment, for all boundary waters and principal tributaries to the boundary waters. (Such an assessment has been termed a *longitudinal base line study* by some basin experts.)

##### *Methodology*

Prepare a peer-reviewed scientific report that examines literature and public data sets on contaminants in the Basin and evaluates ongoing monitoring programs. The scope is on boundary waters and primary tributaries to the boundary waters, and should focus primarily on contaminant data collected over the past 10 years. Longer time frames may be considered for specific priority contaminants, where sufficient data exist, so that contaminant concentration trends can be placed within the context of pollution control efforts.

The assessment should include: contaminants that are primarily water-borne; contaminants, such as mercury, which are primarily associated with edible fish tissues, and sediment-associated contaminants of concern either because the contaminants may leach into water, or may be toxic to organisms that spend part of their life cycle in benthic environments.

The 2014 State of the Basin Report (Clark and Sellers, 2014) provides a summary of contamination issues, which should be used to guide the more comprehensive report. These issues include: known high-priority contamination sites tracked by U.S. and Canadian governments; mining-related contaminants (including metals, and sulfate which can harm wild rice production); mercury contamination of fish (largely resulting from atmospheric deposition from sources outside the Basin); organochlorines, including pesticides and PCBs. This report should ascribe priority contaminants to source type (point source, diffuse source within Basin, atmospheric source), and make recommendations for more quantitative assessment of sources. Where information on source type is lacking, provisional source-type attribution will help guide future inventories of point, diffuse, and atmospheric inputs.

In the expert workshop, it was noted that historical mining operations within the Basin have contaminated sediment in some locations with heavy metals. Where sediment surveys establish that contaminated sediments are present near such locations, there should be an effort to assess and delineate these areas and possibly have them listed as federal contaminated sites. This activity should avoid duplication of effort for current federally listed sites in Canada. The State of the Basin Report (Table 29, page 139; Clark and Sellers, 2014) lists known soil and sediment contamination sites for areas under federal jurisdiction in Canada that are both High and Medium priority for remediation. The Government of Canada is developing remedial action plans and/or conducting further testing to address these priority contamination sites. This project would be complementary, in that areas outside of federal jurisdiction would be included in the assessment.

Mercury-related fish consumption advisories are prevalent throughout the Basin. Furthermore, there is considerable potential for trends in fish-mercury concentrations. In recent decades, both Canada and the United States have reduced anthropogenic mercury emissions to the atmosphere—the primary route of contamination of remote waters—and further reductions are anticipated as controls on emissions from coal-fired power plants are enacted. However, counter to North American reductions, mercury emissions continue to increase globally due largely to rapidly industrializing countries in Asia.

In addition to changing mercury emissions in North America and globally, mercury bioaccumulation to game fish may be affected by other environmental changes. Reductions in acid rain pollutants (sulfate and hydrogen ion) likely reduce the amount of mercury methylation within aquatic ecosystems, thus potentially less methylmercury is available for bioaccumulation in the food web (Coleman Wasik *et al.*, 2012; Brigham *et al.*, 2014). In addition, changes in food web structure may affect the amount of methylmercury transferred to top predators (Kelly *et al.*, 2006; Lepak *et al.*, 2009). Such changes may result in Basin waters as a result of fishing pressure, AIS, or other disturbances. Lastly, hydrological and climatic fluctuations may also affect the mercury cycle. An example of this is the increased mercury bioaccumulation in perch with increased water-level fluctuation in lakes and reservoirs of northern Minnesota (Sorensen *et al.*, 2005).

Owing to the numerous factors related to the source, geochemistry, and bioaccumulation of mercury in aquatic ecosystems, it is likely that fish mercury levels will change over time. Therefore, this project should specifically include an assessment of ongoing monitoring efforts to ensure that fish consumption advisories are based on adequate, up-to-date monitoring data. Current practice is to issue advisories, but not make the data, including sampling dates, publicly available so as to allow quick assessment of how up-to-date the advisories are. Basin scientists and resource managers would like access to the underlying data sets that are used to inform fish consumption advisories. These data should be compiled and shared in a comparable format between the U.S. and Canada and made publicly available.

### ***Organizations and Key Linkages***

MPCA, MNRF, Ontario Ministry of the Environment and Climate Change, Manitoba Conservation and Water Stewardship, Lake of the Woods Water Sustainability Foundation, U.S. National Park Service. Evaluate the IMA's Tiered Monitoring Plan to assess contaminant monitoring at strategic locations. The Health Professionals Advisory Board prepares a Basin Health Report. Minnesota Department of Natural Resources, Minnesota Department of Health, Voyageurs National Park, the USGS, and University of Wisconsin-LaCrosse, and other researchers have been researching and monitoring mercury contamination of Rainy Lake and Namakan Reservoir and upstream lakes for decades, providing a foundation for understanding factors that control mercury concentrations in lakes in the region.

### ***Timing***

Start in next 1-2 years; 2-year duration from project initiation to published report.

### ***Project Benefits***

This activity fills a key information need within the Basin, as identified by Basin experts at the March 2014 expert workshop. Information will be used to inform Basin managers and the public on the key contaminant issues in the Basin, as well as to adapt and improve monitoring programs so that priority contaminants can be tracked as management alternatives (for example, source-reduction initiatives, and best management practices to reduce pollutant runoff) are implemented. Consumption of fish is nutritionally beneficial, and is valued both for recreational anglers and subsistence anglers. Keeping the advisories up-to-date, in vis-à-vis potential trends in fish mercury levels is critical to allowing the angling public to balance desired levels of fish consumption with the best, most current health advice so that informed anglers can reduce their exposure to methylmercury.

## **Project 26**

### **Spatial Survey of Contaminants of Emerging Concern**

#### ***Objective***

Determine the prevalence and concentrations of contaminants of emerging concern (CECs) on major boundary lakes that span gradients of human influence.

