Evaluation of Institutional Arrangements to Affect Nutrient Management Through Adaptive Management

A report submitted to the
International Joint Commission by the
Great Lakes Science Advisory Board-
Research Coordination Committee
Institutional Arrangements of Nutrient Adaptive
Management Work Group

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Foreword

Binational and domestic efforts to improve water quality in the Lake Erie basin have been organized under the Great Lakes Water Quality Agreement since the early 1970s. Under the 2012 Great Lakes Water Quality Agreement Annex 4 (Nutrients), Canada and the United States focused on nutrient pollution delivered from upstream watersheds that cause ecosystem harm in Lake Erie, evidenced by events such as harmful algal blooms, and developed updated phosphorus targets to curtail ongoing eutrophication impacts. Annex 4 is implemented by the Annex 4 Subcommittee, which organizes pollution reduction activities in the region by coordinating development of Domestic Action Plans through which Canadian and US jurisdictions have sought to reduce phosphorus loads to the lake.

To evaluate alternative phosphorus targets, the Agreement Annex 4 Adaptive Management subcommittee used nine available water quality models, operating on differing spatiotemporal scales, to predict changes in three endpoints of concern (harmful algal blooms, hypoxia and *Cladophora*) under differing phosphorus input scenarios. The updated targets were finalized in 2016. The nutrient reduction targets are mainly achieved by the development and implementation of the states/provinces and federal Domestic Action Plans.

Tracking progress toward meeting the targets and lake responses to changing conditions requires implementation of an adaptive management approach, which is identified in Article 2 of the 2012 Agreement to further advance its goals and objectives. In 2021, the Adaptive Management Task Team formed under the Annex 4 Adaptive Management Subcommittee released its draft Binational Lake Erie Nutrient Adaptive Management Framework to guide jurisdictions on improving ecosystem conditions of Lake Erie by taking an adaptive management approach. The Lake Erie Nutrient Adaptive Management Framework brings an adaptive management process to the 2019 Lake Erie Binational Phosphorus Reduction Strategy, a framework for binational cooperation under Annex 4 toward achievement of the 2016 binational phosphorus reduction targets for Lake Erie.

In order to advance the agenda of the Agreement's Annex 4, the board undertook a project from 2017 to 2019 to synthesize the current state of the science on watershed and Lake Erie nutrient modeling and to provide advice on using modeling in an adaptive management framework. In 2019, the board published its report: "Use of Modeling Approaches to Affect Nutrient Management Through Adaptive Management." This report provides a comprehensive review of the suite of models used by Annex 4 to set the Lake Erie 40 percent phosphorus loading reduction target, and compiles and synthesizes the current state-of-the-science on watershed and lake modeling used to set binational targets for

nutrients and as the basis for establishing Domestic Action Plans. This 2019 report recognized the need for, and recommended an evaluation of, institutional arrangements of adaptive management for nutrients in Lake Erie.

To follow up on its 2019 report recommendation for such an evaluation, the board subsequently developed this "Evaluation of Institutional Arrangements to Effect Nutrient Management Through Adaptive Management" report that focuses on progress to date in implementing the Lake Erie Nutrient Adaptive Management Framework. This report is based on a literature and document review, surveys of a broad spectrum of individuals involved in the Lake Erie Nutrient Adaptive Management Framework process or related work, and interviews of individuals who have been involved in developing and implementing the framework. The work group that guided the report included the Annex 4 Adaptive Management Subcommittee co-chairs and members, key agency members involved in the federal, state and provincial Domestic Action Plans, leading scientists and members of the board's Science Priority Committee and the International Joint Commission's Great Lakes Water Quality Board. The report describes and assesses the progress to date in the implementation of the Annex 4 Subcommittee's Lake Erie Nutrient Adaptive Management Framework and offers several recommendations to advance the adaptive management approach.

The report finds that:

- Considerable progress has been made toward the institutional recommendations contained in the board's 2019 report, but further effort is needed to coordinate, communicate, integrate and engage various stakeholder groups. Unmet needs include addressing data and research gaps, coordinating and integrating modeling and monitoring activities, communicating the work of Annex 4 under the Lake Erie Nutrient Adaptive Management Framework to a broader set of stakeholders, and identifying and securing dedicated and sustainable funding for framework-related activities.

- The Lake Erie Nutrient Adaptive Management Framework document provides an umbrella adaptive management framework that guides binational and domestic processes and identifies their essential components for each. The Annex 4 Subcommittee and Annex 4 Adaptive Management Task Team do not have the authority to require the jurisdictions to implement actions. For this reason, the jurisdictions have developed Domestic Action Plans that reflect authorities they presently have. While the watersheds draining into Lake Erie comprise a single ecological system, jurisdictional authority is varied. For this reason, the Annex 4 Subcommittee divides the work on a watershed basis (e.g., domestic action plans for each jurisdiction) and a lake basis (e.g., the binational Lake Erie Nutrient Adaptive

Management Framework). Stronger coordination between the lake-based binational Lake Erie Nutrient Adaptive Management Framework and the watershed-based jurisdiction Domestic Action Plans may improve the effectiveness of the implementation.

- The Lake Erie Nutrient Adaptive Management Framework leverages ongoing Lake Erie research, monitoring and modeling activity that supports binational and domestic efforts at nutrient reduction. Toward that end, an institutional structure has been established to coordinate these various activities to address some of Lake Erie's most challenging environmental problems, such as harmful algal bloomss and hypoxia.

- The adaptive management process reflected in the Lake Erie Nutrient Adaptive Management Framework is at a start-up phase. The process is not yet fully operational although the identification of adaptive management elements and necessary data and models are underway. The communication, coordination and collaboration of activities that implement nutrient reduction adaptive management is reliant upon available funds from the various Canadian and US jurisdictions.

- A multi-layered institutional arrangement exists around Lake Erie nutrient management but is not fully aligned. The adaptive management process envisioned by the Lake Erie Nutrient Adaptive Management Framework is unfolding but, at present, the process remains in a relatively nascent phase and (in certain instances) is *ad hoc*. Some elements of the process have been established (e.g., reporting timelines), but mechanisms for coordination and communication between the binational and domestic Lake Erie Nutrient Adaptive Management Framework processes lack detail. In addition, Lake Erie institutional arrangements are subject to the goals of individual jurisdictions which, in some instances, make them vulnerable to various institutional, financial, climatic, political and economic factors. Opportunities for sustainable funding may also be impacted by this largely unaligned arrangement of institutions.

- Stakeholders are generally supportive of Annex 4 goals, but collaborative efforts (and funding levels) tend to vary among jurisdictions. Institutional collaboration to meet Annex 4 goals provides certain venues for knowledge sharing and learning, but bottom-up research efforts that can inform the adaptive management process need to be aligned for greater effectiveness in meeting those goals.

The report recommends to:

- **Improve communication to link domestic and binational adaptive management processes.** Address the limited understanding of the Lake Erie Nutrient Adaptive

Management Framework process by improving communication and coordination among all involved in or affected by management of nutrients in Lake Erie. Address gaps at the interface of binational and domestic adaptive management processes under the framework by expanding membership on the Annex 4 Subcommittee to a broader range of stakeholders and/or formalizing a communications work group under the Annex 4 Subcommittee.

- **Institutionalize the Lake Erie Nutrient Adaptive Management Framework through dedicated funding and staffing.** A dedicated funding source for framework implementation is needed. Reliance to date has been on funding sources from domestic jurisdictions that are often short-term and sporadic, particularly for critical water quality monitoring activities. Dedicated funding would support work plan and schedule development, thereby moving the framework from an *ad hoc* to a more formal and predictable process. Prospective funding sources include the US Great Lakes Restoration Initiative, the Canadian Great Lakes Protection Initiative, and state/provincial appropriations (among others). Review of the five-year Domestic Action Plan assessments will identify the number and types of staff needed for more effective implementation of the Lake Erie Nutrient Adaptive Management Framework.

- **Identify and charge an existing group (or establish a new group) under Annex 4 to focus specifically on integrating and increasing linkages and collaboration among existing activities in the Lake Erie basin.** A group specific to Lake Erie under Annex 4 would coalesce the many disparate groups working on water quality in the Lake Erie basin. Annex 4 implementation would benefit from improved alignment of institutional arrangements, research, monitoring, modeling, and knowledge exchange.

- **Address key research and data gaps.** Key data and research gaps must be addressed to achieve Annex 4 goals and advance adaptive management in the Lake Erie basin. Data and research gaps include data and research to support *Cladophora* target development, and the role of nitrogen and legacy phosphorus in algal blooms.

- **Provide additional guidance to both Canadian and US jurisdictions to improve phosphorus load reduction outcomes**. Strengthen Annex 4 implementation by standardizing approaches to modeling and monitoring water quality across domestic jurisdictions, and actively promoting knowledge sharing for nutrient pollution reduction strategies. Strengthened implementation of Annex 4 will also encourage domestic jurisdictions to adopt best practices for their Domestic Action Plans and evaluate progress at sub-watershed scales to achieve Annex 4 goals.

- **Explore lessons learned and best practices from other examples of adaptive management.** The Annex 4 Subcommittee and Adaptive Management Task Team should implement a webinar series to highlight best practices and lessons learned from other adaptive management initiatives around the world. Efforts to showcase might include (among others) adaptive management efforts in the Chesapeake Bay, the Everglades and the Mississippi River/Gulf of Mexico.

The previously noted findings, as well as these recommendations, were informed by survey responses, document review, consultant input and interviews, all of which were directed at means to address gaps in the Lake Erie Nutrient Adaptive Management Framework process and help achieve nutrient reduction goals and lake ecosystem objectives in Lake Erie. These recommendations for action are directed at the International Joint Commission with the understanding that they will be of interest to the parties to the Agreement as well as to Canadian and US jurisdictions in the Lake Erie watershed.

This report recognizes and praises the significant efforts and progress that have been made toward Great Lakes nutrient reduction goals using an adaptive management approach. The report also recognizes the complex environment of numerous jurisdictions, states and provinces, and other governments required to be involved in the nutrient adaptive management process, which is challenging to communicate and collaborate within and among these entities, as well as communicate to the public. Additionally, climate change and increased intensity of human activities further complicate the efforts in achieving Lake Erie's nutrient reduction goals.

Adaptive management has been proven as an effective tool to provide the framework for addressing problems in complex and changing systems. The Annex 4 Subcommittee Adaptive Management Task Team's Lake Erie Nutrient Adaptive Management Framework provides a high-level overall conceptual framework, organizational structure and key questions and current hypotheses to affect adaptive management. The Lake Erie Nutrient Adaptive Management Framework is expected to evolve and become more detailed as stakeholders' input is received, roles and responsibilities are finalized and sources of funding are secured. The board's report identifies the information needed for updating the framework and recommends actions that Annex 4 may take to improve communication within the adaptive management entities and with the public. Improved alignment of institutional arrangements, filling research and data gap, monitoring, and knowledge exchange would benefit from designated leadership and dedicated funding and staffing.

The elements of the findings and recommendations of this report should be viewed as a portfolio and implemented together as a whole. Fragmented implementation of the recommendations will not fully achieve the nutrient adaptive management goals identified by the Lake Erie Nutrient Adaptive Management Framework. This is because of the

intertwined and inseparable need for clear communication and collaboration among domestic and binational adaptive management processes, designated leadership to communicate and provide guidance to participants, and the need to fill research and data gaps.

This report acknowledges that the findings and recommendations of this project represent the importance of using science in decision-making, which is strongly tied to several other reports from the International Joint Commission's Great Lakes advisory boards. These include the Water Quality Board's "Oversight of Animal Feeding Operations for Manure Management in the Great Lakes Basin" report, the Science Advisory Board and Water Quality Board's latest report on "Nutrients in Lake Erie and Lake Ontario: Synthesis of International Joint Commission Recommendations and Assessment of Domestic Action Plans," and the Science Advisory Board's forthcoming "Developments and Operationalizing an Early Warning System for Great Lakes" report. These reports are highly linked to each other and collaboratively demonstrate the critical roles of science in management and policy decision-making.

There is an urgency to have an enhanced and robust adaptive management framework in place for Lake Erie. Although significant progress has been made in the development of the draft Lake Erie Nutrient Adaptive Management Framework and the development of Domestic Action Plans, their effective implementation requires additional elements be implemented. These elements include:

1. Institutionalize the Lake Erie Nutrient Adaptive Management Framework through dedicated funding and staffing.
2. Identify and charge a group under Annex 4 to focus specifically on integrating and increasing linkages and collaboration among existing activities in the Lake Erie basin.
3. Fill key research and data gaps.
4. Provide additional guidance to both Canadian and US jurisdictions to improve phosphorus load reduction outcomes.

Additionally, because adaptive management is an iterative assessment and adjustment process, applying lessons learned and best practices from other examples of adaptive management would improve the effectiveness of its implementation in the Great Lakes basin. The implementation of the Lake Erie Nutrient Adaptive Management Framework will not progress as expected without also incorporating such requirements using clear and effective communication within entities and with the public.

The 2019 Lake Erie Binational Phosphorus Reduction Strategy outlines the nutrient management actions to reduce excessive phosphorus loading and address the eutrophication of Lake Erie. The Strategy is a blueprint for action to inform the respective

agencies of management actions needed to mitigate nutrient threats to Lake Erie. Since climate, physicochemical and biological properties of the lake, and human activities in water and on land continue to change with uncertainties, adaptive management plays a key role in the implementation of the blueprint for action. The 2012 Agreement defines adaptive management as: "implementing a systematic process by which the Parties assess effectiveness of actions and adjust future actions to achieve the objectives of this Agreement, as outcomes and ecosystem processes become better understood."

It is the hope that our report's findings and recommendations enhance the effectiveness of the Lake Erie Nutrient Adaptive Management Framework and improve the success of nutrient reduction through continuously updated science, policy, communication and stakeholders' joining forces to change behaviors around the use, application, transport and discharge of nutrients.

We would like to acknowledge the leadership and efforts of the International Joint Commission Great Lakes Science Advisory Board-Research Coordination Committee project work group members and the input from Science Advisory Board and Water Quality Board members along, with valuable staff support and insight.

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List of Acronyms

AM	adaptive management
BMPs	best management practices
DAPs	domestic action plans
ECCC	Environment and Climate Change Canada
GLNAM	Great Lakes Nutrient Adaptive Management
GLRI	US Great Lakes Restoration Initiative
HABs	harmful algal blooms
LEOs	Lake Ecosystem Objectives
LE-AMF	Lake Erie Nutrient Adaptive Management Framework
NOAA	National Oceanic and Atmospheric Administration
USEPA	US Environmental Protection Agency

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1.0 Introduction

1.1 The Great Lakes Water Quality Agreement

Algae occur naturally in freshwater systems. They are essential to the aquatic food web and healthy ecosystems. However, nutrient over-enrichment can lead to problems associated with excessive algae growth, oxygen depletion, harmful algal blooms (HABs) and taste and odor problems.

During the 1960s, Lake Erie experienced an increase in algal growth—specifically toxins producing cyanobacteria—resulting in impairment of the use and enjoyment of this tremendous natural resource. To protect clean water in the Great Lakes, Canada and the United States signed the Great Lakes Water Quality Agreement in 1972, a nonregulatory framework document within which the two countries commit to working together toward the restoration and protection of the Great Lakes. Environment and Climate Change Canada (ECCC) and the US Environmental Protection Agency (USEPA) lead implementation of the Agreement for Canada and the United States (the Parties), respectively.

Early efforts to reduce nutrient pollution focused on point sources and resulted in significant success in controlling nuisance algae. However, during the 1990s, HABs returned to Lake Erie with significant impacts. The Parties' State of the Great Lakes 2022 report

Lake Ecosystem Objectives in the 2012 Great Lakes Water Quality Agreement Annex 4 (Nutrients)

Through Annex 4 of the 2012 Agreement, Canada and the United States committed to following six Lake Ecosystem Objectives (LEOs) for the Great Lakes:

- Minimize the extent of hypoxic zones in the waters of the Great Lakes associated with excessive phosphorus loading, with particular emphasis on Lake Erie;
- Maintain the levels of algal biomass below the level constituting a nuisance condition;
- Maintain algal species consistent with healthy aquatic ecosystems in the nearshore waters of the Great Lakes;
- Maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the waters of the Great Lakes;
- Maintain an oligotrophic state, relative algal biomass, and algal species consistent with healthy aquatic ecosystems, in the open waters of Lakes Superior, Michigan, Huron and Ontario; and
- Maintain mesotrophic conditions in the open waters of the western and central basins of Lake Erie, and oligotrophic conditions in the eastern basin of Lake Erie.

graded Lake Erie's status as "poor and unchanging" and the status of the nutrient objective as "poor," the lowest status across all nine general objectives (ECCC and USEPA, 2022a). The Agreement was amended in 1983, 1987 and 2012. It is structured around 13 articles that set General Objectives and responsibilities of each party (e.g., Canada and the United States) along with ten annexes that address specific Great Lakes water quality issues.

The sixth of the General Objectives of the Agreement states that the waters of the Great Lakes should:

> (vi) be free from nutrients that directly or indirectly enter the water as a result of human activity, in amounts that promote growth of algae and cyanobacteria that interfere with aquatic ecosystem health, or human use of the ecosystem (Canada and the United States, 2012).

Correspondingly, Annex 4 of the Agreement addresses nutrient pollution issues in the Great Lakes specifically, organized around six Lake Ecosystem Objectives (LEOs, see box on previous page) and containing a number of commitments by the Canada and the United States (see box to the right).

To implement actions that achieve Annex 4 LEOs, the Agreement charges the Annex 4 Subcommittee, composed of federal, state, provincial and municipal agencies along with other partners, with reviewing interim phosphorus targets for Lake Erie, last revised in 1983.

In 2013, the Agreement Annex 4 Subcommittee established an Objectives and Targets Task Team to recommend revisions to phosphorus reduction targets for achieving nutrient-related LEOs. As part of their work, the Task Team recommended eutrophication

Commitments under Annex 4 of the 2012 Agreement

Under Annex 4 of the Agreement, Canada and the United States committed to the following activities:

- By 2016, develop binational substance objectives for phosphorus concentrations, loading targets, and loading allocations for Lake Erie;
- By 2018, develop binational phosphorus reduction strategies and domestic action plans to meet the objectives for phosphorus concentrations and loading targets in Lake Erie;
- Assess, develop and implement programs to reduce phosphorus loadings from urban, rural, industrial and agricultural sources. This will include proven best management practices, along with new approaches and technologies;
- Identify priority watersheds that contribute significantly to local algae development, and develop and implement management plans to achieve phosphorus load reduction targets and controls; and
- Undertake and share research, monitoring and modeling necessary to establish, report on and assess the management of phosphorus and other nutrients and improve the understanding of relevant issues associated with nutrients and excessive algal blooms.

response indicators to evaluate the effects of phosphorus loading reductions and track progress toward achieving LEOs. **Table 1** summarizes the recommended eutrophication response indicators.

Table 1. Summary of recommended eutrophication response indicators for Lake Erie (Annex 4 Objectives and Targets Task Team 2015).

Indicator	Metric	Quantitative Benchmark
Overall trophic status	To be determined	To be determined
Cyanobacteria blooms in the western basin	Maximum 30-day western basin cyanobacteria biomass in metric tons	Reduce algae to non-severe levels (less than 9.6 metric tons), such as those experienced in 2012, 90 percent of the time
Hypoxia in hypolimnion of the central basin	Average hypolimnion dissolved oxygen concentration during August and September	Maintain dissolved oxygen levels at or above 2 mg/L in the hypolimnion during the August to September period
Cladophora in the nearshore areas of the eastern basin	To be determined	To be determined

The Agreement Annex 4 Objectives and Targets Task Team recommended revisions to the phosphorus loading targets for Lake Erie using a suite of models that evaluated phosphorus load and eutrophication response relationships (Annex 4 Objectives and Targets Task Team 2015). In February 2016, Canada and the United States adopted the revised phosphorus reduction targets summarized in **Table 2**.

Table 2. Binational phosphorus load reduction targets for Lake Erie (ECCC and USEPA, 2016a; Great Lakes Water Quality Agreement Nutrients Annex Subcommittee 2019).

Lake Ecosystem Objective	Phosphorous Load Reduction Target
Minimize the extent of hypoxic zones in the waters of the central basin of Lake Erie.	40 percent reduction from 2008 levels in total phosphorus entering the western and central basins of Lake Erie from Canada and the United States to achieve an annual load of 6,000 metric tons to the central basin, which equates to reductions from Canada and the United States of 212 metric tons and 3,316 metric tons, respectively.
Maintain algal species consistent with healthy aquatic ecosystems in the nearshore waters of the central and western basins of Lake Erie.	40 percent reduction from 2008 levels in spring (March to July) total phosphorus and dissolved reactive phosphorus loads from the following watersheds where algae is a localized problem: in Canada the Thames River and Leamington Tributaries; and in the United States the Maumee River, River Raisin, Portage River, Toussaint Creek, Sandusky River and Huron River.
Maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health in the waters of the western basin of Lake Erie.	40percent reduction from 2008 levels in spring (March to July) total phosphorus and dissolved reactive phosphorus loads from the Maumee River in the United States.

In 2015, the Objectives and Targets Task Team concluded that there was insufficient scientific understanding to quantify the relationship between phosphorus loads and *Cladophora* levels in the nearshore areas of the eastern basin (Annex 4 Objectives and Targets Task Team 2015). The Annex 4 Subcommittee recommended that a target for the eastern basin of Lake Erie be established after additional research is completed (ECCC and USEPA, 2016b).

1.2 Adaptive management under the Agreement

Adaptive management (AM) is well suited to address uncertainties associated with ecosystem management; it is designed to help managers learn about ecosystem response by monitoring the results of a suite of management initiatives (Gregory et al. 2006; Gunderson and Holling, 2002). As presented in this report, AM draws heavily from Williams 2011, in which a set-up phase is followed by an iterative phase, each with specific components and criteria that can support successful AM practices (**Figure 1**).