#### ***Description***

While there are not many studies documenting CECs in the Lake of the Woods Basin, a few sites throughout the watershed including sites in Voyageurs National Park have been sampled as part of other ongoing investigations. Presence of some of these chemicals (hormones, pesticides, personal care products, synthetic musks, surfactants, and pharmaceuticals) has been established in both the heavily used (for example, Kabetogama) and remote lakes within Voyageurs National Park (Writer *et al.*, 2010; Barber *et al.*, 2012; Ferrey *et al.*, 2012; U.S. Geological Survey, 2014) and throughout the Lake of the Woods Watershed (Lee *et al.*, 2004; Minnesota Pollution Control Agency, 2010; Lee *et al.*, 2011). In addition to direct inputs through wastewater and industrial discharges and runoff from land surfaces, aerial deposition of some of these compounds is suspected. Among other negative effects, these compounds can disrupt reproduction of aquatic organisms.

This activity would assess the prevalence and concentrations of contaminants of emerging concern (CECs) on major boundary lakes that span gradients of human influence.

#### ***Methodology***

Multi-agency assessment/research project, involving collection of new data to assess contaminant concentrations along gradients of anthropogenic disturbance. Publish peer-reviewed report or paper summarizing findings on occurrence of contaminants of emerging concern, as well as human health and ecotoxicological implications.

#### ***Organizations and Key Linkages***

U.S. National Park Service, USGS, university researchers, Ontario Ministry of the Environment and Climate Change, Environment Canada.

#### ***Timing***

2-year field effort, 1 year for analysis and report publication. Start in year 2 or 3.

#### ***Project Benefits***

This project would fill a key information gap on the concentrations, sources, and levels of concern with respect to contaminants of emerging concern.



### **3.4.2 Assessment of Potential Contamination from Mining, Agriculture and Petroleum Transport**

There is concern within the Lake of the Woods Basin over potential contamination from mining, particularly new mining activities including mining of low-grade metal sulfide ores in northeastern Minnesota, and gold mining in Canada. Mining has caused substantial degradation of water resources in many locations, due to increased transport of toxic metals into natural waters; acidic drainage from waste metal-sulfide material, and the use (and improper recovery and disposal) of toxic chemicals to extract metals. Proponents of mining claim that with proper design, treatment, and post-mining reclamation, the environmental impacts can be minimized while realizing important economic benefits.

There also are concerns over agriculture, and the potential for pesticides to contaminate surface and groundwater resources.

Finally, there is concern that transport of petroleum resources (including diluted bitumen, or dil-bit) via rail (as is currently done through the Basin) or via pipeline has the potential for catastrophic failure that would adversely affect water resources and the ecosystem services they provide including drinking water supply. With petroleum resources in Alberta actively being developed and transported to market, and recent rail and pipeline failures within North America, there is considerable concern among some Basin residents.

Basin experts placed a high priority on improving the knowledge base about potential sources of contamination, assessing vulnerability of water resources, and ensuring protections are in place to minimize risk associated with contamination from these sources.

#### **Project 27**

#### **Assess Vulnerability of Border Waters to Contamination from Mining, Agriculture and Petroleum Transport**

##### *Objective*

Assess vulnerability of border waters to contamination from mining, agriculture and petroleum transport to inform management decisions regarding protective measures.

##### *Description*

Where potential contaminant sources from mining, agriculture and petroleum transport are greatest (as determined from the inventory and mapping project (Project 5), assess vulnerability of the surface and groundwater resources. This vulnerability assessment necessarily includes: the potential for direct contamination of boundary waters; direct contamination of tributaries with subsequent runoff to boundary waters; and indirect contamination of surface waters via transport of contaminants through groundwater.

Given that contaminant transport via groundwater discharge into surface waters is an important component of this study, detailed hydrogeological mapping of groundwater resources and flow paths will be needed. Basin experts indicated that detailed hydrogeological information would be needed only in a

small fraction of the entire Lake of the Woods Basin, specifically only in those areas that will be affected by (or are in close proximity to) mining, agriculture and petroleum transport operations (rail or pipeline). Pending a more detailed synthesis of existing data on agriculture-related chemicals in the Basin (that is, an assessment of whether measured concentrations of any pesticides reach levels of concern in the Basin), it is possible the agricultural chemical component of this study need not proceed. In contrast, both mining activities and petroleum transport have potential to contaminate water catastrophically (for example, catastrophic failure of a mine-waste basin or a train derailment that spills crude oil), this vulnerability assessment cannot rely on historical water-quality monitoring data to assess risk or prioritize contaminants.

This activity should include:

- conduct an inventory of locations and, where known, amounts of potential contaminants (mine waste stored on site or proposed to be stored under permit; amount of petroleum transported);
- prepare an analysis of key transport pathways to boundary waters, and analysis of dilution potential;
- conduct an assessment of safeguards in place and recommended new safeguards; and,
- assess the risks associated with increased climate variability; for example, consider whether there are structures such as holding ponds that are designed for 50-year or 100-year precipitation events and if so, assess likelihood of exceedance of events of that magnitude, given shift toward more extreme precipitation events.

### ***Methodology***

Team of experts prepare peer-reviewed report on vulnerability assessment.

### ***Organizations and Key Linkages***

Diluted bitumen spill report (Government of Canada, 2013);  
Contaminant mapping project (Project 5); and,  
Agencies with permitting authority for mine permits.

### ***Timing***

Years 2-4, after contaminant mapping is complete.

### ***Project Benefits:***

There is considerable concern over the potential for contamination from catastrophic failures of infrastructure, or from mining operations. A comprehensive, science-based assessment of vulnerabilities would help ground truth the concerns, and allow prioritization of issues and areas that may need more active management of risks.

## **Project 28**

### **Annual Mining Effects Science Workshop**

#### *Objective*

Provide a forum for ongoing exchange of scientific information on water quality effects related to mining activities in Lake of the Woods Basin.

#### *Description*

Considerable efforts related to mining are underway in the Basin, including mineral exploration, formal applications for mine permits, agency reviews of mine permit applications, advocacy for greater protective assurances such as cumulative impact assessment and programmatic review, and advocacy against any expansion of mining in the region.

Given the considerable interest in mining in the Basin, as well as opposition to expansion or development of new mines, there is a need to provide for improved communication of science information related to mining. In particular, there is a need for communicating the science on: baseline water quality conditions and availability of data; water quality risks associated with mining options and technologies; treatment, mitigation and reclamation technologies; and analysis of infrastructure design criteria *vis-à-vis* future climate uncertainty.

This activity would:

- establish a diverse stakeholder group, including scientists and engineers from the mining industry, permit-review-authority agencies, non-regulatory earth science agencies, universities, and scientists (or consulting scientists) representing advocacy groups who are opposed to mining; and,
- establish a process for periodic (annual or biennial) exchange of science-based information on science issues related to environmental effects of mining within the Basin. The process should include:
  - a workshop (or forum) where relevant science information on environmental effects of mining is presented. The presentations would be drawn from a diverse cross-section of the stakeholders described above;
  - a focus on presenting and communicating scientific information among diverse stakeholder groups;
  - robust processes to ensure balance and scientific integrity;
  - organized site visits to historical, ongoing, and proposed mining areas to allow all parties to observe conditions “on the ground,” and exchange information. This is important to provide a sense of scale of mining operations, relative to surrounding areas; and,
  - reviews of mining operations in other locales, particularly when similar mining activity is proposed in the Lake of the Woods Basin.

The emphasis should be on science that informs policy-relevant decisions. Policies should be established to ensure that advocacy is kept out of this forum, as alternate venues are available for public input and advocacy on policies and specific permit applications.

The issues differ somewhat between Nations, with proposed gold mining in Canada; and iron mining and proposed nickel and platinum group metal mining of low-grade sulfide ores in Minnesota. A number of mining issues straddle the watershed divide between the International Lake of the Woods Basin, and the Lake Superior Basin (part of the International Great Lakes Basin) to the east. Therefore, as an IJC boundary waters concern, the IJC should consider establishing a process that encompasses both Basins, and ensure that mining issues in both Canada and the United States are addressed.

### ***Methodology***

Create a mining expert group, representative of diverse (but relevant) interests and expertise in the Basin. Charge the group with establishing the detailed processes for enhanced scientific communication outlined above.

### ***Organizations and Key Linkages***

Mining company scientists and engineers; Society for Mining, Metallurgy, and Exploration; MDNR; Mine Water Research Advisory Panel; U.S. Forest Service; U.S. National Park Service; Minnesota Geological Survey; U.S. Geological Survey; Geologic Survey of Canada; Mineralogical Association of Canada; Lake of the Woods Water Sustainability Foundation; Minnesota Pollution Control Agency; Ontario Ministry of Northern Development and Mines, Ontario Ministry of Environment and Climate Change; MNRF; Manitoba Conservation and Water Stewardship; Universities; science advisors or consultants to advocacy groups opposed to mining (including Northeastern Minnesotans for Wilderness; Minnesota Center for Environmental Advocacy).

### ***Timing***

Annual and ongoing.

### ***Project Benefits***

Due to the heightened public and political sensitivity of mining issues, improved dissemination of science-based information related to water quality issues associated with mining would fill information gaps among the public, regulatory agencies, and researchers who approach mining from very different perspectives.

### 3.5 Binational Water Quality Management

Projects in this section are intended to set the stage for effective international water quality management in the Lake of the Woods Basin over both the short- and long-terms. Existing arrangements and partnerships between agencies and organizations in Canada and the United States have done exceptional work towards understanding and addressing the priority issues in this Draft Plan of Study. There is value now in looking at mechanisms to foster these partnerships into the future.

The projects listed here are meant to fill current gaps in how water is managed across the border and assess the feasibility of adopting more formal mechanisms that will accelerate resolution of transboundary water quality issues and ensure ongoing public engagement consistent with the spirit of the IJC's International Watershed Initiative. While these projects will need further discussion and refinement, the end goal is the development and adoption of an international water quality management framework for the Basin.

#### **Project 29**

#### **Determine the Most Appropriate Working Relationship Between the International Multi-Agency Work Group and the International Rainy-Lake of the Woods Watershed Board**

##### *Objective*

Determine the most effective future working relationship between the IMA Work Group and the IRLWWB.

##### *Description*

The complementary but interconnected goals of the IMA and the IRLWWB will be addressed in this project whereby the most effective future working relationship of the two groups will be assessed. As the IMA has developed and implemented a successful workplan and received strengthened leadership and stability through the International Watershed Coordination Program, its role in the Basin has become more and more critical. Although there are pending discussions regarding the geographic scope and the issues within its purview, the time seems right to address the formalization of the relationship.

##### *Methodology*

This project will assess options for the future relationship of these two entities. Options that could be investigated include:

- dissolving the IMA, with its responsibilities transferred to the Board;
- merging the two organizations, with the IMA becoming a subcommittee or technical advisory committee of the Board; and,
- establishing an informal working arrangement, allowing the IMA and Board to work together on mutual projects/activities of interest, but maintaining the independence of both entities.

Other options could be identified and considered, as well, as the project moves forward.

An investigation of this kind is not without precedence; as stated in the IMA Arrangement of 2009, “the continuation of this Arrangement, should a subsequent formal international management framework be established, will be at the discretion of the individual partner agencies listed in the Arrangement”. As stated in the International Rainy-Lake of the Woods Watershed Task Force report of 2011, the goals and objectives of the IMA are impressive and support from governments is needed to allow the IMA to move towards more of a watershed focus “as already outlined in the Arrangement”. Hence, there is a connection between the IMA scope and the scope of the IRLWWB and, through this Plan of Study process, the IMA has been a valuable resource to this Board initiative (the Plan of Study).