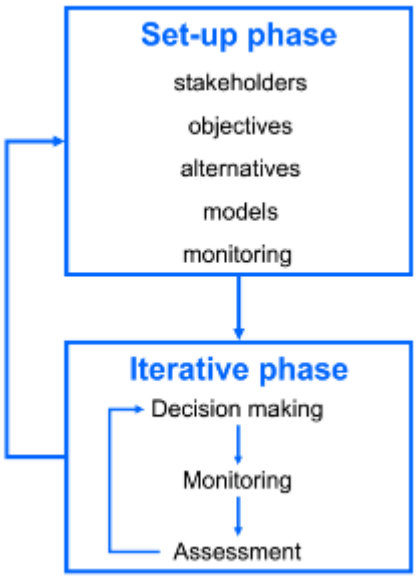


Figure 1. Two-phase learning in adaptive management, reproduced from Williams 2011.

In the set-up phase, key components underlying the AM process are developed (e.g., stakeholder engagement, definition of objectives, delineation of management actions, modeling and monitoring systems). A variety of important factors need to be considered as these aspects are developed. Involving stakeholders is important in assessing the resource problem and reaching agreement on scope, clear and measurable objectives, and management actions. Management actions should be both feasible (given social, economic and environmental constraints) and effective in producing measurable changes. In addition, modeling should be organized with a clear sense of inputs required and outputs generated; and management actions should be linked with system responses and resource status to allow for cost comparisons, forecasting and hypothesis testing. Monitoring is critical to effective AM, as it is essential in evaluating progress, testing hypotheses, decreasing uncertainty associated with the system and key environmental variables, and in refining the models used in the AM effort.

Modeling and monitoring processes developed in the set-up phase are leveraged for iterative decision-making guided by management objectives. For decision-making, it is important to understand the decision points in the system where changes may be made based on new information from modeling and monitoring of implemented management actions. The latter is a long-term activity that creates opportunities for changing and prioritizing management actions.

The Agreement includes AM as a guiding principle for its implementation; under "Principles and Approaches," the Agreement states that the Parties will be guided by multiple principles and approaches including 4(b) adaptive management: "implementing a systematic process by which the Parties assess effectiveness of actions and adjust future actions to achieve the objectives of this Agreement, as outcomes and ecosystem processes become better understood" (Canada and the United States, 2012).

The Annex 4 Objectives and Targets Task Team recognized several sources of uncertainty intrinsic in the set-up phase, the approach used to set targets (including the lack of data regarding

bioavailable phosphorus loads and the role of nitrogen loads, *Dreissenids* and other invasive species) and the hydrometeorology of nutrient load-ecosystem response relationships. Accordingly, the Task Team endorsed adoption of an AM process to monitor ecosystem response to load reductions and revisit nutrient management recommendations as more is learned about the processes underlying the response (Annex 4 Objectives and Targets Task Team 2015). The Objectives and Targets Task Team transitioned into the Adaptive Management Task Team under Annex 4 to devise the AM approach for meeting the revised Agreement targets.

1.2.1 The Lake Erie Nutrient Adaptive Management Framework (LE-AMF)

The Annex 4 Subcommittee's AM Task Team completed a Draft Binational Lake Erie Nutrient Adaptive Management Framework (LE-AMF) in 2021 (GDIT/LimnoTech 2021, unpublished). The LE-AMF brings an AM process to the 2019 Lake Erie Binational Phosphorus Reduction Strategy, a framework for binational cooperation under Annex 4 toward achievement of the 2016 binational phosphorus reduction targets for Lake Erie (Great Lakes Water Quality Agreement Nutrients Annex Subcommittee 2019).

The 2019 Lake Erie Binational Phosphorus Reduction Strategy has four components:

1. An updated assessment of environmental conditions to guide lakewide nutrient management in Lake Erie.

2. A summary of the process used to develop the 2016 targets and allocate load reductions between Canada and the United States.

3. Binational priorities for implementation of measures to manage phosphorus loading, including the identification of watersheds that are a priority for nutrient control and binational priorities for research and monitoring.

4. A description of how progress will be tracked using an AM approach.

The LE-AMF provides coordinated guidance on the AM approach and implementation of activities to meet revised Agreement targets. The LE-AMF calls for coordinated monitoring plans, undertaking modeling and research to support decision making, and organizing their execution and analysis. The goal is to monitor ecosystem response to load reductions and revisit nutrient management recommendations as more is learned about the processes underlying the response (Annex 4 Objectives and Targets Task Team 2015).

The LE-AMF includes both technical and process elements. Technical elements include lake monitoring for HABs, hypoxia and *Cladophora*; data management and coordination across entities; data analysis and synthesis; modeling of nutrient-response relationships in Lake Erie; and decision support for changes in the nutrient reduction goals and/or to the binational AM framework. For monitoring, the AM Task Team is charged with developing coordinated, binational monitoring programs. Process elements detail how the technical elements will be implemented. In the LE-AMF, process elements include four technical working groups for HABs, hypoxia, *Cladophora*, and data synthesis and modeling. Together, these groups review

lake monitoring and modeling data and information to track progress and inform future priority-setting practices.

The LE-AMF explicitly incorporates hypothesis development and research, predictive modeling, and monitoring to prioritize and systematically reduce uncertainties, improve information available to decision makers, and support more effective management actions over time (GDIT/LimnoTech 2021). In addition to the requisite elements of data collection and review, the AM approach is most effective when sufficient leadership, stakeholder and institutional support, and institutional capacity are present (Gregory et al. 2006). These elements encompass the institutional arrangements necessary to successfully affect AM. By evaluating the implementation of institutional arrangements, an understanding can be gained as to whether the technical aspects of AM are sufficiently supported to continue in perpetuity despite various uncertainties.

The LE-AMF is buoyed by additional agreements and institutional arrangements for nutrient management and water quality that have already prompted the Parties to undertake actions to reduce nutrient pollution and develop binational relationships (see box below).

Existing Water Quality Agreements for Lake Erie

2015 Great Lakes Protection Act
Ontario adopted the target of 40 percent phosphorus load reduction for the western and central basin of Lake Erie. The Canada-Ontario Lake Erie Action Plan (LEAP) serves as the plan for meeting this target.

2015 Western Basin of Lake Erie Collaborative Agreement
Between the Premier of Ontario and Governors of Michigan and Ohio.

2015 Great Lakes Commission Joint Action Plan for Lake Erie
Among US states.

2014 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health
Federal-provincial agreement in Canada.

The AM cycle for the LE-AMF is presented in **Figure 2**. This framework reflects the key components required for effective AM: setting goals, planning, implementing management actions and AM processes, monitoring progress, synthesizing results, evaluating progress and adapting decisions.

1. Set Goals:
   Frame the problem and identify goals in terms of ecosystem outcomes that reflect broader societal values (e.g., LEOs, eutrophication response indicators, phosphorus reduction targets).

2. Plan:
   Develop plans for monitoring, and other, intentional processes that support AM (e.g., modeling, research synthesis, hypothesis development, prioritization of uncertainties, stakeholder engagement, communication).

3. Implement:
   Implement AM activities and processes.

4. Monitor:
   Monitor AM implementation progress and collect data to assess environmental conditions and ecosystem responses, help isolate impacts of management actions from natural variability in the system and improve understanding of relevant social behaviors and natural processes.

5. Synthesize:
   Synthesize monitoring data, compare monitoring data to predicted/modeled outcomes, review conceptual models and emerging research to assess potential sources of divergence in predicted and observed outcomes, and refine key uncertainties.

6. Evaluate:
   Convene decision-makers, scientists and stakeholders to review monitoring data and progress toward ecosystem goals, refine syntheses (e.g., data, modeling, research), and develop and communicate recommendations for modified research priorities, model and hypothesis refinements, adjustments to monitoring programs, and revisions to ecosystem goals.

7. Make Decisions and Adapt:
   Review recommendations and make decisions regarding adaptation of ecosystem goals and plans to improve understanding and more effectively reach desired ecosystem states.

Figure 2. Adaptive management steps of the binational Lake Erie Adaptive Management Framework (GDIT/LimnoTech 2021).

2.0 Project Scope

2.1 Objectives and tasks

The objective of this project is to evaluate progress made by Annex 4 in implementing the Commission's Great Lakes Science Advisory Board-Research Coordination Committee's recommendations on institutional arrangements contained in their 2019 report "Use of Modeling Approaches to Affect Nutrient Management Through Adaptive Management" and summarized in **Table 6** (International Joint Commission Great Lakes Science Advisory Board 2019).

This has been accomplished by reviewing the AM process presently underway through the LE-AMF, and by consulting with the board's work group members, the AM Task Team and various other stakeholders. Central to evaluating Annex 4 implementation progress is understanding how recommendations have been included in the LE-AMF process. The International Joint Commission's Great Lakes Science Advisory Board and Great Lakes Water Quality Board also recently completed a separate report, "Nutrients in Lake Erie and Lake Ontario: Synthesis of International Joint Commission Recommendations and Assessment of Domestic Action Plans" that is a broader assessment of the implementation of Commission recommendations into the Lake Erie and Lake Ontario Domestic Action Plans, which complements this assessment on adaptive management of nutrients in Lake Erie (International Joint Commission Great Lakes Science Advisory Board and Water Quality Board, 2023).

This assessment addresses the following through a specific number of tasks:

- Assessment of the progress that Annex 4 has made in establishing the LE-AMF
- Evaluation of the extent to which the LE-AMF has achieved coordinated planning and implementation of a nutrient adaptive management framework
- Evaluation of the extent that the LE-AMF has achieved sustainable institutional arrangements for calculating nutrient loadings and developing a research and monitoring program

To accomplish these goals, this project carried out the following five tasks:

Task 1: Background research

Relevant information associated with Annex 4 of the Agreement was reviewed during this initial task in the interest of securing a detailed understanding of the LE-AMF. This literature review provided the basis for background research.

Task 2: Assess the progress Annex 4 has made towards establishing the Lake Erie Adaptive Management Framework

Based on Task 1 research, Task 2 activities entailed an assessment of progress toward implementing Annex 4 programs and objectives as it relates to establishing the LE-AMF. The assessment addresses the following:

- The extent to which the LE-AMF has established long-term, sustainable institutional arrangements that foster collaboration across government agencies and jurisdictional lines.

- Whether sustainable funding sources to support the work of the LE-AMF have been identified and secured.

- Whether the adaptive management components of the LE-AMF have resulted in a framework as described in the Commission's Great Lakes Science Advisory Board-Research Coordination Committee 2019 report.

Complementing the literature review were interviews with selected subject matter experts and other interested stakeholders. This list, along with a series of questions to guide the interview, was presented to and approved by the board's project work group and Commission staff. A simple survey instrument was employed to gather data.

Task 3: Evaluate to what extent the Lake Erie Adaptive Management Framework has achieved coordinated planning and implementation of a nutrient adaptive management framework

Drawing from the literature search, interviews and the survey (conducted in Tasks 1 and 2), an evaluation of the LE-AMF was made as to the Framework's success in coordinating planning and management activities. Resultant findings and recommendations were informed by:

- A descriptive listing of LE-AMF participants and the extent to which these individuals reflect recommendations embodied in the SAB-RCC report.

- A determination of gaps and unmet needs, both in terms of personnel and program elements, to advance an effective nutrient AM Framework.

- An evaluation of the extent to which the LE-AMF has achieved a regular and predictable cycle for planning, assessment, and reporting.

Task 4: Evaluate the extent the Lake Erie Adaptive Management Framework has achieved sustainable institutional arrangements for calculating nutrient loadings and developing a research and monitoring program

This task leveraged past knowledge of institutional arrangements in the binational Great Lakes basin to investigate institutional sustainability as defined as: funding, presence within/support of the Great Lakes community, active participation of Framework members, overall impact, and success in addressing the nutrient problem.

Institutional sustainability was evaluated on the basis of the following objectives:

- An integrative watershed/lake modeling framework is pursued in LE-AMF design and implementation.

- A research and monitoring program has been established (in a sustainable manner) to track the effectiveness of LE-AMF actions.

- Critically, consistent data have been collected to evaluate progress in meeting stated phosphorus reduction goals.

Task 5: Provide advice on how the institutional framework can be strengthened to advance the Lake Erie Adaptive Management Framework

Based on materials reviewed, interviews conducted, survey outcomes and the consultant team's familiarity with Annex 4, a series of recommendations were developed to strengthen the LE-AMF. An emphasis is placed on practical, pragmatic, and actionable recommendations that lend themselves to an assessment of progress. The development of recommendations are based upon the consultant team's in-depth understanding of overall institutional arrangements for the Great Lakes and a commitment to cost and operational efficiency for the LE-AMF.

2.2 Report organization

Section 2 provides the methodology for the interviews and survey conducted for this project. **Section 3** presents an overview of the AM framework, associated institutional arrangements, current planning efforts regarding state and provincial domestic action plans (DAPs), sustainable funding sources identified and unmet needs. **Section 4** assesses the LE-AMF coordination and planning measures that have been undertaken and the overall collaborative process. **Section 5** presents an assessment of the sustainable institutional arrangements, various modeling frameworks and research/monitoring programs. **Section 6** presents a set of recommendations to strengthen the institutional framework to advance the LE-AMF. **Section 7** presents the references consulted during the preparation of this report. **The appendices** to this report contain detailed summaries of DAPs and information on the survey and interviews conducted.

2.3 Data sources

Data sources employed to address the key tasks detailed above included document review, interviews and a survey.

2.3.1 Document review

The consultant team reviewed a broad range of documents associated with the LE-AMF effort and nutrient management in the Great Lakes basin for preparation of this report. Documents included:

- Literature about AM in theory and its implementation in other geographies.

- Key research, planning, and progress reports produced to support Annex 4 activity under the Agreement at the binational and domestic levels (e.g., work group and other technical reports on water quality monitoring and modeling, the LE-AMF, the Commission's Great Lakes Science Advisory Board-Research Coordination Committee 2019 report, DAPs and the 2019 Binational Phosphorus Reduction Strategy, the Lake Erie Lakewide Action and Management Plan, and recent Progress Reports of the Parties).

- Research reports and literature on Great Lakes water quality and water quality management.

- Research reports and literature providing evidence of the impact of management strategies and actions on nutrient pollution in the Lake Erie basin and other Great Lakes.

2.3.2 Interviews

To deepen the consultant team's understanding of the current status of LE-AMF implementation, a series of interviews were conducted with individuals involved in the LE-AMF process. Interviewees included Annex 4 Subcommittee members, Annex 4 Subcommittee AM Task Team members, and individuals working at the state and provincial levels on activities in Canada and the United States that inform the LE-AMF process. The list of interview questions and interviewees is provided in **Appendix C**. The board recognizes that his was a sampling of interview candidates given budget and time limitations.

2.3.3 Survey

The purpose of the survey is to capture perceptions and experiences of experts working on nutrient management and/or adaptive management in the Lake Erie basin. Along with interview results, survey outcomes were used to assess progress in implementing the LE-AMF, evaluate the status of coordinated planning and implementation, and evaluate the status of sustainable institutional arrangements.

Based on a review of materials, as well as discussions with the work group, an online survey (via Survey Monkey) was developed and directed to 113 carefully selected individuals identified by the work group and consultant team. All are considered experts that work on nutrient management and/or AM in the binational Great Lakes basin. The survey was emailed and accepted responses for a period of two weeks. A total of 36 individuals returned a completed the survey, yielding a 32 percent response rate. Nearly all these respondents (97 percent) indicated that they work in the Lake Erie watershed. Most respondents were from the public sector (56 percent) and respondents from Ohio, Ontario and Michigan were particularly well represented (47 percent, 25 percent, and 19 percent, respectively).

The survey captured respondent perceptions and experiences through a series of 31 questions developed by the consultant team and reviewed and finalized by the work group. The survey supplemented information obtained from the work group, individual interviews and other LE-

AMF related documents. The final survey questionnaire and survey results for quantitative questions are included as **Appendix B** of this report.[1]

As noted, the survey includes an array of questions that allow respondents to share thoughts, opinions and recommendations on an anonymous basis. The questionnaire also contained a subset of questions to allow the consultant team to categorize respondents by geographic area, sector, area of expertise, understanding of the issue, and the extent of their involvement in the LE-AMF. Those who identified themselves as directly involved in the LE-AMF process (40 percent of total respondents) responded to a series of additional questions that explored specific details about the LE-AMF. The final survey question invited respondents to identify themselves and indicate if they would be available for follow-up conversations by the consultant team.

[1] Open-ended question responses have been withheld from this report for confidentiality reasons.

3.0 Progress Towards Establishing the Lake Erie Adaptive Management Framework

This section assesses the progress Annex 4 has made in establishing the LE-AMF by evaluating:

- The extent to which the LE-AMF has established long-term, sustainable institutional arrangements that foster collaboration across government agencies and jurisdictional lines.
- Whether sustainable funding sources to support the work of the LE-AMF have been identified and secured.
- Whether the adaptive management components of the LE-AMF have resulted in a framework as described in the Commission's Great Lakes Science Advisory Board-Research Coordination Committee 2019 report.

3.1 Sustainable institutional arrangements

The LE-AMF leverages both binational and domestic institutional arrangements for implementation. These binational and domestic institutional arrangements pre-date the LE-AMF and support the binational priorities identified in the Lake Erie Binational Phosphorus Reduction Strategy through the preparation of DAPs that outline actions for meeting phosphorus load reduction targets in each domestic jurisdiction.

The DAPs and the LE-AMF work together to address the impact of management actions on phosphorus reductions in waterways, and the impact of these reductions on Lake Erie. (**Table 3**). The LE-AMF notes that binational and domestic processes are separate, and each are at different points on the AM cycle. The LE-AMF is the framework for the binational AM process only, which includes modeling, monitoring and research to understand the impact of phosphorus load reductions on LEOs in Lake Erie. The LE-AMF describes plans for exchanging information with the domestic AM and DAP processes and calls for stakeholder engagement using existing forums (e.g., the Great Lakes Public Forum) to support the LE-AMF, including annual reporting and five-year reporting.

Table 3. Domestic action plan and Lake Erie Adaptive Management Framework scope.

In Order to Meet Lake Erie Lake Ecosystem Objectives (LEOs)	Adaptive Management Scope
Domestic Actions Plans Domestic State AM Frameworks	Do phosphorus reduction management actions reduce phosphorus and achieve phosphorus reduction targets?
2019 Lake Erie Binational Phosphorus Reduction Strategy 2021 Binational Lake Erie Nutrient Adaptive Management Framework	Do the target phosphorus reductions achieve the LEOs?

Through the LE-AMF, a framework has been developed for the binational (Great Lakes Nutrient Adaptive Management (GLNAM) framework) and domestic institutional arrangements that contain guidance on the AM approach and how the various processes should relate to each other. Sustainability of the domestic processes for the development and implementation of the DAPs is easier to gage as these processes have been functioning for a longer period than the binational LE-AMF process. Overall, the domestic DAP processes exhibit strong stakeholder engagement and inclusion of an AM approach, although the level of specificity of that approach varies from one DAP to the next. The binational LE-AMF process is presently in the set-up phase and the final LE-AMF document in preparation. This makes gauging sustainability of the binational institutional arrangements difficult at the current time. However, the framework for institutional coordination established by the LE-AMF bodes well for fostering future sustainability.

3.1.1 Binational institutional arrangements

The Annex 4 Subcommittee AM Task Team developed the LE-AMF that provides "…coordinated guidance on the AM approach and its implementation to measure progress towards meeting phosphorus reduction targets and achieving LEOs to address the issues of HABs, hypoxia, and *Cladaphora* in Lake Erie" (GDIT/LimnoTech 2021, page i). The audience for the LE-AMF is the Annex 4 Subcommittee, AM Task Team, technical workgroups under the AM Task Team, and domestic programs implementing nutrient reduction programs and plans at the state/provincial level.

The AM Task Team is responsible for implementing the LE-AMF by developing a workplan, communicating progress, coordinating four technical work groups and implementing the binational AM evaluation. The AM Task Team reports on and communicates progress through annual progress reports and five-year progress evaluations that include a review of nutrient reduction targets. The principal audience for the five-year progress evaluation is the Great Lakes Executive Committee, a binational committee that meets twice a year to carry out commitments of the Agreement. The LE-AMF takes an active AM approach including hypothesis development and research, predictive modeling, and monitoring to reduce uncertainty and adapt management actions new information becomes available. The LE-AMF is expected to evolve and become more detailed as stakeholder input is received, roles and responsibilities are finalized, and

sources of funding are secured. Updates to this strategy are expected to be documented in future versions of the LE-AMF, as well as through annual progress reports and work plans.

The draft LE-AMF includes detail on the institutional framework that will be utilized to implement the LE-AMF, and notes that "…the organizational structure is likely to evolve over time to reflect lessons learned and potential changes in technical focus and shifting agency roles and commitments" (GDIT/LimnoTech 2021, page 17). The LE-AMF institutional framework includes the following components:

Agreement Annex 4 Subcommittee

- ECCC and USEPA co-chair the Nutrients Annex 4 Subcommittee, which has representation from more than 20 federal, state, provincial and regional organizations. The Annex 4 Subcommittee is composed of mid-level representatives within these agencies and organizations. The Subcommittee meets monthly and dedicates a portion of the meeting time to announcements from the domestic jurisdictions.

- Coordinates binational actions to reduce phosphorus loads and meet LEOs.

- Oversees commitments under the Agreement for nutrients through:

    - Establishing binational phosphorus loading targets for nearshore and offshore waters to reach LEOs for each lake, including Lake Erie (required by February 2016).

    - Assessing and developing regulatory and nonregulatory programs to reduce phosphorus loads from point and nonpoint source activities.

    - Developing a binational phosphorus reduction strategy and DAPs that detail how phosphorus load reductions will be achieved by the federal and domestic jurisdictions (required by February 2018).

Agreement Annex 4 Adaptive Management Task Team (AM Task Team)

- Implements the binational LE-AMF.

- Comprised of a core AM team of three to five representatives from federal agencies, as well as a larger working group of 15 to 20 representatives. AM Task Team members tend to be at the scientist/program manager level from the various organizations represented. The core team meets weekly and organizes the work of the broader AM Task Team. The core team includes ECCC, United States Geological Survey and the National Oceanic and Atmospheric Administration (NOAA).

- The AM Task Team meets quarterly and is composed of a subset of Annex 4 Subcommittee members who represent entities with jurisdiction over voluntary and compliance mechanisms for nutrient reduction (management and implementation) and scientific entities who support modeling and monitoring.

- Schedules meetings to occur before Annex 4 Subcommittee meetings to facilitate an update that is presented to the Subcommittee. In addition to quarterly meetings, the AM Task Team engages in more frequent internal communication (e.g., email) when action is required on tasks such as document review or decision-making.