A planning process to determine the best option will be undertaken and it will be critical that the resource agency leaders who represent the IMA work closely with a project facilitator to determine the best course of action. Not only should the process identify strengths, weaknesses and needs of both entities, it also should address future study needs, implementation/restoration activities, adaptive management and, importantly, resources and capacity issues.

### ***Project Benefits***

The benefit of addressing this relationship has become more apparent with time as the IMA has developed a workplan that has parallels to the new mandate of the IRLWWB. Efficiencies are needed to ensure resources are used effectively and members of each entity are in favour of the end result.

## **Project 30 Feasibility of Establishing a Binational Agreement on Water Quality and Ecosystem Health of the Lake of the Woods Basin**

### ***Objective***

Mechanism for ongoing commitment to joint water quality management.

### ***Description***

The Basin lacks an international agreement or governance mechanism to support binational ecosystem health and water quality management objectives. A binational agreement will solidify a commitment from Canada, the U.S., Tribes, Métis and First Nations to manage and protect water quality together.

### ***Methodology***

Discussions would be held in the form of a workshop or summit to discuss application of international water quality agreements or other mechanisms to the Lake of the Woods Basin. Assessing the feasibility of an agreement or comparable mechanism would include consideration of governance issues, costs, resource needs, and other issues.

Data sources would include other binational agreements including the Great Lakes Water Quality Agreement and the Memorandum of Understanding on Environmental Cooperation on the Management of Lake Champlain.

### ***Project Benefits***

Watershed protection and restoration requires a commitment over the long term to continue to work together on common goals and objectives (as would be developed in a watershed management framework (see Project 33, below); such an agreement would provide the mechanism by which to promote that ongoing commitment.

## **Project 31 Pilot Project to Apply and Adapt Minnesota's Watershed Assessment Process to Ontario Waters**

### ***Objective***

To provide a more comprehensive assessment of water quality in the Ontario portion of the Lake of the Woods Basin at a spatial and temporal resolution comparable to the Minnesota portion of the Basin.

### ***Description***

This project will be a pilot study that will use the MPCA watershed assessment process as a template to determine a relevant process for more comprehensive assessment of water quality in Ontario. The constitutional amendment in Minnesota that provides funding for comprehensive monitoring and watershed assessment work in that state that is difficult to replicate elsewhere (see section 2.3.1). To fully understand the dynamics of the Basin as a whole, however, there needs to be a balancing of efforts and resources in Canada. The Watershed Restoration and Protection Strategy employed by Minnesota is a process whereby sub-basins are monitored and assessed (against state standards) for impairments; where impairments are found, implementation and restoration are initiated. This project will assess the feasibility of a similar program on the Canadian side, including anticipated costs.

### ***Methodology***

This project would involve collaboration between MPCA and the Ontario Ministry of Environment and Climate Change to scope out a pilot project in one of the sub-basins (preferably one that is binational) to replicate, as appropriate, aspects of the MPCA watershed assessment process to include Ontario waters. Components of the watershed assessment process would be reviewed and adapted as needed to collect data that could be compared to existing standards or targets, where they exist or where they get developed. As other Plan of Study projects are completed and water quality objectives are given consideration, the pilot project would be used as a way to determine adjustments needed to meet those objectives and would be used as a learning tool for balancing out watershed assessment tools binationally. With the MPCA getting ready to move into the phase of implementation and adaptive management for

certain sub-basins, the feasibility of binational adaptive management planning would be incorporated into the pilot project methodology.

As part of the work, current water quality work in Ontario's portion of the basin would be defined. A review of case studies that involve use of adaptive management to address water quality issues would be conducted.

### ***Project Benefits***

This project would contribute to the annual water quality reporting of the Board to the IJC and accelerate basin-wide application of watershed assessment processes in Ontario waters.

## **Project 32 Feasibility of Establishing a Funding Program for Non-governmental Organizations to Promote Stewardship**

### ***Objective***

To investigate the possibility of establishing a Lake of the Woods Basin Guardian Fund, similar to that which has been established for the Great Lakes, to provide funding to groups to carry out stewardship work in the Lake of the Woods Basin.

### ***Description***

The feasibility of establishing such a Guardian Fund is needed given the paucity of funding opportunities available to non-governmental organizations and community groups in the Basin for stewardship work, especially on a binational level. This project would review the components of other funding programs and inventory the needs of the Basin to determine the best type of program and its focus. The Great Lakes Guardian Community Fund, for example, has three goals: protect water quality for human and ecological health; improve wetlands, beaches and coastal areas; and, protect habitats and species. Goals such as these could be considered and adapted to best suit the needs of the Basin.

This Plan of Study recognizes the effectiveness of the efforts of lake associations, non-governmental organizations and citizen groups. However, it is critical that these groups have access to funds that will allow them to focus their efforts on stewardship, implementation of best management practices and activities that, collectively, will enhance watershed protection.

### ***Methodology***

A committee will be established to review current funding programs and identify gaps, assess the feasibility of a binational funding program specific to this Basin, and determine, through public consultation, the desired focus of such a program and provide rationale for such a fund. Current stewardship funding programs such as the Lake Winnipeg Basin Initiative, Trillium Foundation, Bush



Foundation, RBC Bluewater, and the Great Lakes Guardian Community Fund will be reviewed to help identify both gaps and opportunities in the Basin.

### ***Project Benefits***

Establishing a fund specific to this watershed would be a definite asset – the needs of this Basin differ from those of other Basins and the funding needs to reflect that.

## **Project 33 Binational Water Quality Management Framework for Lake of the Woods Basin**

### ***Objective***

Improve management of Basin activities that affect water quality by developing a binational framework with guiding principles and common goals.