- Oversees four technical work groups.

Technical work groups

- Four technical work groups are listed in the LE-AMF: three issue-focused groups on HABs, hypoxia and Cladophora, and one work group on data synthesis and modeling. Other work groups have been mentioned in interviews as well, such as a group focused on the eastern basin and a group focused on monitoring.

- These groups currently meet on an ad-hoc basis.

- Each technical working group is made up of experts from binational federal, state, and provincial agencies and other participating organizations that contribute to the development of AM Task Team's work plans and progress reports.

3.1.2 Domestic institutional arrangements

In response to the adoption of new binational targets, domestic jurisdictions released DAPs in 2018. The DAPs address the following:

- Implementation targets for meeting LEOs for Lake Erie

- How resources can be allocated to meet those implementation targets

- Management actions and policy and program needs

- Methods and measures to track progress

Four states in the Lake Erie basin (Ohio, Michigan, Pennsylvania and Indiana) have developed DAPs. The USEPA Great Lakes National Program Office developed the "US Action Plan for Lake Erie (2018-2023)" to summarize both federal and domestic actions (USEPA 2018). New York State participates in the overall effort but has not developed its own DAP. The Canadian federal government and the province of Ontario developed a joint DAP, the "Canada-Ontario Lake Erie Action Plan" or LEAP (Environment and Climate Change Canada and Ontario Ministry of the Environment and Climate Change, 2018). Using an AM approach, these plans outline strategies for meeting the new targets in specific jurisdictions and watersheds (Great Lakes Water Quality Agreement Nutrients Annex Subcommittee 2019). **Appendix A** contains detailed summaries for each of the DAPs.

DAPs present objectives for nutrient load reductions from specific tributaries in each jurisdiction. Strategies identified in the DAPs to meet the load reduction objectives include

reducing phosphorus loadings from agricultural sources, reducing phosphorus loadings from municipal sources, supporting watershed-based planning and restoration efforts, coordinating science, research and monitoring, and enhancing communication and outreach. These strategies support the LE-AMF process and track progress toward the targets.

A detailed comparative analysis of the DAPs was outside the scope of this project and is part of a 2023 report by the Commission's Great Lakes Science Advisory Board-Science Priority Committee and Water Quality Board (International Joint Commission Great Lakes Science Advisory Board and Water Quality Board, 2023). The research into each DAP conducted as part of the current report, however, did yield important insights concerning the institutional opportunities and barriers present in the DAPs that could affect the AM process of the LE-AMF:

- The DAPs tend to serve as umbrella plans for existing programming. Each DAP is managed by a lead state agency or agencies that compile and bring into one document various existing programs and requirements for key management activities for nutrient reduction in the Great Lakes (e.g., voluntary agricultural nutrient management/best management practice (BMP) programs, regulatory wastewater treatment requirements). The DAPs also suggest some new activities that could be undertaken or are in process to optimize current programs.

    - For example, under the state's AM framework, Michigan is aligning agricultural inventories of field and subwatershed cropping practices and additional water quality gages to support data collection and learning that can optimize BMP investment at the subwatershed level for greater water quality benefits. This AM project will allow the state to better leverage existing programs and funding, such as conservation practice cost-share dollars.

- The DAPs were developed with an AM framework in mind, but these AM frameworks are in a nascent stage. There are some pieces of the AM process in place, but the iterative phase of AM, where decision-making points are established and monitoring and assessment leads to adjustments in management alternatives, is not yet concrete and will require additional detail.

    - For example, Michigan has developed a DAP (Michigan Department of Environmental Quality 2018) as well as an AM plan (Michigan Department of Environment, Great Lakes and Energy et al. 2021) that builds on and details the DAP. The AM plan provides a greater level of detail in terms of projects, processes, and institutional arrangements.

- The DAPs include a wide variety of management actions, but information about management alternatives is an identified need for further exploration.

- DAPs primarily outline elements of the set-up phase of adaptive management: defining the stakeholder groups (lead agencies and other stakeholders), the objectives, management actions, and data (e.g., monitoring, assessment) that will be employed to

meet Lake Erie ecological goals under Annex 4. The DAPs are currently nearing the end of the first 5-year phase, and some are evaluating progress for the first time.

- There is some cross-jurisdictional work related to the DAPs occurring in the region. Some states work together on water quality when watershed span political boundaries.
    - For example, Michigan, Indiana and Ohio work together on monitoring approaches for the Maumee River.
- The DAPs reviewed for this report exhibit certain best practices that other states could implement through their evolving AM processes (**Table 4**).
    - For example, in addition to the individual DAPs, some domestic jurisdictions have separate AM guidance documents, such as Michigan's Lake Erie Adaptive Management Plan (Michigan Department of Environment, Great Lakes and Energy et al. 2021). Michigan uses a website to provide frequent updates on progress and present annual progress reports, two-year work plans and five-year DAP updates (Michigan Department of Environment, Great Lakes and Energy et al. 2021). Ohio produces annual Water Monitoring Summaries that measure progress against Annex 4 targets.[1]

[1] Ohio water monitoring summary information can be accessed at: lakeerie.ohio.gov/planning-and-priorities/03-wms/wms.

Table 4. Adaptive management state of practice by jurisdiction.

Domestic Action Plan	Selected Best Practices
Ohio[2]	• Funding streams associated with included management activities • Restructuring of monitoring data to support assessment of DAP activities • Production of annual Water Monitoring Summaries
Michigan[3]	• Formal AM plan including projects—experiments that will yield important data to reduce uncertainties around management action effectiveness, moving the state from passive to active AM • Agricultural inventory initiative in the AM plan to target BMP investments across the landscape for higher water quality benefits matched with US Geological Survey gauges to evaluate impacts • Funding sources identified for the priority management actions in the AM plan
Ontario[4]	• Knowledge synthesis report • Dedicated implementation team, including provincial and federal ministries, agricultural organizations, First Nations and Métis communities, nongovernmental organizations, conservation authorities and municipalities • Dedicated AM team
Indiana[5]	• Prioritization of resource allocation • Extensive stakeholder engagement in DAP development • Milestone table with responsible parties • Hypothesis testing through AM projects
Pennsylvania[6]	• Identification of data gaps

[2] Ohio Lake Erie Commission 2020a
[3] Michigan Department of Environmental Quality 2018
[4] ECCC and Ontario Ministry of the Environment and Climate Change, 2018
[5] Indiana Department of Environmental Management 2018
[6] Pennsylvania Department of Environmental Protection 2017

3.1.3 Survey results: sustainable institutional arrangements

Survey respondents were asked about ways to strengthen long-term sustainable institutional arrangements that foster collaboration across government agencies and jurisdictional lines. The consultant team categorized all survey responses into the following recommendation buckets: stakeholder engagement, communication and collaboration, organization and coordination, and funding (**Table 5**).

Table 5. Survey responses to questions about strengthening institutional arrangements.

Category	Survey Response Ideas
Increase stakeholder engagement	• Increase stakeholder engagement at all levels with an emphasis on the following sectors: agriculture and agribusiness, municipal/utilities, state, federal and binational agencies, and academic entities. • Invite a broader group of nongovernmental organizations into the Agreement/Annex 4 process.
Increase communication and collaboration	• More frequent in-person meetings • Knowledge-sharing opportunities, including relevant tours • Increase communication between scientists and managers
Increase organization and coordination	• Explore how to institutionalize binational coordination and strengthen the International Joint Commission • Work toward consistent regulations across Lake Erie basin jurisdictions • Co-fund important projects • Develop plans that define outcomes and roles for each agency • Establish an executive oversight committee and external advisory board, perhaps as a sub-component of the Interagency Working Group on Harmful Algal Bloom and Hypoxia Research and Control Act • Dedicated leadership teams with senior officials that have the authority to act • Make binational arrangements a part of Agreement deliverables.
Increase funding	• Provide sustainable sources of funding, particularly for local organizations like NGOs and conservation authorities. • Federal support for dedicated state staffing (e.g., the Chesapeake Bay Program). • Identify dedicated staff and money to support all parts of the process.

Survey respondents were also asked about how various jurisdictions could work together more effectively. Responses highlighted communication, coordination and engagement needs, including:

- Establish a formal mechanism, through Agreement Annex 4 and elsewhere, as appropriate, with dedicated positions (at least half time) for directors, co-chairs and a secretariat.
- Leverage existing relationships and institutional frameworks.
- Establish common goals and realistic implementation plans (right now there is a "do your own thing" system)
- Share lessons learned and best practices.
- Leverage existing data and resources.
- Engage local governments. For example, the Great Lakes Executive Committee/Annex Subcommittees/Annex working groups are doing well at the federal/state/provincial level, but they need to expand to local governments as well.
- Engage private sector companies that work across jurisdictions.

Importantly, survey responses (for all respondents, including the core LE-AMF team) reveal that survey respondents are relatively optimistic about the expected timeline for meeting the goals of the LE-AMF (**Figure 3**). Half of the respondents (13 respondents) selected a timeline of 10-25 years, while 30 percent (7 respondents) selected 25 to 50 years, and only 8 percent (2 respondents) selected a timeline of more than 50 years.

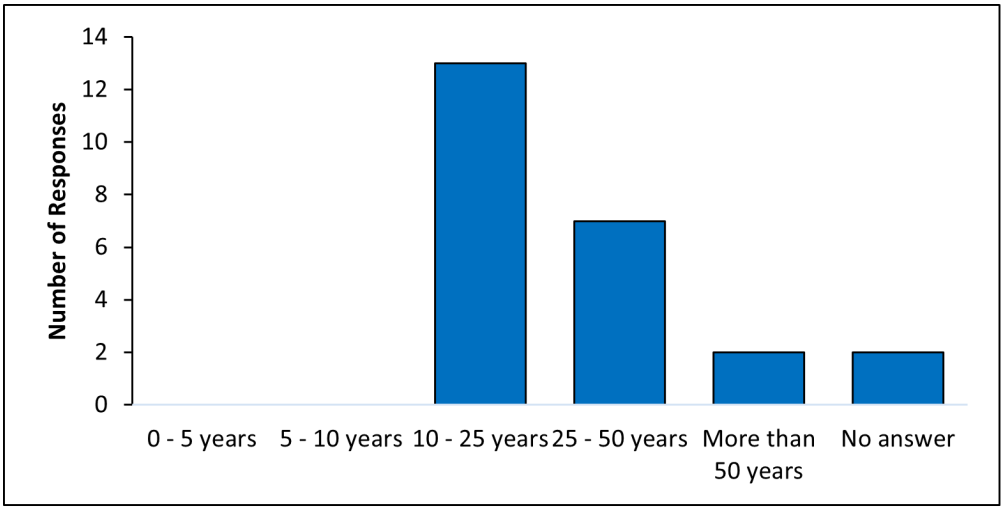


Figure 3. Expected timeline for meeting the goals of the Lake Erie Nutrient Adaptive Management Framework.

3.2 Sustainable funding

Funding for environmental agencies and the work they do is subject to risk. State governments may cut agency budgets, removing funding for programs and staff to implement the work. For example, the Indiana Department of Environmental Management suffered budget cuts and staff turnover that impact the agency's ability to efficiently carry out programs. As a result, implementation of Indiana's DAP relies on a sufficient level of budget and staff which may not be available.[7]

Given that the LE-AMF is a relatively new effort that is not final yet, evaluating the current state of funding for the effort is difficult. Currently, funding for the LE-AMF relies on a variety of sources. Generally speaking, funding is *ad hoc*; the LE-AMF does not have dedicated funding yet. Federal, state and provincial agencies dedicate some staff time to the LE-AMF process. Sustainable funding has not yet been identified or secured for the LE-AMF process; rather, funding to reach Lake Erie ecosystem goals is currently dependent on funding streams associated with a large variety of existing state and local programs. Research of state DAP documents and AM processes indicates that funding associated with implementing the DAPs is largely driven by existing federal, state, provincial, philanthropic and other funding in place for existing programs brought under the DAP umbrella. Information on funding streams, where available, has been included in this report for each jurisdiction.

In some cases, AM efforts for Lake Erie have attracted additional funding. One example is Ohio's budget bill 166. For the states, additional funding may become available through vehicles such as the Great Lakes Restoration Initiative (GLRI), which has seen an increase in funding through the recent US federal infrastructure legislation. A large focus of this funding, however, is for aquatic organism passage.

The GLRI funds some activities under the LE-AMF, but funding is primarily allocated to on-the-ground activities as opposed to the LE-AMF data collection, monitoring and AM work. The GLRI Action Plans have consistently included the Maumee River watershed as a priority for nutrient reduction, and Focus Area 3 covers nonpoint source reductions. The USEPA Great Lakes Advisory Board[8] released a report in April 2022 to the USEPA that provides recommendations (among others) on addressing legacy phosphorus and reducing nutrient pollution (Great Lakes Advisory Board 2022). Recommendations on GLRI funding for the LE-AMF process are included in this report, and call for sustainable funding to address existing data

[7] In December 2019 the Indiana Star reported a 20 percent cut in the Indiana Department of Environmental Management's budget over the past decade even as overall state spending increased by almost that much. News article accessed at: indystar.com/story/news/environment/2019/12/26/idem-funding-fell-20-last-decade-even-state-spending-increased/2637483001/, May 18, 2023.

[8] The USEPA Great Lakes Advisory Board is one of the USEPA's Federal Advisory Committees. According to the USEPA's GLRI website, the USEPA Great Lakes Advisory Board "operates in accordance with the Federal Advisory Committee Act. The Great Lakes Advisory Board is chartered to provide advice and recommendations to the [US]EPA Administrator, through the Great Lakes National Program Manager, on matters related to implementation of the Great Lakes Restoration Initiative. It will also advise on domestic matters related to implementation of the Great Lakes Water Quality Agreement between the U.S. and Canada." Information accessed at: glri.us/glab, May 18, 2023.

gaps and needs; financial support of projects in critical source areas; funding of long-term watershed monitoring activities; development of metrics to associate nutrient load reductions with land and watershed management planning efforts; and the use of modeling efforts among regional policy and management committees to identify and prioritize watersheds contributing high loads of nutrients to the Great Lakes (Great Lakes Advisory Board 2022).

Lack of sustainable funding for monitoring efforts has been identified as a significant risk to the long-term effectiveness of the LE-AMF. Monitoring at the watershed and lake level is funded through a combination of federal grants, state and provincial appropriations, and other funding sources. The amount of funding from these programs can depend on appropriations.

3.2.1 Sources of potential funding

Sources of potential funding for LE-AMF activities at the binational and domestic levels are summarized below. Some of these funding sources are already being leveraged at the domestic level to fund activities related to nutrient reduction in Lake Erie watersheds, DAPs and the activities related to nutrient reduction in Lake Erie.

US Clean Water Act Section 319: Provides US federal funding to states, territories and tribes for nonpoint source control projects in the Lake Erie basin.

US Clean Water Act Section 106: Provides US federal funding to states, territories, interstate agencies and tribes to support ambient water quality monitoring programs and participation in the National Aquatic Resource Surveys, a collaborative program between the USEPA, states and tribes designed to assess the quality of the nation's coastal waters, lakes and reservoirs, rivers and streams, and wetlands using a statistical survey design.

US Clean Water Act Section 118(c)(7): Provides US federal funding to carry out activities in support of the GLRI and the Agreement. Provided US$300 million (CDN$405 million) per fiscal year from 2017 through 2021.

US Department of Agriculture Natural Resource Conservation Service Funding Programs: Provides technical and financial assistance to producers in the Lake Erie watershed through the voluntary Conservation Technical Assistance Program, the Environmental Quality Incentive Program, the Conservation Stewardship Program, the Agricultural Conservation Easement Program, and the Regional Conservation Partnership Program. Funds the Western Lake Erie Basin Initiative to assist farmers in applying conservation systems on cultivated cropland across the western Lake Erie basin.

US Department of Agriculture National Institute of Food and Agriculture: Invests in and provides national leadership to advance agricultural research, education, and extension to solve societal challenges by providing competitive and capacity funding grants.

GLRI: Restores and maintains the environmental integrity of the Great Lakes ecosystem, in accordance with the Agreement and the US Clean Water Act. The Great Lakes National Program Office coordinates implementation of the GLRI, by leading an Interagency Task Force of 11

federal departments or agencies. The federal partners fund work directly or through others such as states, tribes, cities, universities and nongovernmental organizations.

NOAA: Funds HAB and hypoxia research through base research funds from NOAA's Great Lakes Environmental Research Laboratory and Sea Grant, and the NOAA National Center for Coastal Ocean Science offers competitive research grants.

Canada's Great Lakes Protection Initiative: Addresses water quality and ecosystem health in the Great Lakes under the Agreement (ECCC and USEPA, 2019a). Prevents toxic and nuisance algae as one of eight priority areas of action. Eligible recipients of grants include Conservation Authorities, Indigenous communities or their governments, industry associations, municipalities, nongovernmental organizations and research institutions. Projects that demonstrate the effectiveness of BMPs and/or innovative approaches to reducing phosphorus loads to Lake Erie are considered under the toxic and nuisance algae priority area.

Ontario's Great Lakes Guardian Community Fund: Helps people take action to protect and restore the Great Lakes. Since it launched in 2012, the Great Lakes Guardian Community Fund has awarded CDN$7.5 million (US$5.5 million) to 375 community-based projects, which supported more than 37,000 volunteers to plant over 285,000 trees and shrubs, release over 800,000 fish, create or enhance 760 kilometers of trail, and collect over 2,800 bags of garbage.

Ontario's Great Lakes Local Action Fund: Invests in projects across Ontario that address issues critical to the health of the Great Lakes, including shoreline health, excess nutrients, protecting and restoring habitats and species, and improving water quality.

3.2.2 Survey results: sustainable funding

Survey respondents were asked about sustainable funding sources that could support the work of the LE-AMF. These funding sources included:

- GLRI
- 2021 US Infrastructure Act (P.L. 117-58)
- Canadian Federal Great Lakes Funding, Environment and Climate Change Canada
- Canadian Agricultural Partnership
- Great Lakes Water Quality Agreement, Canada-Ontario Agreement
- NOAA, USEPA, US Geological Survey, US Army Corps of Engineers, US Department of Agriculture and Natural Resource Conservation Service base funding and Canadian equivalents
- HSBC Bank
- Multi-stakeholder voluntary contributions

3.3 Adaptive management components

The AM components of the LE-AMF have generally resulted in a framework as described in the Commission's Great Lakes Science Advisory Board-Research Coordination Committee 2019 report. Annex 4 used the board's recommendations in developing the LE-AMF. Most components are present in the structure of the LE-AMF; however, implementation of the LE-AMF to meet the broad institutional arrangement recommendations of the board's report goals will require additional focus and effort. Annex 4 plans to update the LE-AMF from information and engagement with stakeholders.

This section describes the institutional recommendations contained in the board's 2019 report, the components of the LE-AMF, and strengths and areas of need of the LE-AMF in light of the institutional recommendations.

3.3.1 Great Lakes Science Advisory Board-Research Coordination Committee institutional recommendations

The Commission's Great Lakes Science Advisory Board-Research Coordination Committee plays an important role in researching and providing science-based advice to the Commission on water quality issues in the binational Great Lakes basin. The board undertook a project to assess the current state of watershed and lake modeling for eutrophication in Lake Erie and to develop recommendations on how modeling could be used within an AM framework to evaluate the impact of management actions on nutrient loadings. The board adopted the Great Lakes Nutrient Adaptive Management Framework (GLNAM Framework, **Figure 4**) with the purpose to "…guide the development and conduct of an adaptive management approach revolving around the phases: Plan-Act-Monitor-Evaluate-Learn-Adjust" (International Joint Commission Great Lakes Science Advisory Board 2019).

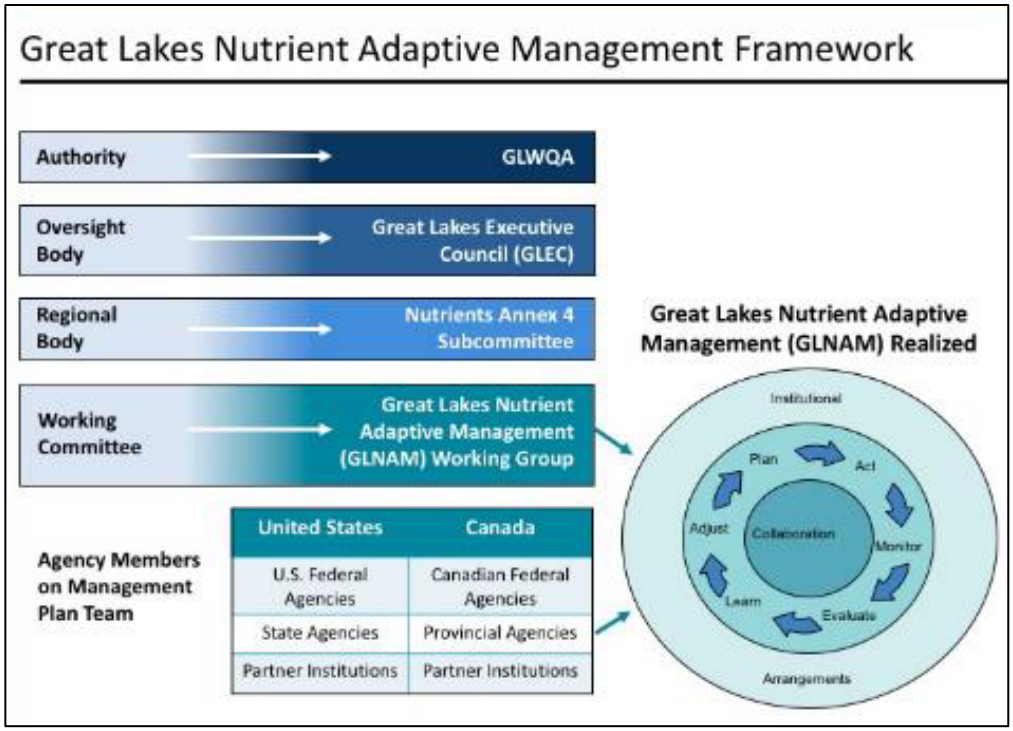


Figure 4. Great Lakes Nutrient Adaptive Management Framework (International Joint Commission Great Lakes Science Advisory Board 2019).

The board produced both a technical report (University of Toronto, Scarborough Ecological Modelling Laboratory 2018) and a findings and recommendation report from the board (International Joint Commission Great Lakes Science Advisory Board 2019) that includes both technical and institutional recommendations. This report benefits from these earlier efforts while evaluating the progress Annex 4 has made in implementing the board's institutional recommendations contained in the 2019 report. The recommendations (and steps to implement them), as articulated in the board's 2019 report are captured in **Table 6**. Annex 4 language reflects the board's 2019 recommendations in drafting the LE-AMF. This section evaluates the extent to which the AM components of the LE-AMF have resulted in a framework as described in the board's 2019 report.

Table 6. International Joint Commission Great Lakes Science Advisory Board-Research Coordination Committee recommendations on institutional arrangements (International Joint Commission Great Lakes Science Advisory Board 2019)

Institutional Arrangement Recommendations	Recommended Implementation Steps
Define Lake Erie's eutrophication problem using the Great Lakes Nutrient Adaptive Management (GLNAM) Framework	• Use an integrated watershed and lake modeling approach on a long-term basis • Institutionalize the Framework through collaboration across government agencies and jurisdictions
Use the GLNAM Framework to inform coordinated planning and implementation of Lake Erie's watershed/lake modeling and nutrient reduction management	• Identify key players currently participating in implementing the Framework • Identify gaps and unmet needs that must be addressed to further advance the Framework • Provide status reports on progress achieves
Establish and integrate monitoring programs as part of the GLNAM Framework	• Establish monitoring on a long-term basis • Evaluate results to adjust research, modeling and management decisions
Update models on a regular basis	• Update models on a regular basis to reduce uncertainty in the adaptive management approach
Institutionalize the GLNAM Framework	• Establish the Agreement as the binational authority to implement the GLNAM Framework through Annex 4 (Nutrients) • Identify agency and institutional partners and programs with experts, resources and stakeholders responsible for developing and carrying out the Framework and implementing model improvements and reducing uncertainty in the adaptive management approach
Identify and establish funding streams to support the GLNAM Framework	• Identify and establish funding streams through existing and/or new authorizations and appropriations
Establish justification for investing in the GLNAM Framework on a long-term and sustainable basis	• Quantify benefits of healthy ecosystem services

3.3.2 The Lake Erie Nutrient Adaptive Management Framework (LE-AMF)

The LE-AMF includes a (draft) AM cycle that links binational and domestic AM processes and institutions (**Figure 5**). AM steps (e.g., planning, implementation, monitoring and synthesis, evaluation, and adaptation) are included for both. As noted, stakeholder engagement around the AM effort is included, and all AM processes are linked via knowledge sharing, collaboration and coordination. The LE-AMF informs potential changes to nutrient management goals, targets, and/or approaches, thereby leading to potentially revised targets that domestic processes can incorporate through the DAPs.

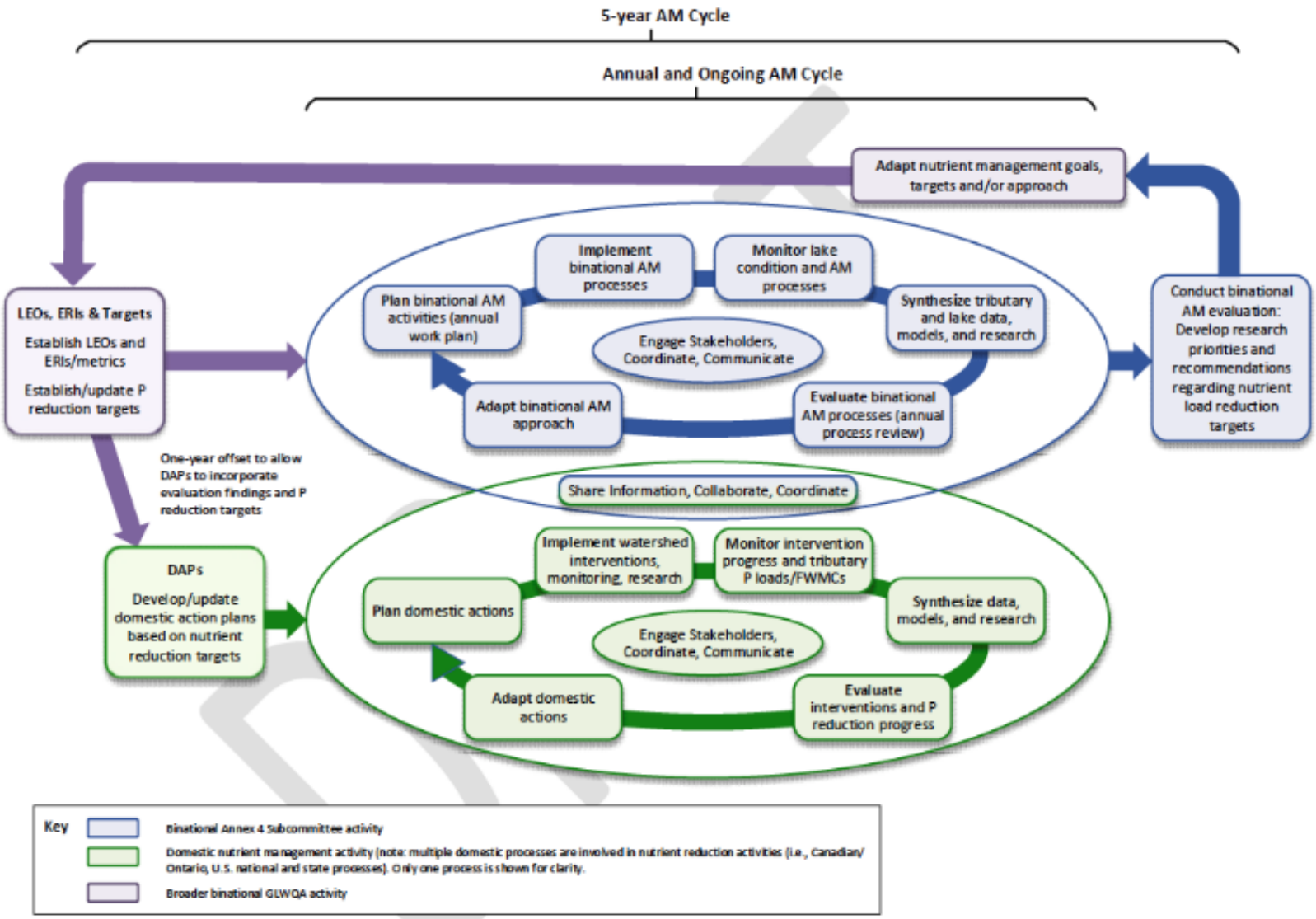


Figure 5. Draft binational and domestic adaptive management processes in the Lake Erie Nutrient Adaptive Management Framework (GDIT/LimnoTech 2021).

3.3.3 Strengths and areas of need

Mapping the LE-AMF guidelines to the institutional recommendations and GLNAM framework in the board's 2019 report identifies the following strengths and areas of need to align the LE-AMF more closely to the recommendations. **Table 7** provides an assessment of LE-AMF progress toward meeting the institutional recommendations in the board's 2019 report.

Strengths

- The LE-AMF created a binational coordinated and collaborative process, bringing different stakeholders in the Lake Erie region working on nutrient management together, including federal, provincial and state governments, practitioners, scientists, academics, and the interested public. This process brings together the research, modeling and monitoring spaces. The LE-AMF provides for an AM learning process that allows for adjustments to management activities and targets as new information is developed and evaluated.

- The LE-AMF incorporates key elements of the AM process for both the binational and domestic AM processes.

- Evaluation of the LE-AMF allows the incorporation of changes into DAPs and domestic planning. This is due to a one-year offset between establishing/updating LEO targets and updates to the domestic DAPs.

- The LE-AMF allows for evaluation of progress and adjustment of work without having to wait for a revision to the GLWQA. Goals can be revised as work progresses and learning occurs.

Areas of need

- The AM process is in an early stage; this study recommends changes.

- The AM process varies substantially from one jurisdiction to the next in terms of level of detail and comprehensiveness. Formalizing the AM processes in the domestic DAPs is needed to better link them to the LE-AMF.

- Strengthen stakeholder engagement within both the binational and domestic AM processes.

- Strengthen information sharing, collaboration and coordination between the binational and domestic AM processes. Some DAP teams are not aware of binational efforts presently underway. For example, LE-AMF updates could be provided to domestic DAP teams by the Annex 4 Subcommittee (AM Task Team), as opposed to the current process that relies on the DAP team leads for these updates.

- Stakeholders in domestic jurisdictions that are not Annex 4 members, but who are working on DAP planning and implementation efforts, could be better engaged in the LE-AMF process either through membership on the Annex 4 Subcommittee or through greater information sharing and coordination with Annex 4 Subcommittee members.

Table 7. Inclusion of the Commission's Great Lakes Science Advisory Board-Research Coordination Committee 2019 report recommendations into LE-AMF implementation.

Institutional Arrangement Recommendation	Recommended Implementation Steps	Inclusion of Recommendations In LE-AMF
Define Lake Erie's eutrophication problem using the Great Lakes nutrient adaptive management (GLNAM) Framework	Use an integrated watershed and lake modeling approach on a long-term basis	Integrated approach not yet developed or in use; modeling subgroup established in 2022
	Institutionalize the Framework through collaboration across government agencies and jurisdictions	Domestic (DAP) and binational (LE-AMF) processes linked in the LE-AMF establish collaborative avenues for jurisdictions
Use the GLNAM Framework to inform coordinated planning and implementation of Lake Erie's watershed/lake modeling and nutrient reduction management	Identify key players currently participating in implementing the Framework	Not included in board report but identified in this report
	Identify gaps and unmet needs that must be addressed to further advance the Framework	Addressed in board report and further explored in this report
	Provide status reports on progress	DAP evaluations are underway
Establish and integrate monitoring programs as part of the GLNAM Framework	Establish monitoring on a long-term basis	Integrated monitoring not yet developed or in use; monitoring subgroup developed draft recommendations
	Evaluate results to adjust research, modeling, and management decisions	Included in LE-AMF
Update models on a regular basis	Update models on a regular basis to reduce uncertainty in the adaptive management approach	Model updates ongoing through individual modeling institutions
Institutionalize the GLNAM Framework	Establish the GLWQA as the binational authority to implement the GLNAM Framework through Nutrients Annex 4	Need to formally recognize the GLWQA as the binational authority to implement the GLNAM Framework through Nutrients Annex 4
	Identify agency and institutional partners and programs with experts, resources, and stakeholders responsible for developing and carrying out the Framework and implementing model improvements and reducing uncertainty in the adaptive management approach	Agency and institutional partners and programs identified in DAPs
Identify and establish funding streams to support the GLNAM Framework	Identify and establish funding streams through existing and/or new authorizations and appropriations	Existing funding streams identified in DAPs
Establish justification for investing in the GLNAM Framework on a long-term and sustainable basis	Quantify benefits of healthy ecosystem services	Research ongoing but not coordinated under Annex 4

3.3.4 Survey results: LE-AMF AM components

Survey results indicate that most respondents do not know whether the AM components of the LE-AMF have resulted in a framework as described in the board's 2019 report (**Figure 6**). Only 12 out of 36 respondents answered this question and, of those that answered, five said they did not know. Aligning the AM components of the LE-AMF more closely with the board's 2019 report is an unmet need that can be addressed via adequate resources for LE-AMF implementation.

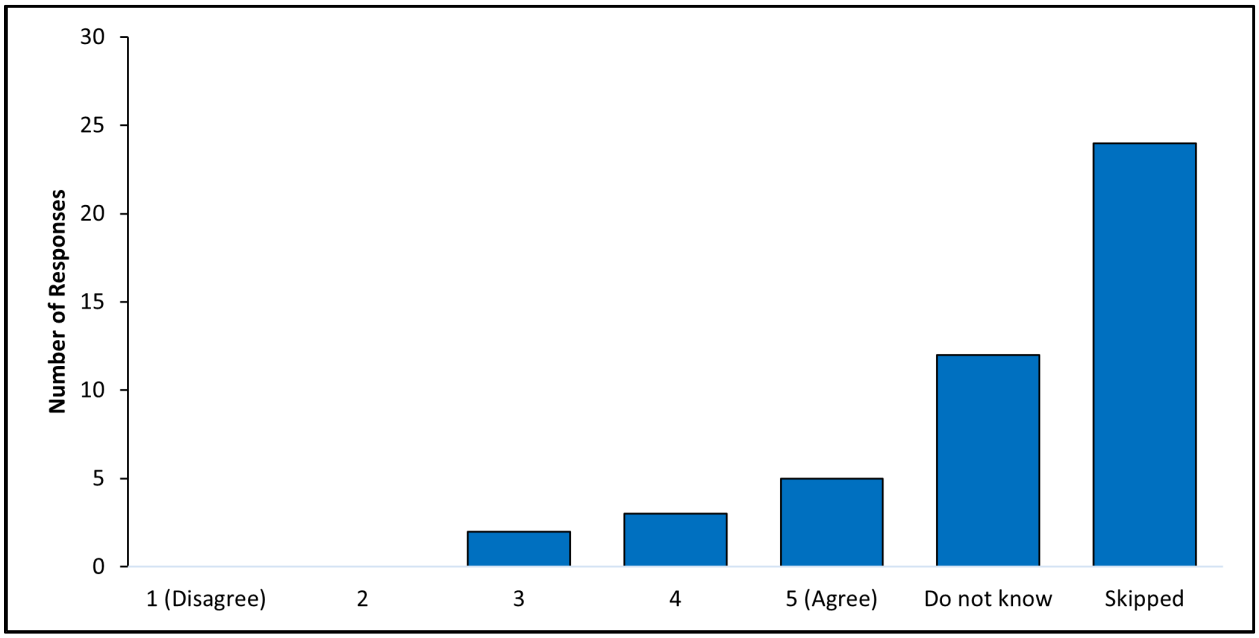


Figure 6. Survey responses, all respondents, to the question about the alignment of the LE-AMF adaptive management components to the International Joint Commission Great Lakes Science Advisory Board-Research Coordination Committee 2019 report.

4.0 Coordinated Planning and Implementation

Section 4 assesses the extent to which the LE-AMF has achieved coordinated planning and implementation of a nutrient adaptive management framework. The assessment includes:

- A descriptive listing of LE-AMF participants and the extent to which these individuals reflect recommendations embodied in the board's 2019 report
- A determination of gaps and unmet needs, both in terms of personnel and program elements, to advance an effective nutrient AM Framework
- An evaluation of the extent to which the LE-AMF has achieved a "regular and predictable" cycle for planning, assessment, and reporting

4.1 Lake Erie Nutrient Adaptive Management Framework participants

The development and implementation of the LE-AMF takes place in a larger ecosystem of water quality activity in the Great Lakes coordinated by entities at the binational, federal, regional, state, provincial and local levels. Entities also include public, private and nongovernmental agencies and organizations. At the binational level, the LE-AMF is part of the Agreement Annex 4—overseen by the Agreement Great Lakes Executive Committee—and is implemented alongside other annexes covering various Great Lakes issues. Also, at the binational and domestic levels, the Great Lakes Commission, International Joint Commission, Great Lakes Fishery Commission, and the Conference of Great Lakes and St. Lawrence Governors and Premiers coordinate efforts to bring policy and science together for nutrient management and other water quality/environmental challenges. In addition, the Lake Erie Partnership brings natural resource managers together from federal, state, and provincial jurisdictions.[1] To a limited extent, various domestic regional agencies (e.g., Conservation Authorities, county-level councils of government) are also engaged in nutrient management issues. The following section addresses

[1] Lake Erie Partnership members include ECCC, Essex Region Conservation Authority, Fisheries and Oceans Canada, Michigan Department of Environmental Great Lakes and Energy, NOAA, Ohio Lake Erie Commission, Ontario Ministry of Agriculture, Food and Rural Affairs, Ontario Ministry of the Environment, Conservation and Parks, Ontario Ministry of Natural Resources and Forestry, Pennsylvania Department of Environmental Protection, New York State Department of Conservation, Upper Thames River Conservation Authority, US Army Corps of Engineers, US Department of Agriculture Natural Resources Conservation Service, USEPA, US Fish and Wildlife Service, US Forest Service and the US Geological Survey.

LE-AMF participants at the Annex 4 binational level, the federal level, and the state and provincial levels.

4.1.1 Annex 4 Subcommittee

Under Annex 4, development and implementation of the LE-AMF process is conducted by participants at various tiers. Annex 4 is implemented by the Annex 4 Subcommittee led by ECCC and USEPA, and the Subcommittee membership also includes representatives from various other Canadian and US federal agencies as well as state and provincial representatives and those from regional agencies and nongovernmental organizations (**Table 8**).

Table 8. Annex 4 Subcommittee members.

Federal Agencies	State/Provincial/Regional Agencies and Organizations
ECCC	Conservation Ontario
Agriculture and Agri-Food Canada	Ontario Ministry of Agriculture, Food and Rural Affairs
USEPA	Ontario Ministry of the Environment, Conservation and Parks, Ontario Ministry of Natural Resources and Forestry
NOAA	Great Lakes and St. Lawrence Cities Initiative
United States Department of Agriculture	Indiana Department of Environmental Management
	Michigan Department of Environmental Quality
	New York State Department of Environmental Conservation
	Ohio Department of Agriculture
	Ohio Department of Natural Resources and Forestry
	Ohio Environmental Protection Agency
	Pennsylvania Department of Environmental Protection

4.1.2 Federal stakeholders

Federal stakeholders that participate directly in the LE-AMF process or impact activities related to LE-AMF implementation are described below.

USEPA: Provides technical and financial support to states for nutrient management and HABs prevention work. The agency assists Great Lakes states and partners working collaboratively to minimize and prevent HABs. USEPA also implements a national research program and studies the effects of HABs in order to provide the latest scientific information on health effects, analytical methods and recommendations for public water systems on treatment technologies available to manage risks from harmful algal blooms and cyanotoxins. Additionally, SEPA co-leads the development of binational action plans for each Great Lake, known as Lakewide Action and Management Plans.

Great Lakes National Program Office: Housed within the USEPA, the Great Lakes National Program Office provides liaison services with Canada and is specifically charged with coordinating USEPA actions with those of other US federal agencies, states and local authorities in the interest of achieving Agreement objectives and commitments. The Great Lakes National Program Office is authorized under the US Clean Water Act to monitor the water quality of the Great Lakes and develop and implement action plans and strategies to improve Great Lakes water quality.

United States Army Corps of Engineers: Leverages several authorities to address concerns related to HABs and leads the Great Lakes Tributary Modeling Program and the Ecosystem Management and Restoration Research Program.

United States Department of Agriculture Natural Resources Conservation Service: Promotes innovation in agriculture and preservation of US natural resources through conservation, restored forests, improved watersheds and healthy private working lands.

US Geological Survey: Provides a key science support role in nutrient load estimation, assesses water quality trends, and forecasts the presence of HABs and hypoxia.

NOAA: NOAA's Great Lakes Environmental Research Laboratory and National Center for Coastal Ocean Science work with academic, agency and private sector partners to actively monitor Lake Erie, conduct fundamental HABs research, and transition models to operation to issue forecasts on cyanobacteria location and concentration. NOAA also leads a number of HABs and hypoxia research efforts in the Great Lakes, works with Great Lakes states and the USEPA to address nonpoint source pollution through coastal zone management programs, and supports vital education and outreach through the Sea Grant Program.

ECCC: Collaborates with Ontario through the Canada-Ontario Agreement. ECCC also co-chairs the Annex 4 Subcommittee and co-leads the development of binational Lakewide Action and Management Plans.

Agriculture and Agri-Food Canada: Federal agency in Canada focused on a competitive and sustainable Canadian agriculture and agri-food sector.

4.1.3 State and provincial level stakeholders

State and provincial level stakeholders for the LE-AMF are engaged in the design and implementation of domestic DAP processes and related activities. Some (but not all) state and provincial level stakeholders are members of the Annex 4 Subcommittee as summarized in **Section 4.1.1**. State and provincial level stakeholders summarized in **Table 9** represent entities responsible for DAP design and implementation. However, this may not reflect all entities that are stakeholders in the DAPs, given that the DAPs vary in comprehensiveness in listing stakeholders.

Table 9. LE-AMF state and provincial stakeholders

State	Core DAP Stakeholders
Ohio	• Ohio Department of Agriculture • Ohio Environmental Protection Agency • Ohio Lake Erie Commission • Ohio Department of Health • Ohio Department of Natural Resources
Michigan	• Michigan Department of Environment, Great Lakes, and Energy, Water Resource Division • Michigan Department of Agriculture and Rural Development • Michigan Department of Natural Resources
Pennsylvania	• Pennsylvania Department of Environmental Protection
Indiana	• Indiana Department of Environmental Management • Indiana Department of Agriculture • Multiple members of a DAP Advisory Committee
Ontario	• Ontario Ministry of the Environment, Conservation and Parks • Ontario Ministry of Natural Resources and Forestry • Ontario Ministry of Agriculture, Food and Rural Affairs

4.1.4 Survey results: coordinated planning and implementation

Survey results suggest that more work is required to develop a higher level of engagement of various stakeholders with the LE-AMF. The level of engagement across all respondents to the survey in developing the LE-AMF was relatively low (average of 2.7 out of a scale of 1 through 5), and, while there was a high level of understanding of how the LE-AMF compares to the AM framework contained in the board's 2019 report, this high level of understanding was only present among a small number of people (average of 4.14 out of a scale of 1 through 5, but this average reflects only seven respondents).

Survey respondents were asked about relevant stakeholders that could or should be engaged in the LE-AMF process. A substantial list of relevant stakeholders spanning both public and private entities at various scales was compiled through the survey (**Table 10**). Respondents listed a number of stakeholders that are not directly included in the LE-AMF process through the Annex 4 Subcommittee or related workgroups, such as the local public sector (e.g., municipalities, local conservation entities such as Soil and Water Conservation Districts) and the private sector (e.g., industry, other affected sectors such as agribusiness and landowners).