### ***Description***

There are numerous U.S. water management plans, at both state and county levels, and more limited plans in Canada. However, there are no comparable basin management plans in Canada and *no management planning framework for the entire Lake of the Woods Basin*. Numerous basin planning efforts have identified the need for a shared management framework. These efforts have included:

- The LOWWSF states as one of its objectives “To develop a water quality sustainability plan that will ensure the long term viability of the Lake of the Woods basin”;
- The IMA, in its purpose statement, indicates that it is to provide the “science and support for the development of a Lake of the Woods Water Sustainability Plan”, with reference to this being the Lake of the Woods and Rainy River watershed as its area of focus;
- The International Rainy-Lake of the Woods Watershed Task Force, in its closing remarks, indicated that recommendations they submitted to the IJC were meant to “facilitate the coordination of existing and developing watershed management plans and the formation of a common vision, with shared goals, objectives and implementation”;
- The IJC’s Directive to the IRLWWB states that, as a mechanism for its review of boundary waters water quality and aquatic ecosystem health, “One example of a major water study or plan is a binational comprehensive basin water management plan for Lake of the Woods and Rainy River watershed, which could have subsequent major updates, anticipated each decade.”

It is recommended that a unifying management framework be developed that provides the common, agreed-upon goals and guiding principles for the Basin, which the watershed plans of local responsible jurisdictions can support and reinforce.

The outcome of all of the projects proposed in the Plan of Study include an enhanced monitoring and communication strategy for the Basin, a nutrient management strategy (including, for example, the call

for water equality objectives in Project 8 for open water concentrations and river load targets), an AIS prevention strategy and an inventory/vulnerability assessment of contaminants in the Basin. Each of these will provide input into an effective water quality management framework for the Basin.

This project will look at existing frameworks and management planning initiatives already at play in the Basin in order to determine the best strategy for an international approach. Consideration will be given to County water plans, the planned update of the Rainy Basin Plan in Minnesota, the Integrated Watershed Management Framework for Ontario (Conservation Ontario, 2010) and the Minnesota Water Sustainability Framework (University of Minnesota Water Resources Center, 2011).

## 4. Looking Ahead

The projects and other recommended activities in this Plan of Study are ultimately intended to protect and restore water quality in the Lake of the Woods Basin. The purview of the IJC, and this Plan of Study, is largely on the international (border) waters within the Basin. However, because pollutants and invasive species do not respect jurisdictional boundaries, some of the projects described here will lead to improved management of waters across the basin (that is, not limited to border waters).

Effective management of water quality issues and their complex interactions with environmental, climatic, and human influences requires high quality information gleaned from monitoring, research, modelling, analysis, and public consultation. Furthermore, it requires an adaptive management framework where problems are addressed with the best information available and evaluated using sound science, and where approaches are adapted as new information is learned. Finally, it requires the will and the commitment of governments to dedicate the necessary short and long term funding and resources to share the responsibilities of managing water quality together across the border and to provide opportunities for public participation.

This Draft Plan of Study calls for several **foundational projects** designed to provide high quality monitoring data across the basin, including parts of the basin where data are limited or lacking. Such data will form the basis for improved understanding of ecosystem health through science initiatives and indigenous knowledge, inputs and/or movement of constituents of concern including nutrients and contaminants, and assessment of trends in water quality in response to changing management practices and other environmental changes. The other foundational projects are designed to make information widely available through a web-accessible geospatial mapping framework. This will enable natural resource managers and the public to better understand conditions within the basin and have input into the knowledge base, and will improve water quality and water resource management.

Numerous large lakes within the Basin are impaired by **harmful algal blooms**, some of which produce algal toxins of concern for wildlife, and the health of humans and domestic animals. This Draft Plan of Study recommends several projects designed to: better understand sources and movement of nutrients, in particular phosphorus, within the Basin; understand how other environmental factors conspire to produce harmful algal blooms; understand conditions that lead to production of algal toxins; and develop better communication tools for alerting the public of risks when blooms occur. This information will be critical to improved management of algal blooms—ultimately to reducing the severity and frequency of harmful algal blooms and the risks associated with algal toxins.

**Aquatic invasive species** have the potential to permanently alter aquatic ecosystems, causing disruptions including nuisance to anglers, loss of high-value native species, reductions in game fish populations and costly degradation of water infrastructure. The projects recommended in this Draft Plan of Study are designed to increase and coordinate ongoing prevention efforts and pursue control efforts in some cases where AIS have infested waters in the Basin. Concerted efforts on prevention and on early control and eradication of AIS, where possible, are essential to protecting the highly valued lakes and rivers in the Basin and the ecosystem services they provide. Studies are also proposed that will provide improved understanding of effects on fisheries, so that populations can be carefully managed.

Although the Basin is much less densely populated and less industrialized than other parts of North America, there are concerns over existing **contaminants** and over potential for new contamination issues to arise through development of new mining and transport of petroleum. This Draft Plan of Study recommends several projects designed to thoroughly assess contaminants within the Basin, including assessment of risks associated with existing contaminants, and vulnerabilities to new contaminants. This information is critical to improved management of contaminants, and improved communication of science-based information related to the potential for resource extraction and transport activities to contaminate lakes and rivers in the Basin.

Finally, the recommended projects and activities in the International Water Quality Management section target the need to investigate mechanisms for cooperation and more formal commitment to joint **watershed management**, as well as enhancing opportunities for public involvement and outreach. The good working relationships and synergies already at work in the Basin need to be supported, enhanced and solidified. Projects that will promote this include consideration of an international agreement, piloting watershed assessment/protection in Ontario waters, developing efficient working relationships among key players, building on existing watershed coordination, and looking at options to provide funding to promote watershed stewardship to community-based groups. In essence, these suggested projects focus on mechanisms to not only support a way for Canada and the United States to manage waters more effectively together, but to uphold the mission of the International Watersheds Initiative of the IJC to support local solutions to local issues.