Table 10. Stakeholders identified by survey respondents

Stakeholder Scale	Stakeholder Suggestions
Binational	• International Joint Commission • Great Lakes Commission • Great Lakes Fishery Commission
US federal	• NOAA • US Geological Survey • US Army Corps of Engineers • US Department of Agriculture Natural Resource Conservation Service
Canadian federal	• None mentioned by survey respondents
State/Provincial	• State/provincial officials • State/provincial personnel responsible for DAPs
Local	• Municipalities • District conservationists • Conservation Authorities • County commissioners, engineers, auditors, and staff • Soil and Water Conservation Districts • Watershed groups
Private sector/nongovernmental organizations	• Industry/affected sectors (e.g., recreation, drinking water utilities) • Agriculture • Agribusiness • Landowners, including absentee landowners • Farmers • Concentrated Animal Feeding Operations • Environmental justice groups • Academic institutions
Indigenous governments	• Tribes, First Nations, Métis communities

4.2 Gaps and unmet needs

The current status of AM processes within the LE-AMF demonstrates that several important gaps and unmet needs must be addressed in order to meet the goals of the LE-AMF.

4.2.1 Communication and coordination

- The tight-knit, collaborative nature of Annex 4 provides a shared sense of purpose reflected in progress to date. However, Annex 4 participation by other stakeholders is needed.

- In addition to expanding its level of stakeholder participation, the Annex 4 Subcommittee needs to focus on providing an adequate depth of scientific knowledge, maintaining a productive working relationship among members, and strengthening its focus on the AM process. Survey responses demonstrate that, while the understanding of nutrient management within Lake Erie is high across all respondents, there is only a moderate understanding of the LE-AMF planning and implementation process (and of the AM framework) (**Figure 7**). It is important to note, however, that the LE-AMF is still in draft form and communication and coordination have opportunities to expand as the document and the process moves to the final stage.

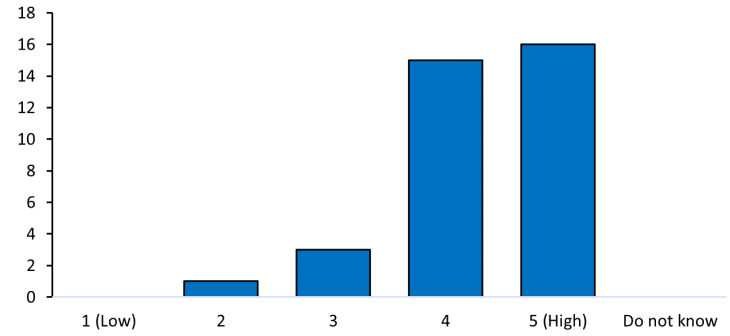
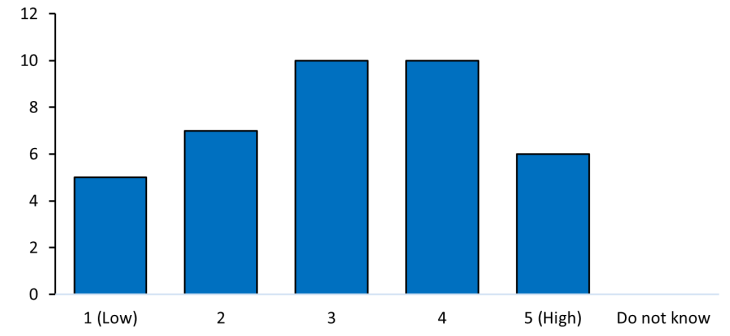
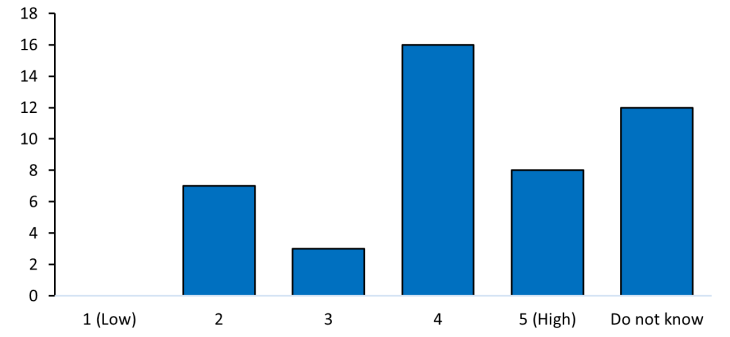
Survey respondents' understanding of nutrient management within Lake Erie was **high** (average of 4.3)	
Survey respondents' understanding of LE-AMF planning and implementation was **moderate** (average of 3.31)	
Survey respondents' understanding of AM frameworks in theory was **moderate** (average of 3.77)	

Figure 7. Survey responses, all respondents. Average ranking relates only to responses received between 1 and 5.

- The binational and domestic processes interface through the Annex 4 Subcommittee meetings. However, many unknowns remain as to how the LE-AMF will coordinate with the domestic DAP processes, particularly because the domestic jurisdictions focus primarily on a watershed scale while the LE-AMF binational process is focused on the Lake Erie basin scale. More dialogue between the domestic and binational efforts is therefore needed.

- While elements of the AM process are present in the LE-AMF, a formal schedule or workplan should be developed to identify how the different AM components will be implemented, by which workgroups, and when. This will eliminate the current *ad hoc* approach.

4.2.2 Funding

- A sustainable, dedicated source of funding to support attainment of Lake Erie ecosystem goals is lacking. At both the binational and domestic levels, the process relies on agency representatives that have many other responsibilities; there are no funds to hire staff that can work exclusively on Lake Erie nutrient reduction goals. Dedicated funding would provide for the identification and resolution of unmet needs relative to monitoring, modeling and management actions. Dedicated funding would also make the LE-AMF process timelier and more strategic and provide for a formal institutional home. Dedicated funding could include (among others) funding through the US GLRI, the Canadian Great Lakes Protection Initiative, and/or dedicated state and provincial funds from agencies involved in Lake Erie management efforts.

- Survey results support these findings, given that the survey concluded that resources directed toward research, modeling and monitoring were limited. Current resources directed at collaborative modeling averaged 2.92 (out of a scale of 1 to 5) across all responses, and resources to support a collaborative research/monitoring program averaged 2.86 (out of a scale of 1 to 5) across all responses. Comments also indicated a significant concern over the lack of sustained resources for these activities.

- One survey comment noted that a funding strategy is needed. Respondents also noted that states, provinces and the federal government have made commitments to support the LE-AMF. However, the Commission needs to increase public engagement and leverage more on-the-ground support to ensure that these commitments are met. Comments indicated that a move to more sustainable funding could include:

    - Funding the purchase and operation of equipment to support multiple years of activity.
    - Leveraging funding from other agencies or departments that have management and/or maintenance responsibilities over particular areas.
    - Requiring adoption or prohibiting certain practices.
    - Funding long-term maintenance activities via trust funds so that money is not tied to budgets that can vary from one year to the next.

Survey respondents were queried as to how additional resources could be brought into the process. The consultant team categorized responses into three buckets: communication and engagement, a focus on innovation, and funding opportunities. Ideas from survey respondents are presented in **Table 11**.

Table 11. Survey responses about leveraging additional resources.

Category	Survey Responses
Communication and engagement	• Increase awareness of the issue • Pursue public-private partnerships (agriculture and municipal) • Hire more lobbyists, marketing, and communications staff • Increase the sense of urgency, with "call to action" messaging
Focus on innovation	• Support development of technology-focused networks to encourage innovation • Pursue innovative approaches to crop insurance • Use remote sensing to document changes in crop practices • Provide scholarships that support scientific work on innovative practices that improve water quality
Funding opportunities	• Secure earmarks • Obtain grants from government and the private sector • Undertake State-specific initiatives such as H2Ohio • Engage Congress on the need to establish agency base funding • Identify existing competitive funding (e.g., National Science Foundation, NOAA) and align with LE-AMF needs

4.2.3 Data and knowledge

Survey data identified a substantial list of data gaps and research needs for meeting phosphorus reduction targets in the Lake Erie watershed and, more generally, the goals of the LE-AMF (**Table 12**). Currently, the research community is providing a substantial proportion of data needs; additional support from agencies is needed to ensure data consistency and sustainability. Examples of state agency support for relevant research are evident. For example, Ohio funds US$2 million (CDN$2.7 million) annually for research on state priorities around HABs with state agency engagement (e.g., through the Harmful Algal Bloom Research Initiative).

Interviews and survey data underscored the importance of additional data for the following:

- Subwatershed nutrient loading data and impacts of management actions on sub-watershed loads
- Sufficient data to support development of a *Cladophora* target
- Data on legacy phosphorus, given that recent research has suggested that soil legacy phosphorus may contribute 80 percent of phosphorus losses (Osterholz 2021)

Table 12. Data gaps and research needs identified by respondents in the survey.

Data Gaps	Research Needs
• BMP implementation/ agricultural practice information: higher temporal and spatial resolution is needed • Quantification of the benefits of BMPs and low impact development is needed • "Edge of field" monitoring is needed to measure BMP success • Monitoring of additional tributaries over time is needed • Studies are needed on dissolved reactive phosphorus and BMPs that capture it • Land use and land cover change at the HU code-12 level • Watershed nutrient runoff modeling • Sewage treatment plant records • Tracking of placement of manure generated at concentrated animal feeding operations • How the Lake Guardian (US research vessel program) tracks (or doesn't track) in-lake phosphorus and hypoxia • Role of nitrogen versus phosphorus, nutrients versus climate in size, duration and toxicity of harmful algal blooms • Better monitoring of Detroit River	• Mussels and nutrient dynamics • Tile drainage of phosphorus • Effectiveness of BMPs at a subwatershed scale • Role of nitrogen in HAB development • Phosphorus regeneration and resuspension processes in Lake Erie • On and offshore processes impact on Cladophora growth • Hypoxia development in the lake • Impacts of climate change • Legacy phosphorus contribution amounts and management • Instream dynamics of dissolved reactive phosphorus • Remote sensors to measure nutrient concentrations in soil and water • More extensive monitoring, US GLRI edge-of-field research (US Geological Survey) • Nutrient transport processes • Reference Ohio Department of Higher Education Harmful Algal Bloom Research Initiative lists provided in request for proposals for the program • Policies that have been effective to increase BMP adoption • Validating the Phosphorus Loss Assessment Tool for Ontario • Long-term effects of manure digesters • System understandings: interaction between production management, conservation practices, weather, soils and microbiology from the field to the lake • Process occurring between main inputs in late spring and HABs in August

The Annex 4 AM process will also benefit from integrated and coordinated data monitoring and modeling. Presently, the Annex 4 AM effort is informed by high-quality data from Heidelberg University, US Geological Survey, and other independent, existing data monitoring and modeling activities. However, these activities are not sufficiently coordinated at the Lake Erie basin scale and, therefore, are limited in their ability to deliver information at the scale and frequency required for well-informed decision-making. An LE-AMF goal is to develop "coordinated, binational monitoring programs" and the program will "consider options for standardizing and coordinating data access to support adaptive management activities" (GDIT/LimnoTech 2021, page 13). The LE-AMF also recognizes that models of Lake Erie are in "a research status" as the "…infrastructure, funding, and operational frameworks under which such models can be run do not yet exist" (GDIT/LimnoTech 2021, page 14).

Summary of survey responses about regulatory tools

Regulatory tools can have a positive impact on nutrient management. Strict regulatory tools, such as requiring National Pollutant Discharge Elimination System permits, are driven by the US Clean Water Act and are effective for point sources. However, the existing nutrient problem in the Lake Erie watershed is delivered primarily from the nonpoint source sector and, specifically, from agricultural operations that are exempted from regulation under the US Clean Water Act. Survey respondents were asked to provide information on regulatory tools that have had a positive effect on nutrient management in the Lake Erie watershed. Their responses included federal/state/provincial regulations and reflect a mix of impacts to both point source and nonpoint source activities:

- Federal legislation (e.g., US Clean Water Act; the Fisheries Act and Environmental Protection Act in Canada)
- State nutrient water quality criteria and establishing tributary phosphorus load targets
- Total Maximum Daily Load development
- National Pollutant Discharge Elimination System permits for wastewater treatment plants
- Fertilizer applicator licenses and training requirements
- Limitations on manure on frozen soils (e.g., Ohio Rule 901).
- Voluntary programs to reduce pollution from farms (e.g., Ohio's Agricultural Pollution Abatement Program).
-

Survey respondents also noted the importance of incentivizing pollution reduction activities on farms through local planning and engagement efforts, as well as government support for voluntary actions (e.g., cover crop incentive programs).

The survey also asked respondents to report on regulatory tools and BMPs that have had a positive impact on nutrient management in Lake Erie. These responses are in the boxes below.

Summary of survey responses about best management practices (BMPs)

BMPs are used for both regulatory and voluntary conservation practices in the Lake Erie watershed. Survey respondents were queried as to which BMPs have had positive effects on nutrient management in the Lake Erie watershed. The following BMPs were identified in order of most to fewest responses:

- Nutrient management planning, including the 4Rs of nutrient planning (right source, right rate, right time and right place) (13 responses)
- Subsurface incorporation/injection of fertilizer (7 responses)
- Cover crops, no till and other practices that keep soil in place (7 responses)
- Wetlands/water retention and management practices (7 responses)
- Drainage management structures (5 responses)
- Precision conservation/agriculture and profitability mapping (3 responses)
- Variable rate nutrient application (1 response)
- Riparian buffers (1 response)
- Stacking BMPs in high phosphorus contributing areas (1 response)
- Phosphorus filters (1 response)
- Soil phosphorus sampling and testing (1 response)

Respondents also provided qualitative comments on BMPs, including the following:

1. BMP effectiveness is site-specific
2. BMP effectiveness is a data/research gap;
3. BMPs alone may not solve the problem because adoption of BMPs in the Lake Erie watershed is stagnant; large structure/landscape practices may have more impact

4.3 Planning, assessment and reporting

The LE-AMF has incorporated a cycle for AM as illustrated in **Figure 5**. In this cycle, five-year evaluations are timed so that the results of the binational assessment of Lake Erie ecosystem objectives can inform assessment of management actions and nutrient loadings at the watershed level via the DAP process. As a consequence, management actions that have a positive impact on Lake Erie ecosystem objectives will result. However, a "regular and predictable" cycle for planning, assessment and reporting has not yet been achieved because the LE-AMF is very early in the AM process and has not yet completed an initial cycle.

- **Planning:** While the LE-AMF calls for annual and five-year plans, interviews suggest that these plans will be developed after the current evaluation period. LE-AMF planning—both for Framework development and plan implementation—is supported by technical assessment and reporting under the Agreement, including the State of the Great Lakes Technical Report[2] (ECCC and USEPA, 2019b) and the Lakewide Action and Management Plans developed by the Lake Erie Partnership. The Lakewide Action and Management Plans identify priority environmental threats and the strategies and actions to address them.

- **Assessment:** Assessment of the DAPs occurs on a five-year cycle, after which results are reported to allow for adjustments to the DAPs (see below). The DAPs are currently nearing the end of the first five-year period of implementation, as they were finalized in 2018 and the assessment period is underway. The LE-AMF will also undergo an assessment period, but this will be timed later as the LE-AMF is newer than the DAPs. For this reason, it is too early to establish whether a regular and predictable assessment cycle has been achieved. Nonetheless, the DAP assessment period appears to be on schedule.

- **Reporting.** Reporting occurs at several levels. Domestic jurisdictions report on progress of the DAPs every five years. Reporting in the LE-AMF is timed to allow the DAPs to incorporate research findings at the binational level, which would include the impact of phosphorus reductions on LEOs (HABs, hypoxia and *Cladophora*). According to the LE-AMF, the AM task team will produce its five-year progress evaluations, which include a review of nutrient reduction targets, a year before DAP reporting. Other reporting components related to the LE-AMF (and required by the Agreement) include Progress Reports of the Parties every three years, and the Triennial Assessment of Progress reports by the Commission.

Reporting that can also support the AM process of the LE-AMF occurs through ErieStat. ErieStat is a web platform that tracks progress (in a consistent manner) toward phosphorus reduction goals in Lake Erie. ErieStat is hosted on the Great Lakes Commission's Blue Accounting website. The Blue Accounting Program reports lake and watershed outcomes for the governments, providing a bridge between the LE-AMF and watershed-level activities. In 2022, new progress indicators were included on a redesigned ErieStat website (ECCC and USEPA, 2022a).

[2] This 2019 report assessed Lake Erie's ecosystem as in poor condition with an unchanging trend.

5.0 Sustainable Institutional Arrangements

Section 5 presents an assessment of sustainable institutional arrangements, various modeling frameworks, and research/monitoring programs the LE-AMF has achieved. The assessment includes an evaluation as to whether:

- An integrative watershed/lake modeling framework is pursued in LE-AMF design and implementation.
- A research and monitoring program has been established (in a sustainable manner) to track the effectiveness of LE-AMF actions.
- Critical, consistent data have been collected to evaluate progress in meeting stated phosphorus reduction goals.

5.1 Integrative watershed/load modeling framework

The LE-AMF acknowledges the need for robust modeling to support Lake Erie ecosystem goals. The LE-AMF states that:

> The AM Task Team will coordinate current modeling approaches (e.g., ECCC's whole-lake model, LimnoTech's western basin and whole-lake models) and continue to enhance model development and validation using new data collected through monitoring initiatives. The AM Task Team will oversee the development of operational lake models to evaluate relationships between phosphorus loads and in-lake responses and will help reduce uncertainty over time. The AM Task Team will support binational prioritization of needs for model development, operation, maintenance and enhancement (as cited in GDIT/LimnoTech 2021, page 14).

An integrated watershed/lake modeling framework is not yet included in the LE-AMF process, but work is underway to address this. Numerous watershed and lake models for Lake Erie have been developed by different entities, including academic institutions. Ongoing model development and use are evident in the region, including a model supporting in-lake ecosystem assessment for Lake Erie. However, these activities are generally siloed and are not implemented in a coordinated manner on a lakewide/watershed basis.

Modeling is undertaken by various public, private and academic institutions and includes efforts such as the multi-model effort for the Maumee River (University of Michigan), modeling for the Detroit River (University of Michigan),; edge-of-field and BMP effectiveness modeling (University of Waterloo), HAB modeling (NOAA), BMP effectiveness modeling for H2Ohio practices (the Ohio State University), and BMP effectiveness at the watershed scale using models such as SWAT (University of Michigan and the Ohio State University), the Conservation Effects Assessment Project model of the US Department of Agriculture Natural Resource Conservation

Service, and the SPARROW model.[1] These modeling efforts, however, are not yet linked to Lake Erie ecosystem processes in a coordinated and consistent manner.

In many instances, watershed modeling in the Great Lakes region tends to focus on subwatersheds on a topic-specific basis. For example, Michigan is implementing agricultural inventories using the Agriculture Conservation Planning Framework model that identifies opportunities on agricultural land to use BMPs to reduce nutrient loss. While this model is informing Michigan's DAP process, it is not integrated into other modeling efforts. Ohio is also using the Agriculture Conservation Planning Framework. Further, the project has been backed by foundation and state funding but is not funded over the long-term.[2]

During its target setting efforts in 2013-2014, the Objectives and Targets Task Team Modeling Subgroup used an ensemble of nine different lake models to inform its work by developing load-response curves on the impact of phosphorus loads on cyanobacteria, hypoxia and *Cladophora* growth. The Annex 4 Objectives and Targets Task Team used these load-response curves to determine phosphorus load reductions that address Lake Erie ecosystem objectives (Annex 4 Objectives and Targets Task Team 2015).

Efforts to improve coordination and collaboration to enhance ecosystem modeling for Lake Erie have demonstrated some progress to date. For example, a USEPA Science and Advisory Board evaluation of modeling processes and approaches recommended that a model be developed for Lake Erie as a whole (USEPA Science Advisory Board 2017).[3] In response, a contractor with a western Lake Erie basin model was contracted to extend the model to all of Lake Erie. This biophysical/hydrological model takes input data from tributaries and develops stress/response curves for HAB extent/severity from phosphorus inputs. The model can also simulate hypoxia in the central basin.

The USEPA Science Advisory Board report also recommended a process-based eutrophication model be used in an adaptive management process to meet Lake Erie ecosystem objectives. Further, the report advised that "…consideration should be given to developing one process-based model" and also stated that:

> These models can be used to make annual predictions of eutrophication response indicators and to test alternative hypotheses. The [USEPA Science Advisory Board] recommends that: the models be refined based on changing loadings and other new data;

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[1] More information about the SPARROW model can be accessed at: usgs.gov/mission-areas/water-resources/science/sparrow-modeling-estimating-nutrient-sediment-and-dissolved.

[2] Michigan is pursuing other funding opportunities, such as through a US$25 million (nearly CDN$34 million) appropriation the legislature made in 2021 for the Department of Agriculture and Rural Development.

[3] The report states that "Given the limitations of some models used in the analysis and the practical limits of funding, fewer models should be considered with priority given to the process-based models that have the capability to account for the response of key processes. It might prove most efficient to choose a single model for further development based on insights and demonstrated capabilities provided by the other models and the results of ongoing process research and monitoring. Consideration should be given to making the Western Lake Erie Ecosystem Model the consensus model for this purpose, with a goal of extending this model to all of Lake Erie." (USEPA Science Advisory Board 2017).

> future scenarios be evaluated to understand the effects of climate variability; estimates of uncertainty be improved in the models; lake models be linked to upstream source functions through watershed modeling; and that cases where models do not perform well be used to develop alternative hypotheses (USEPA Science Advisory Board 2017).

In brief, the USEPA Science Advisory Board has stressed the importance of linking watershed and in-lake models for AM.[4]

In 2019, the Commission's Great Lakes Science Advisory Board-Research Coordination Committee report concluded that coordinated modeling could beneficially impact nutrient management in Lake Erie (International Joint Commission Great Lakes Science Advisory Board 2019). The board's report reviewed the state of watershed and lake modeling approaches used to establish binational targets for nutrient load reductions and inform the DAP process. Among others, the board recommended the use of integrated watershed and lake models that include ecosystem response indicators that are consistent in temporal and spatial scales and include sediment transport including erosion and deposition.[5]

A modeling technical work group was formed during the summer of 2022 under the AM Task Team to support the LE-AMF. To date, the work group has focused on reviewing the state of the nine lake models used to develop the 2016 targets and new models that have been developed since the original targets were set. The work group is also addressing uncertainty around inputs from the Detroit River that impact the lake models. Membership on the workgroup includes AM Task Team members and is composed of agency, academic and private sector individuals. Resources to support the work group moving forward have not yet been secured.

5.1.1 Survey results: modeling

Survey results indicate that additional work is needed to strengthen institutional arrangements for calculating nutrient loads (**Figure 8**). In addition, survey respondents' understanding of such arrangements was only moderate (average of 3.43 out of a scale of 1 through 5), suggesting that a better understanding of those arrangements is needed as well.

[4] The USEPA Science Advisory Board states that "An important component of adaptive management is the opportunity to identify alternative management actions if reductions in loadings fail to produce the desired or anticipated outcomes. In this regard it, will be important to address the upstream dynamics of nutrient loading. This can be accomplished by linking watershed models to in-lake models and running a suite of scenarios to evaluate the effectiveness of using different combinations of BMPs over space and time" (USEPA Science Advisory Board 2017).

[5] The report was part of the Great Lakes Nutrient Adaptive Management (GLNAM) project that was conducted primarily through contracting the University of Toronto's Ecological Modeling Laboratory.

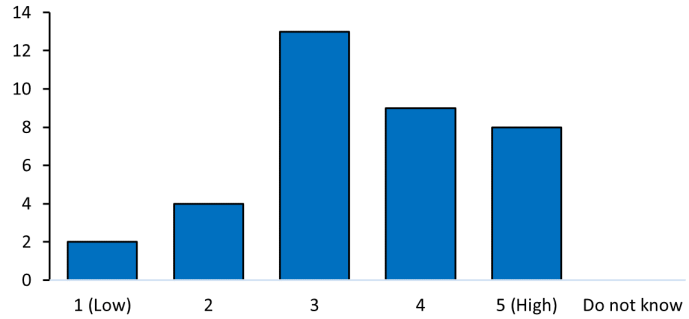
Survey respondents' understanding of institutional arrangements for calculating nutrient loads was **moderate** (average ranking of 3.43)	

Figure 8. Survey results on nutrient loads, all respondents. Average ranking relates only to responses received between 1 and 5.

Survey results from the smaller core group of LE-AMF participants show a similar need to both strengthen and improve understanding of institutional arrangements (**Figure 9**). The core team's understanding of collaboration and coordination among modeling teams within the Lake Erie watershed, and their understanding of collaboration among organizations leading these models, were all found to be moderate.

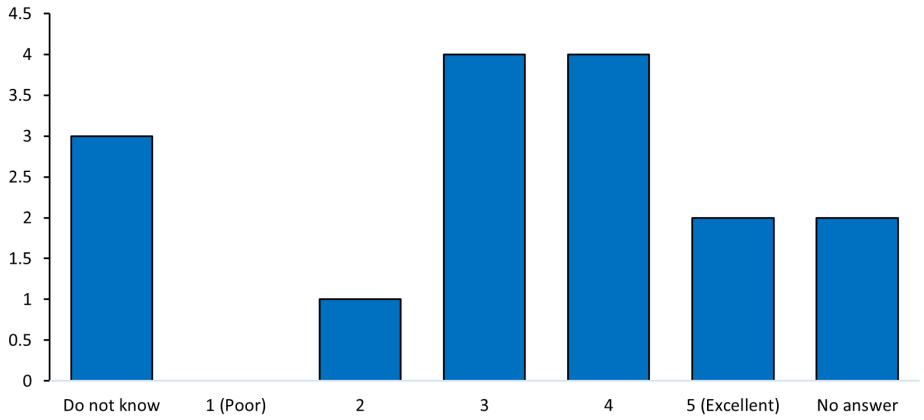
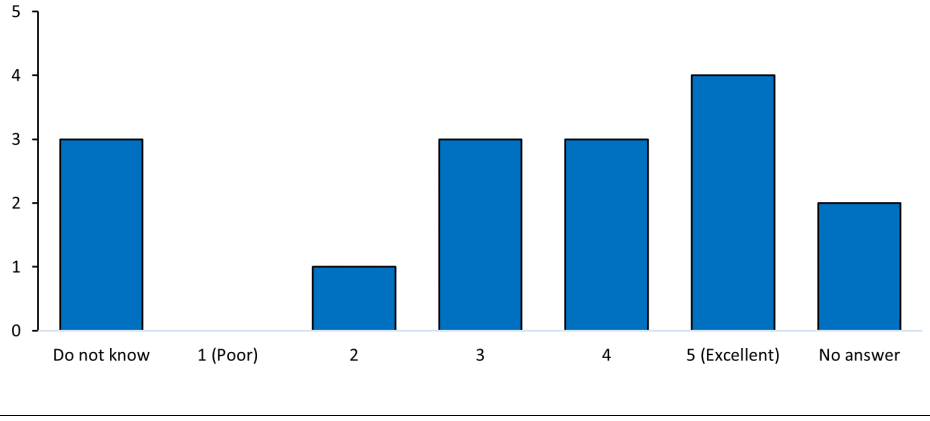
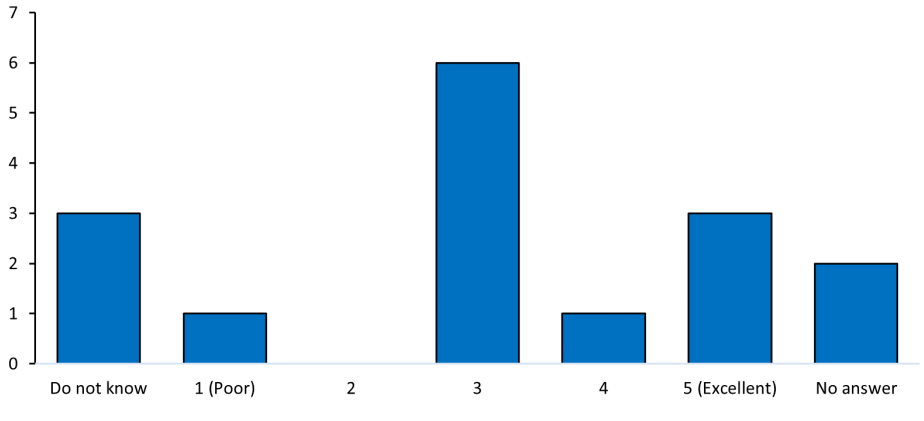
LE-AMF core team understanding of collaboration among modeling teams within the Lake Erie watershed (average ranking of 3.64)	
LE-AMF core team understanding of collaboration among organizations leading these models (average ranking of 3.91)	
LE-AMF core team understanding of coordination among modeling teams (average ranking of 3.45)	

Figure 9. LE-AMF core team understanding of Lake Erie modeling. Average ranking relates only to responses received between 1 and 5.

5.2 Research and monitoring programs to track effectiveness of LE-AMF actions

The Lake Erie watershed has significant research and institutional capacity for monitoring nutrients and other environmental variables; these activities can all contribute to the effectiveness of LE-AMF actions. Some programs and activities are Great Lakes basinwide, while others are more focused on the Lake Erie watershed.

Moderate progress has been made in the development of process, procedures and institutional arrangements to ensure long-term and reliable calculations of nutrient loading. However, programs that track the effectiveness of actions specifically for the LE-AMF have not yet been developed. In brief, a substantial and robust body of research and monitoring activity is ongoing in the region; what is needed is greater coordination, communication and standardization of current efforts.

5.2.1 Monitoring

A substantial amount of nutrient monitoring activity at the Lake Erie and watershed/tributary level is ongoing in the Lake Erie region. For in-lake monitoring, ECCC and the USEPA have longstanding monitoring programs in the Great Lakes including spring and summer surveys of Lake Erie water quality each year. The USEPA has implemented the Great Lakes Water Quality Monitoring Program through the Great Lakes National Program Office since 1983.[6] Data collected by ECCC and the USEPA on water quality in the Great Lakes are available through open-source resources such as the ECCC's Open Government Data Catalogue (Canada) and ErieStat (United States).

These monitoring processes are institutionalized through the Cooperative Science and Monitoring Initiative, a binational initiative under the Science Annex of the 2012 Agreement that conducts monitoring in one of the five Great Lakes every year for parameters including nutrients, invasive species and fish populations. Monitoring activities reflect priorities of the Lake Partnerships of the Agreement's Annex 2 (Lakewide Management). Lake Erie was previously monitored in 2019 and will be monitored again in 2024 under the Cooperative Science and Monitoring Initiative, but the extent to which data will be integrated with watershed monitoring activities and the AM process under the LE-AMF is yet to be determined. For the 2019 survey, the USEPA partnered with a number of other entities, including the University of Michigan's Cooperative Institute for Great Lakes Research, the Michigan Technological Research Institute, the Ohio State University, the University of Toledo, and Cornell University. For the HAB and

[6] Water quality monitoring is conducted for nutrients and metals, water chemistry and physical parameters (e.g., water and air temperature) by the USEPA's Great Lakes Water Quality Monitoring Program using the R/V Lake Guardian vessel. This vessel is also used for monitoring activities under the Cooperative Science and Monitoring Initiative.

hypoxia survey of Lake Erie, ECCC and the Department of Fisheries and Oceans in Canada operated the R/V Limnos vessel, joining the USEPA's R/V Lake Explorer II vessel. [7]

Monitoring of HABs in the western Lake Erie basin has been conducted by NOAA-Great Lakes Environmental Research Laboratory in partnership with the Cooperative Institute for Great Lakes Research at the University of Michigan since 2012.[8] The most recent Progress Report of the Parties states that NOAA conducted weekly water quality monitoring in Lake Erie from 2019-2022 to support multiple research and management purposes, including a HABs Tracker, HAB forecasts, and HABs bulletins (ECCC and USEPA, 2022b). The US Geological Survey also had a program to monitor HABs in the western Lake Erie basin that ended.

Despite these activities, monitoring ecosystem response variables in Lake Erie has been intermittent and research-based and could be better focused to inform questions and management actions under the LE-AMF. A sustainable dataset of ecosystem response in the lake is a data gap in the LE-AMF effort. The Lake Erie and Lake St. Clair HABs Working Group for the Annex 4 Binational AM Task Team prepared a report in 2021 making recommendations for binational monitoring of HABs in Lake Erie and Lake St. Clair to support the LE-AMF and track and report on progress in meeting eutrophication response indicators and LEOs. This report is currently in draft form and findings, and recommendations are not finalized for inclusion in this report. However, this is an important step towards improving binational monitoring of lake ecosystem variables. The 2018 US Action Plan for Lake Erie may also improve monitoring of phosphorus loads to Lake Erie, provided that long-term monitoring stations on tributaries are established (USEPA 2018).

Tributary/watershed-level monitoring of water quality is conducted by a number of entities including public agencies at the federal, state and local level and academic institutions that work cooperatively to compile and publish data (see **Appendix D**). Efforts among academic institutions in the United States are robust and include (among others) the National Center for Water Quality Research at Heidelberg University and the Ohio State University (through the Stone Laboratory and Ohio Sea Grant). Heidelberg University is one example of an effective tributary/watershed monitoring program in terms of its longevity and frequency. Heidelberg has been monitoring the River Raisin, Maumee, Sandusky and Cuyahoga Rivers since the 1970s and conducts frequent monitoring (e.g., a minimum of one time per day and up to three times a day during storm events). This frequency is unmatched by any other monitoring program in Lake Erie.

An existing institutional arrangement for monitoring watersheds draining into Lake Erie from Ohio exists between the Ohio-Kentucky-Indiana Water Science Center at US Geological Survey, the Ohio Department of Natural Resources, Ohio Environmental Protection Agency, and

[7] More information on the surveys conducted by the USEPA on the Lake Guardian for the Cooperative Science and Monitoring Initiative on Lake Erie in 2019 can be accessed at: epa.gov/great-lakes-monitoring/surveys-conducted-lake-guardian-2019.

[8] More information about physical, chemical, and biological water quality monitoring data to support detection of HABs in western Lake Erie, collected by the Great Lakes Environmental Research Laboratory and the Cooperative Institute for Great Lakes Research since 2012 can be accessed at: ncei.noaa.gov/access/metadata/landing-page/bin/iso?id=gov.noaa.nodc:GLERL-CIGLR-HAB-LakeErie-water-qual.

Heidelberg University's National Center for Water Quality Research. This relationship is important given the relative significance of nutrient loads delivered from the Maumee River (Maccoux et al. 2016). The Ohio Lake Erie Commission publishes annual water monitoring summaries of nutrient loads and concentrations for dissolved reactive phosphorus, total phosphorus and nitrogen for the loading season—defined as the season of the year, March through July, where nutrient concentrations are highly correlated with HABs—based on data compiled from these sources to inform progress towards Agreement Annex 4 nutrient goals. The summaries are accompanied by access to the full monitoring dataset. Funding for this tributary monitoring activity is obtained from a variety of federal, state and local sources, all of which must be renewed annually or biannually. A dedicated source of long-term funding does not exist.[9]

Monitoring of priority watersheds draining to Lake Erie from Canada (e.g., Leamington and Thames Rivers) is performed by ECCC, the Ontario Ministry of Environment, Conservation and Parks, and Ontario's Lake Erie Conservation Authorities (watershed-based organizations with jurisdictions over regional environmental activities, including water quality-related work). The Essex Region Conservation Authority and the Lower Thames Conservation Authority intensively monitors the Leamington and Thames Rivers, respectively.

Annex 4 has already invested time to inventory tributary monitoring activities in and around Lake Erie and to make recommendations on improving monitoring. In 2016, a Tributary Monitoring Subgroup was formed under Annex 4 to develop a coordinated monitoring strategy and network for tributary data to support assessment of phosphorus targets. In May 2017, the Tributary Monitoring Subgroup provided a summary to the Annex 4 Subcommittee on progress to date, including an inventory of tributary monitoring sites in the Lake Erie watershed in spreadsheet format. The Subgroup had also assessed sampling programs for calculating loads and flow-weighted mean concentrations and created a map of sampling locations with sampling frequencies.

Enhanced coordination of watershed monitoring in the Lake Erie region under the LE-AMF would lead to more progress in ensuring long-term and reliable calculations of nutrient loading. Monitoring efforts are largely ad hoc and uncoordinated, thereby differing in geographic coverage, sampling methods, environmental data captured, timescale and purposes for which the data are collected. Calculating accurate nutrient loads requires a substantial investment in equipment, personnel and data management, and frequent monitoring is needed to capture storm events during which a large proportion of nutrient loads are delivered.

Despite their importance to Lake Erie and the Great Lakes basin in general, adequate and sustainable funding for watershed monitoring efforts is problematic. As noted in this report,

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[9] Funding sources for tributary monitoring of Ohio watersheds draining to Lake Erie include USEPA GLRI, Ohio Clean Lakes Initiative Healthy Lake Erie Fund, Ohio Department of Natural Resources, Ohio Environmental Protection Agency Surface Water Improvement Fund, US Department of Agriculture Natural Resource Conservation Service Conservation Effects Assessment Project, Northeast Ohio Regional Sewer District, the City of Findlay, The Andersons, Inc. and the Michigan Department of Environmental Quality (Ohio Lake Erie Commission 2020b).

many such monitoring efforts are funded through (highly variable) federal, state or provincial appropriations or through annual grant funding.

5.2.2 Research

A robust research community exists in the Great Lakes region and has the capacity to support decision-making on nutrient reduction management actions and their effectiveness. However, this research is spread across various government agencies (at all levels) and academia. Further, results from research activities are produced at different spatial and geographic scales. Mechanisms to promote collaboration, coordination and information-sharing are limited, but do exist. For example, the International Association for Great Lakes Research is a cross-border organization that brings research together through a peer-reviewed publication, an annual conference and various other avenues. Progress in supporting the assessment of LE-AMF effectiveness could be bolstered by greater coordination of research activities through the AM Task Team.

Research on the effectiveness of BMPs on nutrient load reductions on agricultural lands has entailed watershed modeling at various spatial scales. Such research supports the LE-AMF effort. For example, if certain BMPs are adopted at rates between 50 and 75 percent, a 40 percent reduction in phosphorus loadings has been determined to be achievable (Keitzer et al 2016; Natural Resource Conservation Service 2016 as cited in Wilson et al. 2018; Scavia et al. 2017) However, an adoption rate among farmers of recommended BMP practices has also been determined to range between 20 and 50 percent in the western Lake Erie basin (Wilson et al. 2018).

HABs research is presently extensive and entails prevention, modeling, forecasting, monitoring and detection efforts, as well as communicating results to the research and management communities as well as the public. The Great Lakes HABs Collaborative, founded by the Great Lakes Commission and the US Geological Survey Great Lakes Science Center, is a binational organization that brings scientists together to disseminate knowledge around research and build connections and consensus on HABs. In addition, Ohio Sea Grant manages the Harmful Algal Bloom Research Initiative, an investment by the Ohio Department of Higher Education after the Toledo water crisis in 2014 to fund research into HABs in Lake Erie. Approximately US$7.5 million (CDN$10 million) has been allocated since 2015 into this research. Matching funds have been contributed by the Ohio Environmental Protection Agency and other universities. NOAA invests approximately US$6 million (CDN$7.9 million) annually into HABs research through its Great Lakes Environmental Research Laboratory, National Centers for Coastal Ocean Science, Integrated Ocean Observing System, and Sea Grant (Michigan and Ohio). In addition, in fiscal year 2022 and 2023, the NOAA Great Lake Environmental Research Laboratory received more than US$5.5 million (CDN$7.25 million) through the USEPA GLRI program to address HABs and hypoxia in Lake Erie.

5.2.3 Survey results: research/monitoring

Survey responses indicate that understanding of institutional arrangements for research and monitoring programs is moderate both for all survey respondents and from the LE-AMF core team (**Figures 10** and **11**). As a result, it can be concluded that additional efforts to understand the roles and responsibilities of institutional arrangements are needed, as well as enhanced coordination of research and monitoring activities that support LE-AMF efforts.

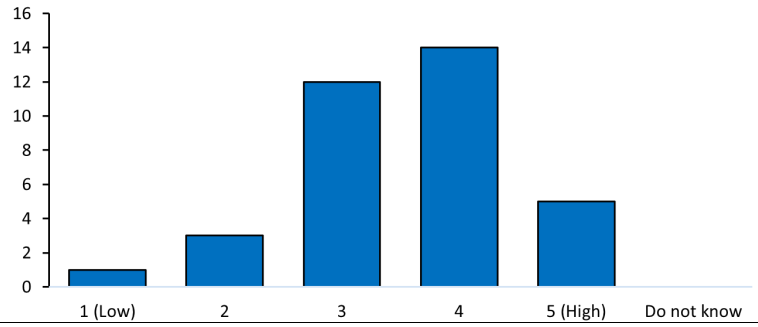
Survey respondents' understanding of institutional arrangements for research/monitoring programs was **moderate** (average ranking of 3.54)	

Figure 10. Survey response, research/monitoring, all respondents. Average ranking relates only to responses received between 1 and 5.

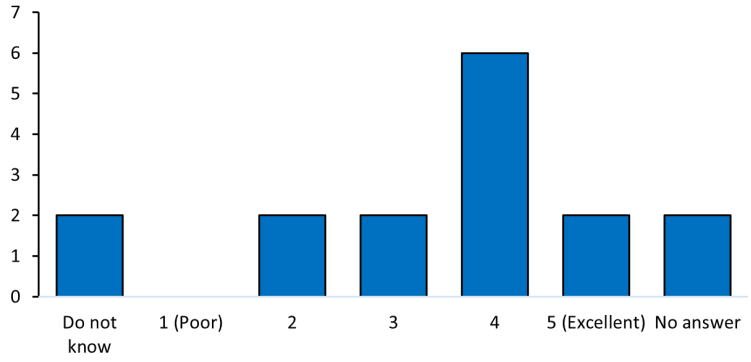
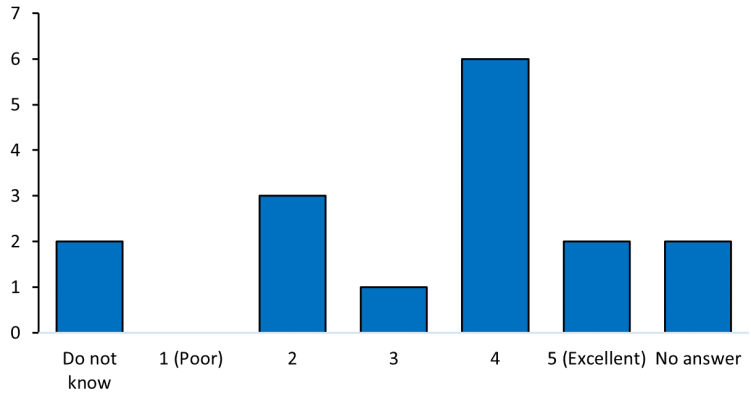
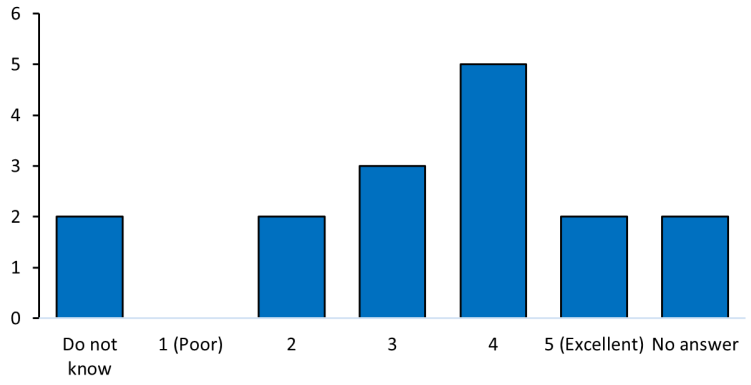
LE-AMF core team understanding of collaboration among research/monitoring teams (average ranking of 3.67)	
LE-AMF core team understanding of collaboration among organizations leading the research/monitoring programs (average ranking of 3.58)	
LE-AMF core team understanding of coordination among organizations leading the research/monitoring programs (average ranking of 3.58)	

Figure 11. Survey response, research/monitoring, LE-AMF core team. Average ranking relates only to responses received between 1 and 5.

5.3 Collection of critical and consistent data to evaluate progress

Models and monitoring activities provide phosphorus data for the Lake Erie basin that allow for LE-AMF assessment efforts, but enhanced coordination and attention to research gaps is needed.

Key data collection findings that support nutrient reduction activities of the LE-AMF were identified through literature review, interviews and the survey. These findings are:

- Data collection supporting HAB and hypoxia assessment and management is relatively robust; better data is required to support *Cladophora* target development.

- Data gaps exist for HABs. The Great Lakes HABs collaborative assessed knowledge gaps for the Great Lakes as a whole and for each individual lake (Great Lakes HABs Collaborative 2021). The gaps for Lake Erie include runoff event timing, legacy phosphorus impacts, and the impacts of nitrogen on blooms.