The projects and activities suggested within this Draft Plan of Study need to fulfill clear objectives and direct the studies and analyses towards clear outcomes. These outcomes will be the basis for future development of international strategies to manage nutrients, prevent/control aquatic invasive species, and inventory possible surface and groundwater contamination. Together, these strategies will enable the development of a water quality management framework for the Lake of the Woods Basin. Working towards such a framework has many steps, starting with this Draft Plan of Study. Considerable work will need to be done to realize this long-term goal for the Basin. The logical progression for this work, linking projects to outcomes, has been set out in a series of logic models for each of the Foundational and Priority Issues (Appendix A).

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## Appendix A

### Logic Models for the International Lake of the Woods Basin Water Quality Plan of Study

\*\*\* Draft Version – July 22, 2014 \*\*\*

For the Plan of Study projects, a series of preliminary logic models were developed to graphically depict linkages between the priority issues and cross-cutting themes as defined in the Directive to the Study Team and overall end-goals expected as a result of support for the POS. Use of logic models assisted with organization of recommended projects and outputs, identification of short-term (direct) outcomes and longer-term outcomes, and visualization of how all the pieces fit together.

This Appendix has five logic models that match the groups of projects described in the draft POS: Foundational Projects and Activities, Nutrient Enrichment and Harmful Algal Blooms (NE-HABs), Aquatic Invasive Species (AIS), Surface and Groundwater Contamination, and International Water Quality Management.

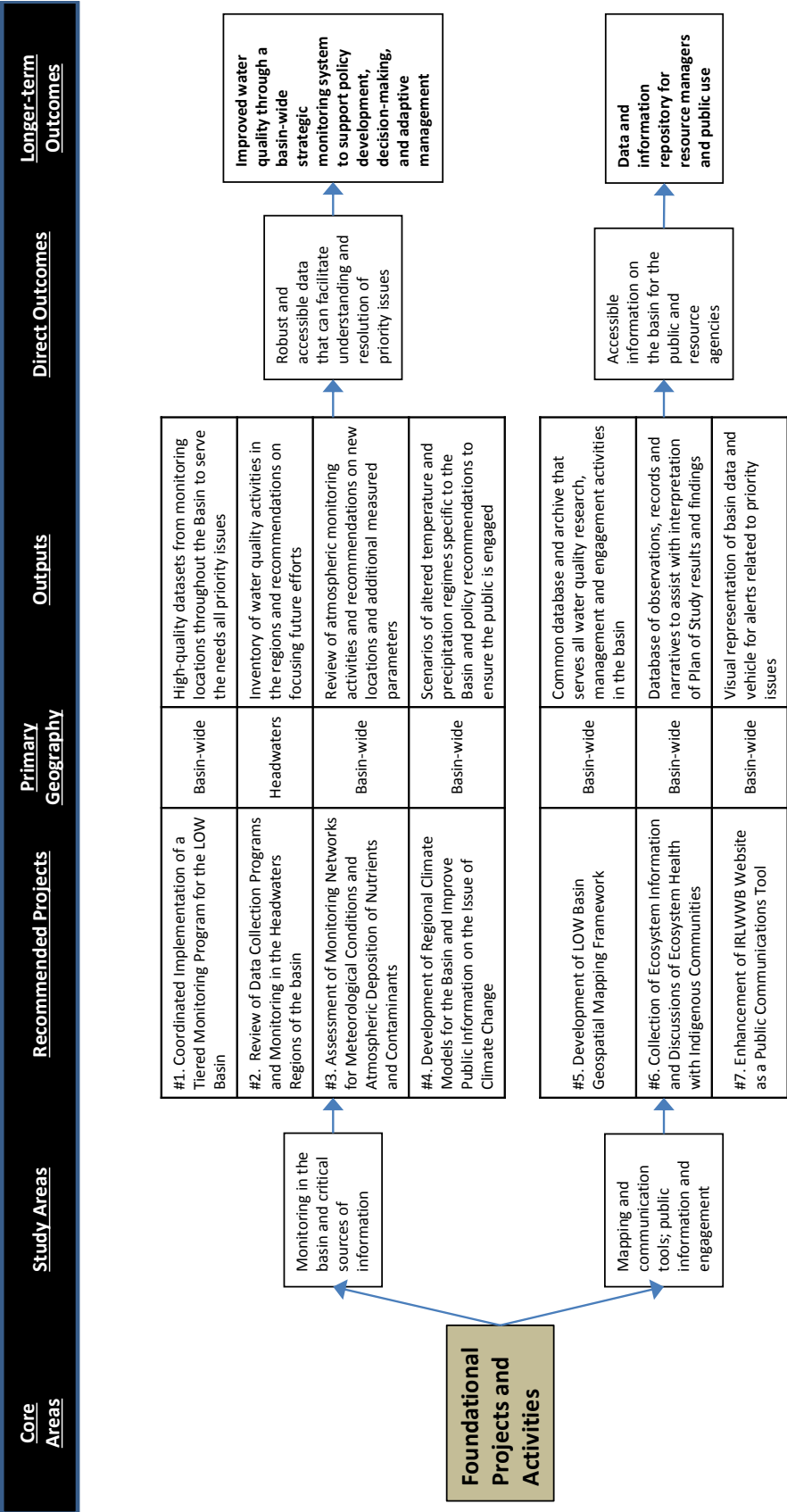
Within each logic model, the same headings are used:

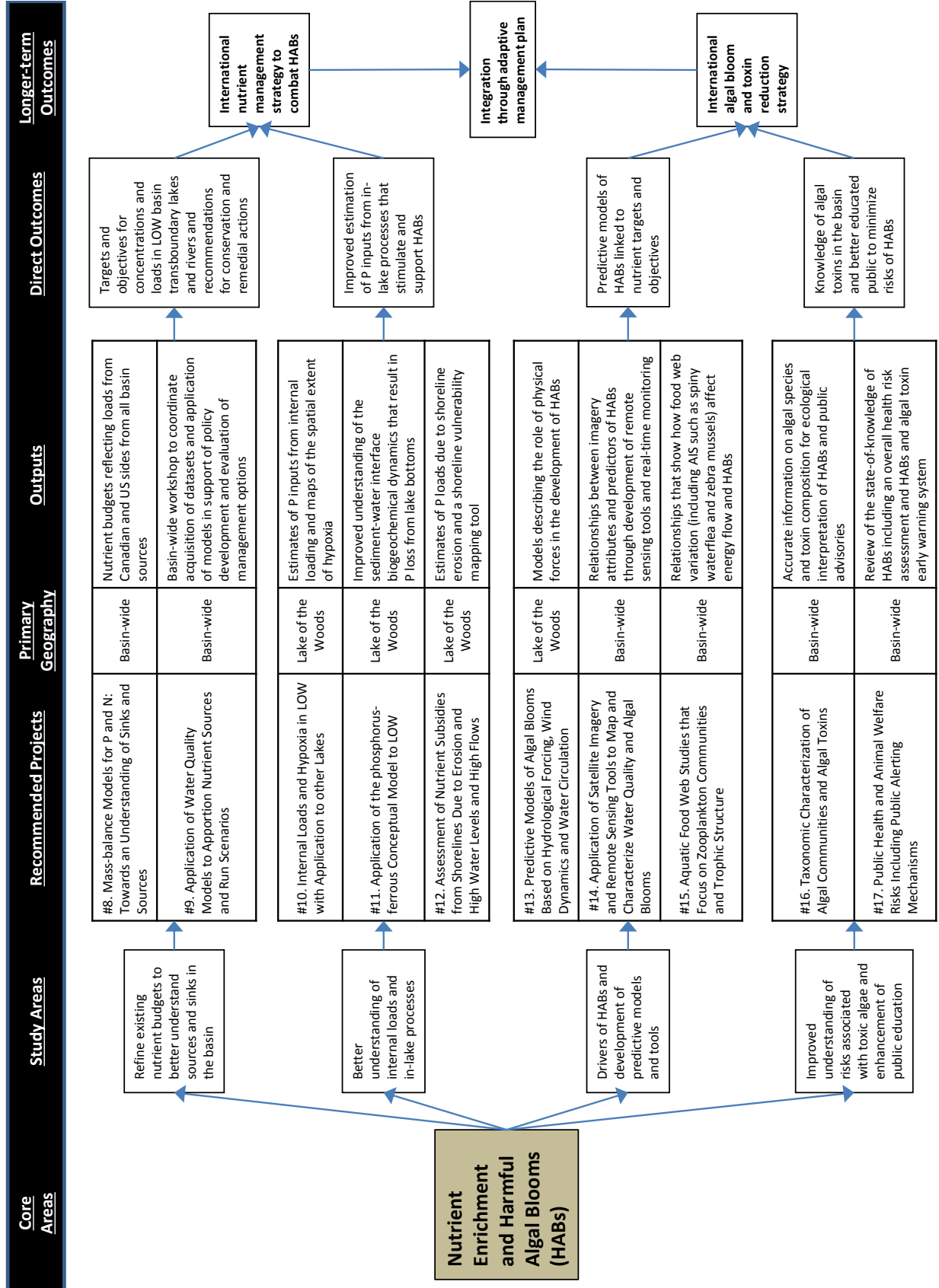
- Study Areas, which break down the high-level aggregation of projects under major headings into small groups of projects that address the same study area
- Recommended Projects and Outputs, which show the titles of each project and their specific outputs
- Primary geography, which indicates the geographic focus of the project (Basin-wide, Lake of the Woods or Headwaters)
- Direct Outcomes, which expresses the benefit of a project or projects in addressing a particular study area, and
- Longer-term Outcomes, which identify big picture goals of the POS.