- More data are required to understand the impact of legacy phosphorus on load reduction goals.

- Loading data from major Lake Erie tributaries are fairly robust; additional data collection and refinement are required to incorporate the impact of the Detroit and Leamington Rivers.

- Tributary monitoring is sometimes collected well upstream of the river mouth (e.g., the Maumee River monitoring station is approximately 20 miles from the river mouth); data on loading at the river mouths is therefore sometimes lacking. Efforts to address this include the Ohio Environmental Protection Agency Nutrient Mass Balance studies.

- Gaps exist in the understanding of how phosphorus loading from the Lake Erie tributaries impact in-lake ecosystem variables. Gaps are small for total phosphorus and dissolved reactive phosphorus in the western Lake Erie basin but greater for hypoxia in the central Lake Erie basin.

- Gaps exist on nitrogen delivery from tributaries and the impact of nitrogen on algal blooms in the lake.

- Gaps exist on the impact of climate change on ecosystem variables and algal blooms in Lake Erie.

Data to support assessment of in-lake ecosystem variables is ultimately used to update ErieStat, a publicly available platform that informs Agreement implementation efforts. The US Geological Survey assembles a Lake Erie loading document each year that compiles data for the previous water year (October 1-September 30) to support assessment of overall progress toward phosphorus reductions in the western and central Basins. Data are solicited include Heidelberg University, ECCC, the Essex Region Conservation Authority, US Geological Survey (for non-Heidelberg monitoring data), and wastewater treatment plants for phosphorus loading data.

6.0 Recommendations to Strengthen the Institutional Framework to Advance the Lake Erie Nutrient Adaptive Management Framework

This report's findings confirm the critical need for a successful AM process to ensure success in controlling nutrient additions to Lake Erie. The complex, multijurisdictional nature of nutrient management in Lake Erie requires an AM process that fosters cooperation, coordination and learning to realize the objectives of reduced HABs and improved ecosystem function with significant benefits to the people of Canada and the United States. The full implementation of an AM process will ensure that the investments in actions under the DAPs are coordinated and supported by measurable outcomes, and that the course of actions can be adjusted to ensure they are successful.

The LE-AMF is making some progress toward realizing the full potential of the AM process reflected in the board's 2019 report. A comprehensive AM framework has been developed within the LE-AMF document, with the requisite AM components included, and leverages a substantial research, monitoring, and institutional infrastructure in the binational Lake Erie region to support the process. Further, significant enthusiasm is evident from various people deeply involved with the process. However, progress to date is somewhat insular and *ad hoc*, compromising the full potential of the LE-AMF. More work remains, particularly in the areas of engagement, collaboration, communication and integration. Increasing and strengthening these considerations will help address other areas of need, such as data and research gaps, integrating existing modeling and monitoring efforts, and identifying more sustainable sources of funding for LE-AMF-related activities.

Survey respondents were asked about the top three ways to improve the LE-AMF institutional framework to advance Lake Erie nutrient management goals. **Table 13** (below) captures the primary categories and indicates the number of responses within each.

Table 13. Survey responses for improvements to the LE-AMF.

Top Categories	Examples
Increase coordination (8 responses)	• Integrate science and management • Couple watershed and in-lake processes • Coordinate models and monitoring
Improve communication (8 responses)	• Create a one-page fact sheet • Communicate who is participating in the LE-AMF
Improve governance of the LE-AMF (6 responses)	• Establish advisory board • Support state and provincial AM needs
Secure more resources (5 responses)	• Estimate funding needed to fully execute the LE-AMF • Increase human resources for the process
Improve *goal setting* and evaluation (5 responses)	• Establish clear nutrient goals for Lake Erie central basin • Establish clear nutrient goals overall
Improve regulation (4 responses)	• Enforce existing regulations • Let Ohio implement a total maximum daily load

Survey responses, document review, consultant input and interviews were used to develop the following recommendations for addressing gaps in the LE-AMF process and moving the Lake Erie region further along to meeting nutrient reduction goals and LEOs in Lake Erie.

Recommendations

1. **Improve communications to link domestic and binational AM processes.**

Overall knowledge and understanding of the LE-AMF process remains limited to a small group of individuals deeply involved in the work at the binational level (e.g., the AM Task Team). In addition, communication and coordination between the binational and domestic AM processes is limited.

- Finalize and release the final LE-AMF document with sufficient communication of the final framework to domestic jurisdictions and to external stakeholders.

- Ask domestic jurisdictions to link the LE-AMF and DAPs together by referencing the LE-AMF in the DAPs.

- Create a communications subgroup under the Annex 4 Subcommittee.

- Increase internal LE-AMF communication and the frequency of meetings in order to increase knowledge exchange/information sharing at the top levels of the LE-AMF process.

- Bring additional stakeholders onto the Annex 4 Subcommittee, especially from state, provincial, local, nongovernmental organization and private sector entities conducting modeling and monitoring work in the Lake Erie basin.

- Increase communication of the work of the Annex 4 AM Task Team around the LE-AMF to domestic jurisdictions. Allow for more time in Annex 4 Subcommittee meetings for domestic DAP updates and for knowledge exchange. Hold biannual meetings of all domestic jurisdictions to share knowledge, best practices and lessons learned from DAP implementation and progress reached.

- Increase external communication of the LE-AMF process with stakeholders. Work with Canadian and US jurisdictions on their communications and outreach around the LE-AMF to stakeholders specific to their work. Create standard communication resources that domestic jurisdictions can use in their stakeholder engagement.

2. Institutionalize the LE-AMF through dedicated funding and staffing.

The LE-AMF lacks dedicated staff focused on activities (e.g., management activities, modeling and monitoring happening in the Lake Erie region) necessary to effectively inform the different AM components. Operationalizing the LE-AMF will require dedicated funding and staffing in order to properly support the AM process of data collection, assessment and enacting change based on the assessment.

- Identify and access sustainable funding sources for research and monitoring, coordination and governance of the LE-AMF effort.

- A review of the various DAPs, as well as interview outcomes, suggest that funding sources to support DAP activities are critical for effective DAP implementation. However, such funding often carries levels of risk associated with sustainability of these funding sources. For example, monitoring activities are often grant-funded and therefore subject to budgetary decisions that may adversely affect implementation efforts.

- Importantly, dedicated funding could support workplan development for LE-AMF implementation by the AM Task Team. Currently, the process functions on a more *ad hoc* basis. The work plan could include a schedule for developing questions to reduce uncertainties, activities and projects to answer those questions, and a plan for how the LE-AMF structure (Annex 4 Subcommittee, AM Task Team, workgroups) will implement the activities and projects. This would include aligning the scope and timing of monitoring and modeling with the decision-making process. The work plan could also identify how results/recommendations of the five-year assessment will be implemented in the years after the assessment—during the next AM cycle—and by which parties.

- Similarly, existing and new resources should be utilized to move the AM process from *ad hoc* to scheduled and consistent. This would include providing resources to support regular meetings of the domestic jurisdictions and the domestic jurisdictions with the binational process.

- Explore new funding pursuant to such prospective opportunities such as the US Inflation Reduction Act, US federal infrastructure legislation, and the GLRI. Explore a dedicated home for the LE-AMF with dedicated staff.

- Individuals supporting LE-AMF development and implementation via the AM Task Team and/or the Annex 4 Subcommittee do so as time permits, given their other employment responsibilities. This is the case for International Joint Commission staff as well. As a result, the ability to focus on LE-AMF implementation is limited.

- Review the results of the five-year assessment to determine where in the AM process additional staff is needed and what type of staff (e.g., administrative, technical).

3. Create a Lake Erie Group under Annex 4 to integrate and increase links between existing activity in the Lake Erie basin.

Many disparate groups are currently working on water quality for Lake Erie. Convening these groups together with domestic jurisdictions and federal agencies working under the LE-AMF for greater alignment of research, monitoring and modeling and knowledge exchange would positively impact the LE-AMF process. While the Lake Erie Lakewide Action and Management Plan is a potential home for this group (Annex 2), the specific focus on the challenge of nutrients makes Annex 4 a more appropriate home for this group. Groups that could be convened under an Annex 4 Lake Erie group (along with active participants in the LE-AMF that sit on the Annex 4 Subcommittee and the various task teams and workgroups) could include the HABs Collaborative, Lake Erie Partnership and the International Association of Great Lakes Research. This group could:

- Increase collaboration and coordination to ensure consistency in modeling and monitoring protocols.

- Encourage domestic jurisdictions to select consistent nutrient loading/load reduction models to enable comparability of BMP effectiveness tracking and progress across jurisdictions. Multiple models are available and used in the Lake Erie basin: some states for example use the USEPA Region 5 BMP load reduction model, while others use the Spreadsheet Tool for Estimating Pollutant Loads, the Soil and Water Assessment Tool, and/or the Canadian Watershed Evaluation Tool.

- Consider recommendations contained in the yet-to-be-finalized November 2021 (unpublished draft) report of the Lake Erie and Lake St. Clair HAB Working Group for monitoring of HABs in Lake Erie and Lake St. Clair. This includes developing a binational HABs monitoring plan through the HABs working group or a sub-group.

4. Address key data and research gaps.

Key data and research gaps remain and need to be addressed to better support the LE-AMF. The Annex 4 Subcommittee and AM Task Team could:

- Through the monitoring subgroup, conduct a workshop to identify how the current Lake Erie in-lake monitoring efforts could be further aligned with the LE-AMF to provide relevant data to support management decisions and assessment under the LE-AMF.

- Communicate support and help to identify funding for research to develop *Cladophora* targets, to better understand the role of nitrogen in algal blooms and toxins and the role of legacy phosphorus in phosphorus loadings, the role of tile drainage in phosphorus and other nutrient delivery to waterways, and the impact of BMPs on load reductions. Many possibilities exist for BMPs at various scales to tackle nonpoint source pollution; a better understanding and precision of the location and type of BMPs (including multiple stacked BMPs) across the landscape will support prioritization of those areas with higher potential for impacting water quality.

5. Provide more guidance to both Canadian and US jurisdictions to improve phosphorus load reduction outcomes.

Standard guidance from the Annex 4 AM Task Team to domestic jurisdictions on how to better carry out the work of phosphorus reduction can leverage best practices and lessons learned across the DAPs. Elements of guidance can be incorporated into the LE-AMF and subsequently in the DAP revisions as appropriate to the domestic jurisdictions.

- Encourage domestic jurisdictions to increase the focus on adaptive management as an organizing principle of the DAPs, either through DAP revisions or through developing specific adaptive management plans that complement enhance the DAP documents (e.g., Michigan).

- Encourage local jurisdictions to include implementation plans in their DAP documents and nutrient reduction activities. Action and milestone tables are helpful to summarize management actions, timelines on which they will be completed and the nutrient load reductions that will result.

- Encourage domestic jurisdictions to evaluate progress at more localized scales and through using additional metrics in addition to load reductions.

- Encourage domestic jurisdictions to evaluate progress at the subwatershed level through the DAP process. Water quality improvements in major rivers or at the final outlets of tributaries to Lake Erie may not show improvement for long periods of time;[1] monitoring progress at subwatershed levels in smaller tributaries (and indeed at the individual facility scale, such as through edge-of-field monitoring on farms and monitoring discharges by

[1] See Meals and Dressing, 2008 for example.

point sources) will identify localities and watersheds where improvements are being made, providing additional data and motivation to support ongoing load reduction efforts and identifying those practices or other elements that contribute to success.

- Encourage domestic jurisdictions to evaluate progress through metrics in addition to load reductions. This can help jurisdictions and stakeholders stay motivated and provide justification for additional funding. Additional metrics (in addition to water-quality related indicators) will also benefit the adaptive management process by providing other lenses through which to gauge progress that can motivate and then leverage additional stakeholder support. Other metrics that could be used include sector-specific indicators, social indicators and other environmental and economic indicators.

- Encourage prioritization of resource allocation at the sub-watershed level (e.g., the 12-digit HU code watershed scale).

- Some states have (through their DAPs) prioritized subwatersheds based on those with the highest phosphorus load deliveries and/or potential for load reductions. Encourage all domestic jurisdictions to do the same and to monitor results at the subwatershed level to support adaptive management and flexible decision-making to change priority areas as programs and practices are implemented and results show changes in loadings. Monitoring at the 12-digit HU code watershed scale (or at more localized geographies, as possible) will help determine progress because water quality changes more rapidly due to BMP implementation and other land-based activities at smaller scales.

- Encourage LE-AMF specific activities that go above and beyond existing regulatory and voluntary approaches. Through the DAPs, jurisdictions leverage existing regulatory and voluntary programs and approaches to meet DAP targets. Various funding sources leveraged by the jurisdictions for these activities tend to be limited in their longevity and sustainability. Therefore, more innovative and LE-AMF-specific approaches are necessary.

- Encourage a sense of urgency for the work both within Annex 4 and in Canadian and US jurisdictions.

- Encourage outreach and technical assistance for BMPs that are likely to make more of an impact on nutrient goals. A focus on BMP installation is important. However, the most familiar BMPs (e.g., cover crops, no-till) are not sufficient to address the scale of nutrient loading to Lake Erie.

6. Explore lessons learned and best practices from other examples of AM.

The Annex 4 Subcommittee and AM Task Team can increase engagement with other AM activities to share knowledge, lessons learned and best practices through implementing a webinar learning series for AM Task Team members and active stakeholders that showcases AM efforts highlighted through interviews and the survey. Potential AM efforts to focus on may include:

- Chesapeake Bay
- Mississippi River/Gulf of Mexico Watershed Nutrient Task Force (Hypoxia Task Force)
- Puget Sound Partnership
- Wisconsin Department of Natural Resources Adaptive Management
- Everglades Restoration Adaptive Management
- Sacramento-San Joaquin Delta, California (Delta Stewardship Council)
- Great Lakes-St. Lawrence River Adaptive Management Committee
- Baltic Ecosystem Adaptive Management

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Appendix A: Domestic Action Plan Summaries

Canada-Ontario DAP

Summary

The Canada-Ontario Lake Erie Action Plan (LEAP)[1] was developed under the nutrients annex of both the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health (a federal-provincial agreement) and the Agreement. The LEAP has an Implementation Team comprised of over 25 partners that have actions under the plan to reduce phosphorus loads the Lake Erie. This team is planning to meet quarterly. The LEAP also has a dedicated AM task team that recently conducted a knowledge synthesis of phosphorus flows to Lake Erie from the Canadian side and pathways from different sectors.

To support the LEAP, the AM task team developed a five-year AM Plan, a formal and detailed plan based on science, monitoring and modeling to iteratively and systematically achieve Canada-Ontario's phosphorus load reduction targets. The AM Plan includes review and recommends adjustments to actions or new actions to enable continuous improvement of the LEAP.

Through the LEAP, the AM task team developed several Lake Erie-specific AM guidance documents and resources including:

1. Adaptive Management Strategies for the Domestic Action Plan for Lake Erie
2. Models to Support Adaptive Management Strategies for the Domestic Action Plan for Lake Erie
3. A Guide for Managers and Watershed Modellers to Design Adaptive Management Implementation in Lake Erie: Evaluation of the Current State of Process-Based Modelling
4. A Guide for Managers and Watershed Modellers to Design Adaptive Management Implementation in Lake Erie: Integrating Watershed and Ecosystem-Service Models to Assess the Efficiency of Best Management Practices
5. Adaptive Management under the Canada-Ontario Lake Erie Action Plan

The LEAP was led by several federal and provincial agencies in Canada: Environment and Climate Change Canada; Agriculture and Agri-Food Canada; the Ontario Ministry of the Environment and Climate Change; the Ontario Ministry of Natural Resources and Forestry; and

[1] ECCC and Ontario Ministry of the Environment and Climate Change, 2018.

the Ontario Ministry of Agriculture, Food and Rural Affairs. Ontario has several existing commitments for water quality and nutrients for Lake Erie, including the 2015 Great Lakes Protection Act; the Western Basin of Lake Erie Collaborative Agreement; the Great Lakes Commission Joint Action Plan for Lake Erie; and the 2014 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health. The LEAP notes that it is based on more than 40 years of science around the sources and contributions of phosphorus in the region.

LEAP AM framework elements

Objectives: The water quality objectives of the LEAP under Annex 4 are presented by basin area:

- Western basin: Cyanobacteria blooms-not applicable to Canada-Ontario
- Central basin: hypoxia-reduction of 212 tons of total phosphorus entering the central basin from Canada
- Eastern basin: *Cladophora*-target not established due to scientific uncertainty
- Priority tributaries: nearshore cyanobacteria blooms-40 percent reduction from 2008 levels in the Thames River and Leamington tributaries in Canada

Management actions: To meet binational phosphorus reduction goals established by Canada and the United States in 2016, the LEAP establishes five comprehensive categories of action through which the plan will be implemented (**Table A-1**).

Table A-1. Management actions and funding sources in the Canada-Ontario Lake Erie Action Plan (source: Canada-Ontario LEAP)

Category Of Action	Actions
A: Reduce phosphorus loadings	A1: Support watershed and nearshore-based strategies and community-based planning for reducing phosphorus loadings A2: Reduce phosphorus loadings from urban areas A3. Reduce phosphorus loadings from agricultural and rural areas
B: Ensure effective policies, programs and legislation	B1: Support and strengthen policies, programs and legislation B2. Strengthen decision-making tools
C: Improve the knowledge base	C1: Conduct monitoring and modelling C2: Conduct research to better understand nutrient dynamics in the Lake Erie basin C3. Conduct research to better understand and predict the impact of climate change on the Lake Erie ecosystem C4. Conduct research to improve existing practices and develop new innovative practices and technologies to reduce phosphorus loadings
D: Educate and build awareness	D1: Enhance communication and outreach to build awareness, improve understanding and influence change D2. Share data and information
E: Strengthen leadership and coordination	E1: Improve communication and coordination E2. Establish an adaptive management framework and governance structure for implementation

For each of the categories of action above, the LEAP provides detail on actions that various stakeholders will undertake, the stakeholders involved and (at times) provides details on funding sources. Activities vary significantly in terms of the level of detail. For example, Action A3 (reduce phosphorus loadings from agricultural and rural areas) presents, in detail, both ongoing and new activities. This action calls on the federal government and the province to "continue to leverage existing funding initiatives (e.g., Species at Risk Farm Incentive Program) to support the implementation of agricultural BMPs and environmental investments in targeted regions of the Lake Erie Basin." It also states that "Canada will create an application-based funding program in 2018 that provides CDN$4.1 million over four years in financial support for projects demonstrating effectiveness of BMPs and/or innovative approaches to reducing phosphorus loads to Lake Erie." On the other hand, some activities are relatively vague. For example, the DAP states that the "Nature Conservancy of Canada will participate with and support partners to undertake initiatives that are actively seeking solutions to Lake Erie's water problems."

Monitoring and modeling: The LEAP describes ongoing monitoring and modeling activities by government agencies. It also notes that uncertainties remain that require additional attention from

a monitoring and modeling standpoint. These include factors that influence the growth of unwanted algae; relative contributions of nearshore, offshore, and legacy sources of phosphorus; the role of invasive species in nutrient cycling; and how all factors are impacted by climate change.

Adaptive management: The Canada-Ontario LEAP demonstrates a relatively strong integration of AM principles, as AM is incorporated into the LEAP in various places. Action E2 for example, calls for the establishment of "an adaptive management framework and governance structure for implementation" (LEAP page 61). The LEAP points out that "In the spirit of adaptive management, the viability of setting science-based numeric targets for the eastern basin will be revisited in 2020. In the interim, there will be targeted research efforts aimed at improving our scientific understanding of how to effectively manage the *Cladophora* problem in the eastern basin and elsewhere in the Great Lakes" (LEAP page 40). Toward this end, the DAP calls for a series of actions (e.g., research, learning, communication) to support Action E2. Also, Category A of the LEAP discusses the need to coordinate and link actions to existing federal, provincial, and municipal government initiatives, and efforts by other stakeholder groups such as conservation authorities and communities. The LEAP will be updated every five years beginning in 2023 according to a set of performance measures including reductions in phosphorus loadings; improvements in lake water quality; changes to land use and land cover; and adoption of agricultural and municipal BMPs. **Figure A-1** shows the AM process as illustrated in the LEAP.

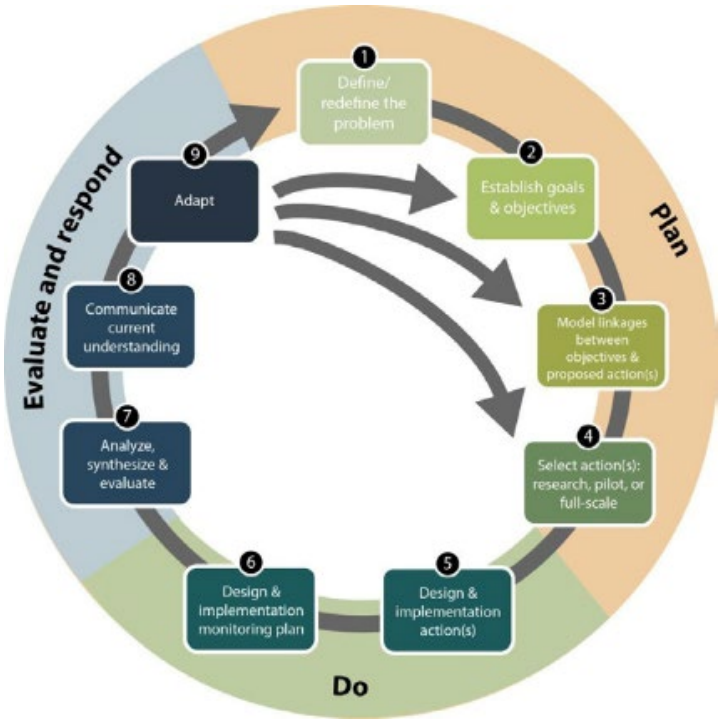

Figure A-1. AM cycle in the Canada-Ontario LEAP (Delta Stewardship Council, 2013a as included in the LEAP).

The AM strategy included in the LEAP includes annual monitoring of phosphorus in key Canadian tributaries leading to Lake Erie and in-lake nutrient eutrophication response indicators;

monitoring research and modeling; evaluation of the system response to phosphorus reduction activities; and a report and review of the LEAP every five years. The LEAP also notes that an Implementation Team will be developed to implement a framework through a collaborative governance model. Data will be held within each participating agency, but the agencies are committed to making their data available through the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health. Reporting is planned through the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health Nutrients Annex Committee and will be made available to multiple stakeholders and the public.