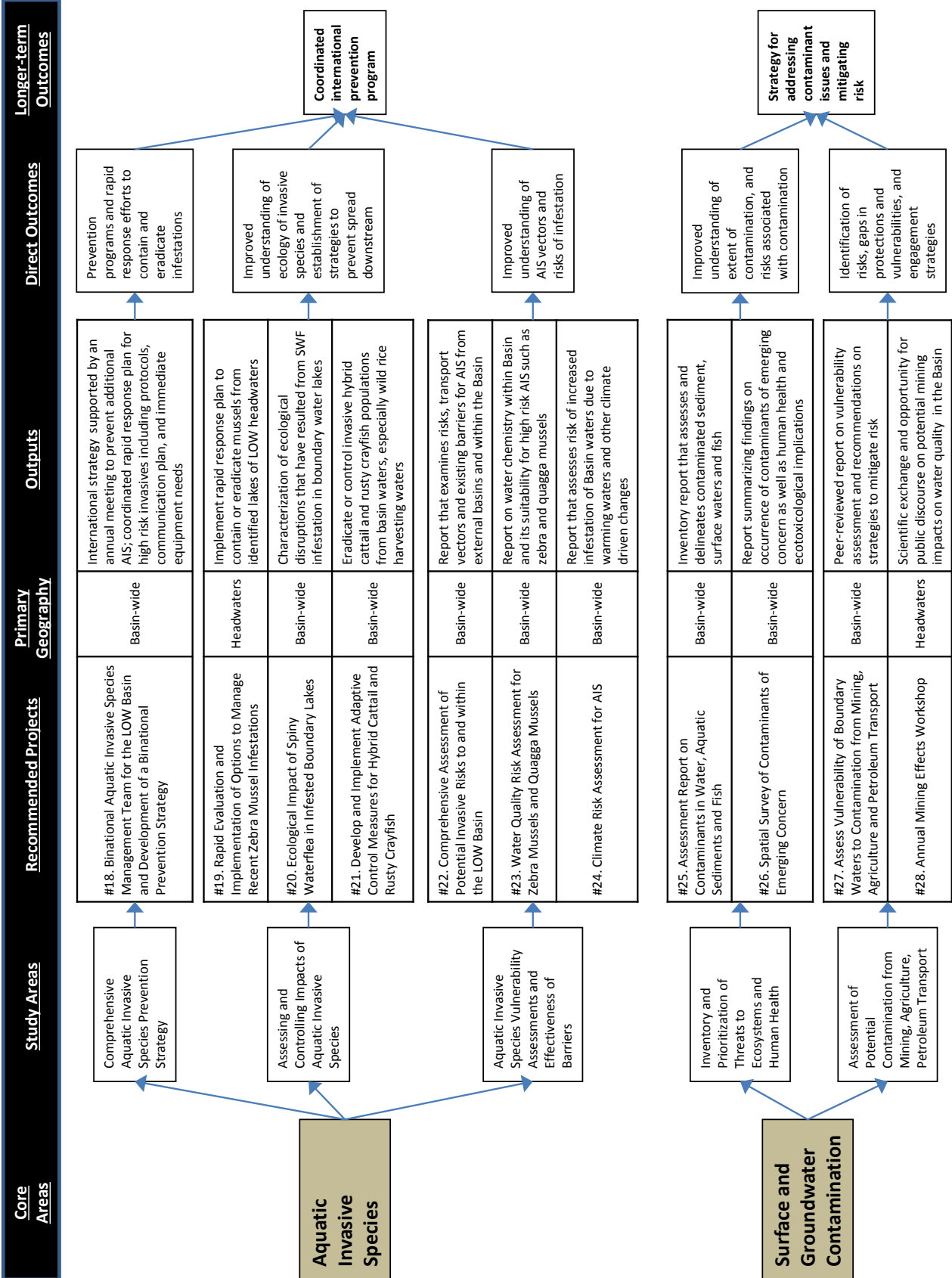
Using these logic models, there are currently 33 recommended projects. The Plan of Study team invites comments on the application of the logic model approach and on the contents of any of the components of the logic models.

Table A1. Lake of the Woods Basin Plan of Study Preliminary Logic Models.

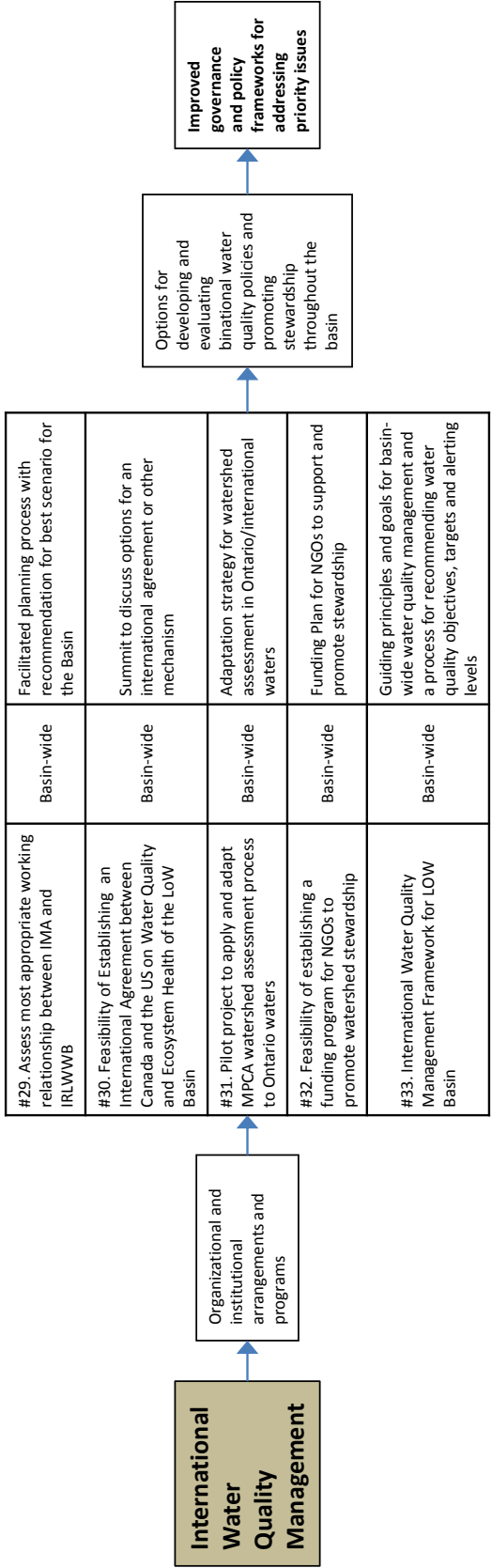
Plan of Study Components	Number of Projects
Foundational Projects and Activities	7
Priority Issue: Nutrient Enrichment and Harmful Algal Blooms	10
Priority Issue: Aquatic Invasive Species	7
Priority Issue: Surface and Groundwater Contamination	4
International Water Quality Management	5
<b>Total Number of Projects</b>	<b>33</b>







**Core Areas**      **Study Areas**      **Recommended Projects**      **Primary Geography**      **Outputs**      **Direct Outcomes**      **Longer-term Outcomes**



**Metric System – United States Customary System Units**

(with abbreviations)

**Length**

1 metre (m) = 3.2808 feet (ft)

1 ft = 0.3048 m

1 kilometre (km) = 0.6214 mile (mi)

1 mi = 1.6093 km

**Area**

1 square kilometre (km<sup>2</sup>) = 0.3861 square mile (mile<sup>2</sup>)

1 mile<sup>2</sup> = 2.59 km<sup>2</sup>

1 hectare (ha) = 2.47 acres

1 acre = 0.405 ha

**Weight**

1 metric tonne (MT) = 1.1 short tons (2,200 pounds)