Provincial stakeholders: In implementing the LEAP, Canada and Ontario established a multi-sectoral Lake Erie Nutrients Working Group in addition to engaging with Indigenous communities, municipalities, conservation authorities, environmental organizations, members of the agricultural community and the public. Feedback on early draft plans was sought from the public, partners and stakeholders, including through in-person meetings. This feedback allowed for the inclusion of partner-led activities in the LEAP. The LEAP also notes that the Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health Nutrients Annex Committee partners are meeting twice a year and engaging a variety of sectors and interests through sector-based meetings and working groups.

The LEAP lists the following stakeholders in the plan:

- Alternative Land Use Services-Elgin
- Conservation Ontario
- City of London
- Ducks Unlimited Canada
- Fertilizer Canada
- Lake Erie conservation authorities
- Land Improvement Contractors of Ontario
- Municipality of Leamington
- Nature Conservancy of Canada
- Ontario Agri-Business Association
- Ontario Cover Crops Steering Committee led by Grain Farmers of Ontario
- Ontario Federation of Agriculture and Grow Ontario Together-a coalition of vested commodity associations
- Ontario Greenhouse Vegetable Growers

Sources of funding: Sources of funding identified in the LEAP for the various management actions detailed include the Great Lakes Agriculture Stewardship Initiative; the Ontario Eastern Habitat Joint Venture; the Habitat Stewardship Program; the National Wetland Conservation Fund; the Species at Risk Farm Incentive Program; the Conservation Land Tax Incentive Program; and the 50 Million Tree Program.

Indiana DAP

Summary

Indiana's DAP was led by the Indiana Department of Environmental Management in conjunction with an Advisory Committee of stakeholder representatives from a range of sectors. The DAP states that it is "…founded on the principle of adaptive management."[2] Intended to be a living document, the DAP is online and includes an Action/Milestone table that will be updated as Indiana's work under the DAP progresses. The DAP is aligned with Indiana's State Nutrient Reduction Strategy.[3]

Indiana AM framework elements

Objectives: Indiana's DAP is focused on the western Lake Erie B=basin because the Maumee River is the state's only drainage to Lake Erie. Indiana drains around 12 percent of the western Lake Erie basin and contributes phosphorus to Lake Erie through the St. Joseph, Maumee, Auglaize and St. Mary's watersheds. Analysis of monitoring data at the 8-digit HU code scale identified the St. Mary's watershed at the largest contributing watershed for total phosphorus to the Maumee River. The DAP is primarily concerned with the Agreement LEO of maintaining cyanobacteria biomass levels to reduce toxins in Lake Erie. To meet the 40 percent reduction target for total phosphorus and dissolved reactive phosphorus in Lake Erie, target goals for flow weighted mean concentration of 0.23 mg/L (total phosphorus) and 0.05 mg/L (dissolved reactive phosphorus) in spring have been established for the Maumee River as it flows from Indiana into Ohio. Indiana will measure progress toward these goals from a baseline year of 2008.

Management actions: While the St. Mary's watershed is identified as the most significant source of phosphorus to the Maumee River, Indiana's DAP identifies management actions across all 8-digit HU code watersheds in the western Lake Erie basin. Management actions have also been prioritized at the 12-digit HU code scale through an effort implemented by the DAP Advisory Committee to overlay and intersect critical areas from watershed management plans, Natural Resource Conservation Service modeled areas of greatest phosphorus load potentials, and water quality data. The DAP states that the "intersections are ranked as the top priorities and the hypotheses and actions proposed to address the serve as the basis of the adaptive management plan included in this DAP"[4]

Indiana's DAP focuses on urban and rural areas, point and nonpoint sources, and regulatory and voluntary (e.g., BMPs) actions to address DAP objectives (**Table A-2**). DAP actions with responsible parties and timelines are detailed in a DAP Action/Milestone Table in Appendix 1 of the DAP.

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[2] Indiana Department of Environmental Management, 2018.
[3] Indiana State Department of Agriculture, 2021. Indiana State Nutrient Reduction Strategy, Version 6. Accessed at: in.gov/isda/divisions/soil-conservation/indiana-state-nutrient-reduction-strategy/, May 22, 2023.
[4] Indiana Department of Environmental Management, 2018.

Table A-2. Management actions identified in Indiana's DAP (Indiana Department of Environmental Management 2018).

Nutrient Source	Management Actions
Point Sources	<u>For urban and rural areas</u> • Optimization of nutrient removal at wastewater treatment plants and publicly-owned treatment works. • Combined sewer overflows community implementation of Long-Term Control Plans. • Stormwater management by regulated entities (municipal separate storm sewer systems, construction site developers and industrial entities). • Sewer development in communities with failing septic systems. • Septic system installation, operation, maintenance and repair <u>For regulated agriculture</u> • Routine inspections to ensure compliance with concentrated feeding operation and Fertilizer Certification rules. • Timely investigation of non-compliance from regulated farms and spills from unregulated farms.
Nonpoint Sources	Overall goals for nutrient management from nonpoint sources include to enhance management, promote healthy soils, and restore natural hydrology and ecological function. Potential areas of work for nonpoint sources are listed as: • Seeking incentives and opportunities for green infrastructure in urban landscapes; Stream restoration, hydrological reconnection in rural landscapes. • Improvement of drainage through maintaining legal drains, installing two-stage ditches, and installing BMPs and saturated buffers that improve water drainage in rural landscapes. • Promoting nutrient management (implementing the 4Rs and increasing outreach on manure management) and better soil health (no specific activities listed, general principles for increasing organic matter and building healthy soils are provided).

The DAP also outlines policies and programs the state enacted between 2008 and 2016 to reduce nutrients through regulatory, non-regulatory, and watershed planning activities. Regulatory activities included fertilizer and concentrated animal feeding operation-related rules and requirements, while nonregulatory activities included development of a state soil health strategy and communication of the state's nutrient reduction strategy. Watershed planning activities included development of the Indiana Western Lake Erie Action Plan, the Western Lake Erie

Basin Partnership Strategic Plan, and the Western Lake Erie Basin Initiative Strategy (years 2016-2018), and approval of several watershed management plans under the US Clean Water Act Section 319.

Indiana has prioritized watersheds to determine where management actions will be implemented. While this has included only the 12-digit HU code watersheds that have monitoring data; the state has also identified other potentially important areas where additional monitoring will be prioritized. **Figure A-2** from the DAP shows priority HU code-12 watersheds identified in the DAP in various colors; grey indicates areas of potential concern based on Natural Resource Conservation Service and Water Management Plan data and identifies where additional monitoring is needed.

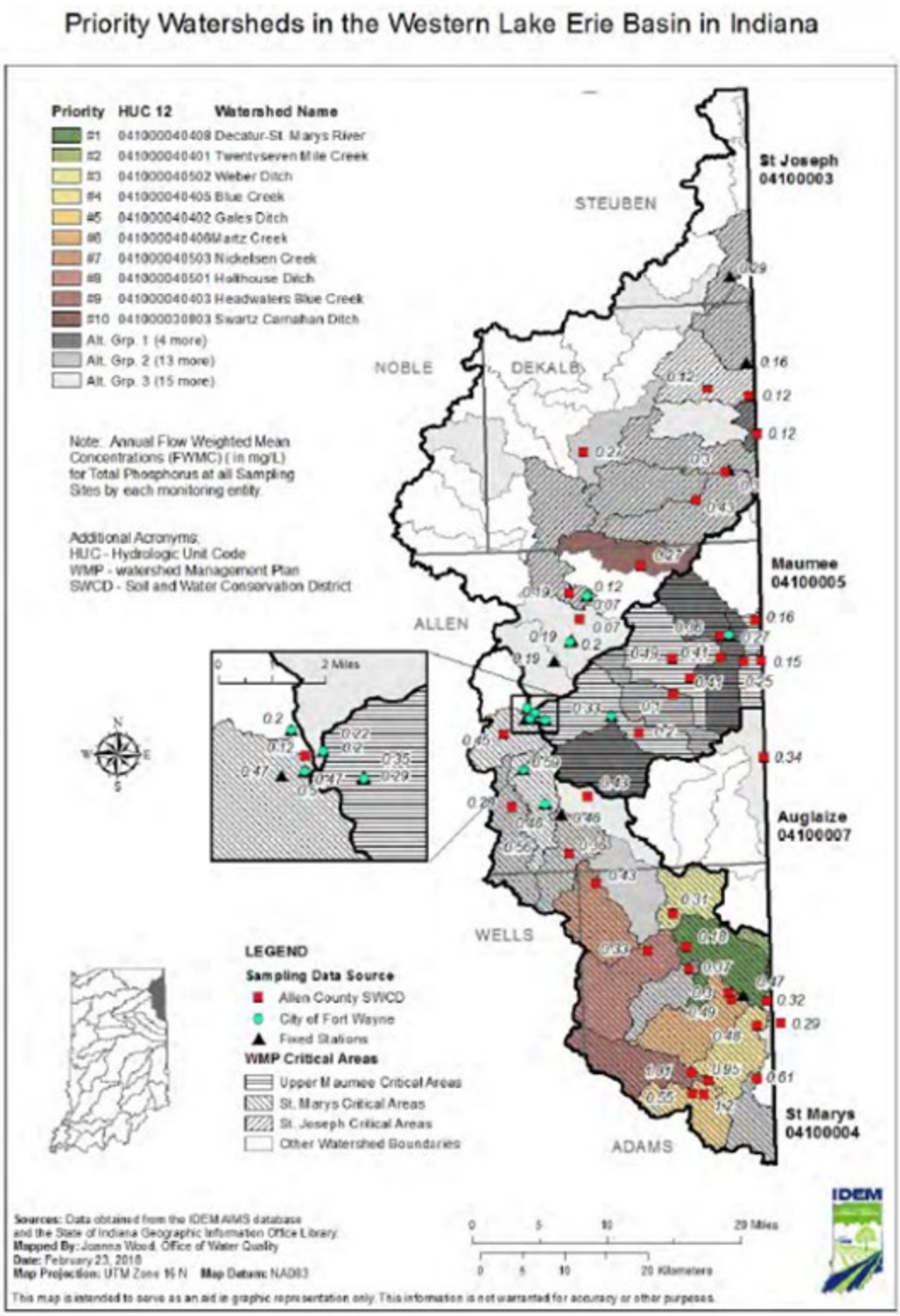

Figure A-2. Priority watersheds in the western Lake Erie basin in Indiana (Indiana Department of Environmental Management 2018, figure 4, page 13).

Monitoring and modeling: Indiana leverages multiple sources of monitoring data to implement water quality monitoring and DAP-specific activity. The Indiana Department of Environmental Management has 12 fixed monitoring station sites in the western Lake Erie basin where data are collected monthly. US Geological Survey stream gauges are also utilized. Grab samples from localities (e.g., soil and water conservation districts, municipalities) are also leveraged and provide data at a higher frequency, such as weekly, which allows for a greater understanding of the impact of storm events. The DAP notes a partnership for monitoring between the Indiana Department of Environmental Management, Indiana US Geological Survey, Ohio Environmental Protection Agency, Ohio Department of Natural Resources, Ohio US Geological Survey, and USEPA Region 5. Ohio and Indiana collaborate on the monitoring at Antwerp, Ohio (approximately 7 miles downstream from the Indiana border) as it was determined to be the most representative site for phosphorus loading on the Maumee River.

The DAP outlines existing and planned monitoring sites, and water quality monitoring parameters that will be collected and how often. Indiana and Ohio have also established priorities for new monitoring sites to understand phosphorus loads and are each funding sites through USEPA GLRI grants.

Adaptive Management: Adaptive management in Indiana's DAP (**Figure A-3**) is supported by planned monitoring and progress reporting activities, and a DAP Action/Milestone table that includes project implementation schedules and associated nutrient load reductions (where they can be calculated).

The DAP outlines hypotheses to be tested through the AM framework in Indiana:

Measuring progress on the Maumee: this will entail a comparison of the flow-weighted mean concentration from the Antwerp, Ohio monitoring site and another monitoring site to determine the most representative monitoring site in assessing Indiana's progress in meeting targets; the more representative site will be used.

Figure A-3. Adaptive management in Indiana's DAP (Indiana Department of Environmental Management 2018).

Priority 8-digit and 12-digit HU code watersheds: this will document phosphorus load reductions using an auto-sampler from actions underway (extension of sewers; construction of manure storage lagoons, and education and outreach) in select priority watersheds.

State-Level Stakeholders: State-level stakeholders (drawn from federal/state/local jurisdictions, for profit entities, nongovernmental organizations, industry, and industry associations) are members of Indiana's DAP Advisory Committee which was extensively engaged in DAP development. Committee members included the Adams County Soil and Water Conservation District; Allen County Soil and Water Conservation District; City of Fort Wayne; DeKalb County Soil and Water Conservation District; Indiana Farm Bureau; Indiana Pork Producers; Indiana University; Purdue University; Fort Wayne; Indiana State Department of Agriculture; Indiana Department of Natural Resources; Natural Resource Conservation Service of US Department of Agriculture; Sierra Club; St. Joseph Watershed Alliance; Steuben County Soil and Water Conservation District; The Nature Conservancy; Tri-State Watershed Alliance; United States Geological Survey; Agribusiness Council of Indiana; Agricultural Research Service, US Department of Agriculture; Allen Co. municipal separate storm sewer system; City of Auburn; Hoosier Environmental Council; and The Andersons, Inc.

Sources of Funding: Indiana's DAP outlines federal, state, county and municipal regulatory entities that have regulatory mechanisms focused on nutrient reduction. For example, cities and towns can utilize zoning ordinances and management of public lands to reduce nutrients; some counties may be municipal separate storm sewer systems with stormwater requirements; and soil and water conservation districts can use the construction storm water control plan review and inspection program (327 IAC 15-5) and education and outreach. Similar programs are listed for Indiana Department of Environmental Management (e.g., National Pollutant Discharge Elimination System permitting and Total Maximum Daily Load development); the Indiana State Department of Agriculture (e.g., InField Advantage Program); US Department of Agriculture Natural Resource Conservation Service (e.g., Environmental Quality Incentive Program) and US Geological Survey (e.g., stream flow gage operation and maintenance and stream and edge-of-field monitoring). These existing policies and programs have sources of funding associated with them as summarized in **Table A-3**.

Table A-3. Sources of funding identified in Indiana's DAP (Indiana Department of Environmental Management 2018)

Regulatory Entity	Sources of Funding
Cities and towns	• Taxation and utility fee authority
Counties	• Taxation and drainage assessment authority
Soil and Water Conservation Districts	• Local, state and federal grants • Partnership with NGOs for watershed planning & BMP installation
Indiana Department of Environmental Management	• State appropriations • Nonpoint source program §319(h) and 205(j)
Indiana Department of Natural Resources	• State appropriations • Lake and River Enhancement grant program
Indiana State Department of Agriculture	• State appropriations • Phosphorus soil sampling through USEPA grant • Clean Water Indiana grant program
Natural Resource Conservation Service	• Federal cost-share programs: Environmental Quality Incentive Program, Conservation Stewardship Program, Agricultural Conservation Easement Program- Wetlands Reserve Easement, GLRI

Michigan

Summary

Funded by GLRI, the Michigan DAP was developed by the DAP Team in 2018,[5] composed of senior management representatives from the state's quality of life departments: the Michigan Departments of Agriculture and Rural Development; Environment, Great Lakes, and Energy; and Natural Resources. **Table A-4** summarizes the key responsibilities of the quality of life agencies. The DAP provides information on objectives that map to Annex 4 ecosystem goals for Lake Erie, a list of management actions the state plans to continue and/or undertake to meet the objectives, a brief description of how the state will monitor and measure progress, and a list of programs that will support the management actions. AM is discussed briefly in terms of both the basin level as the quality of life agencies participate in the Annex 4 subcommittee, and at the state level where quality of life agencies track results of activities and evaluate progress toward DAP objectives.

Table A- 4. Implementing agencies for the Michigan DAP (

Quality of Life Agency	Key Responsibilities
Department of Agriculture and Rural Development	Agricultural conservation programs for nonpoint source load reductions under state and federal programs, including the Michigan Agricultural Environmental Assurance Program
Department of Environment, Great Lakes and Energy	Point source permitting, tributary nutrient load monitoring, watershed planning and implementation support
Department of Natural Resources	Fish and wildlife habitat monitoring, protection and restoration

In 2021, Michigan followed the DAP with a companion Adaptive Management Plan (AM Plan) that formalizes the AM processes to fulfill the DAP.[6] The AM Plan was prepared by the Michigan DAP Team. The AMP formalizes Michigan's move from "passive" to "active" AM, whereby "[a]ctive adaptive management provides for the use of scientific outcomes and experimentation to guide the best direction for achieving the phosphorous reductions in the basin" (Michigan Department of Environment, Great Lakes and Energy et al. 2021). The AM Plan revises and details a more targeted approach to nutrient load reductions from priority subwatersheds and agricultural inventories that will permit further targeting of areas within these subwatersheds. The AM Plan also details priority management actions, including details on implementation, tracking and development of alternative hypothesis.

[5] Michigan Department of Environmental Quality, 2018.
[6] Michigan Department of Environment, Great Lakes and Energy et al. 2021.

Michigan AM framework elements

Objectives: To meet Annex 4 ecosystem goals, Michigan's DAP strives to realize a phosphorous load reduction of 20 percent by 2020, and 40 percent by 2025 in the following tributaries and watersheds:

- Total phosphorus loads from the Detroit River
- Spring total phosphorus loads from the River Raisin
- Spring soluble reactive phosphorus loads from the River Raisin
- Spring total phosphorus and solid reactive phosphorus load contributions from the Maumee River. The DAP notes that this objective will be updated based on watershed monitoring of the Maumee River underway by Michigan, Ohio and Indiana.

Management Actions: To meet these objectives, the Michigan DAP lists 10 specific management actions the state will undertake, along with implementing agencies and programs that can support the actions. These management actions span point source and nonpoint source programs. The AM Plan describes a process of prioritizing nonpoint source phosphorus reduction activities to meet DAP objectives.[7] The AM Plan focuses on prioritizing investments in nonpoint source load reductions through agricultural inventories (developed by the US Department of Agriculture Natural Resource Conservation Service) in the13 priority subwatersheds in the Bean Creek and River Raisin watersheds that map land uses and cropping practices. The state has matched these priority watersheds with new US Geological Survey water quality gages to determine load reduction effectiveness from BMP implementation. As results are compiled, the agricultural inventories will provide for targeted BMP implementation. However, only a portion of the 13 priority subwatersheds have agricultural inventories underway.

The AM Plan details priority management actions with information on implementation, monitoring/tracking, and alternative hypothesis that may be tested (**Table A-5**). The AM Plan notes that "During the development of this Plan, the 2018 DAP Task Tracking Table was updated and is included in Appendix A to show all the various agency programs and efforts being planned or implemented to address the phosphorus issue."

The AM Plan also includes information on six projects specifically focused on adaptive management and reducing uncertainties surrounding the effectiveness of management actions (**Table A-6**). The AM Plan notes that these six projects "…are being planned, implemented, and tracked by the state to gain additional knowledge, fill research gaps, and accelerate actions to achieve the 40 percent reduction by 2025."

[7] The DAP and AM Plan note that Michigan has reached its 2020 goal of a 20 percent load reduction by addressing reductions at point source wastewater facilities, but nonpoint source reduction efforts have not been as successful and will be critical to meeting the 2025 goal of a 40 percent reduction.

Table A-5. Detail on priority management action categories included in Michigan's AM Plan (Michigan Department of Environment, Great Lakes and Energy et al. 2021)

Priority Management Action Category	Priority Management Actions	Activities to Support Actions	Activity Tracking	Funding Sources	Alternative Hypotheses or Contingencies
Point source	**Task 1**: Maintain the phosphorus reductions achieved in the GLWA discharge due in part to the more stringent TP effluent limits placed in the NPDES permit in 2013 **Task 2**: Achieve reductions in phosphorus discharged from the DUWA and continue reductions at YCUA WWTP	Maintenance and continuation of regulatory compliance for NPDES, MS4, and biosolids permits GLWA achievement of long-term CSO Control Program	NPDES required reporting	Not indicated	The influence of Detroit River loads on winter/spring diatom productivity and linkages to hypoxia is unclear; current treatment plant design may not allow for adjustments that can substantially or affordably change bioavailability of phosphorus; phosphorus speciation may not have much influence on important lake phenomena, or this may be hard to measure.
Nonpoint source	**Task 3:** Identify priority areas in Michigan's portion of the Maumee River Watershed for phosphorus reductions. Identify and implement priority actions to reduce phosphorus loads from Michigan's portion of the Maumee River Watershed **Task 4:** Support and invest in research to better understand the causes of HABs, including invasive mussels and SRP, and how these factors increase/decrease HAB events **Task 5:** Use research and field demonstrations to identify the suite of BMPs that work collectively to reduce both TP and SRP at the field implementation level **Task 6:** Implement phosphorus control actions in the River Raisin Watershed to achieve the target load reductions	Agricultural Inventory Development for HUC-12 watersheds will support watershed planning Results of inventories can be used by Conservation District staff and MAEAP technicians in working with landowners and prioritizing BMP locations	Grant reporting CREP - MAEAP database	EGLE NPS Program Erb Family Foundation CREP Funding – MDARD through General Fund	External factors such as precipitation patterns and commodity prices may counteract the impact of BMP placement optimization; cultural or other barriers to adoption may prevent implementation of inventory knowledge; rapid change in practices may cause inventories to become outdated rapidly; privacy concerns may create obstacles to inventory data collection and use; remote sensing approaches (satellite, drone, or aircraft imaging) and other methods may be a more effective and affordable monitoring approach than ground-based methods.
Michigan Agriculture Environmental Assurance Program (MAEAP)	**Task 7:** Maintain and expand partnerships to provide valuable technical and financial assistance to farmers. Continue expanded CD MAEAP technical assistance levels through 2017 and beyond **Task 8:** Increase and maintain MAEAP practice implementation for long-term water quality improvement	Farm verification for practices that reduce environmental risk across several categories	MDARD will use the MAEAP database, and cumulatively track progress using the GLWMS	Various federal, state, local cost-share programs	MAEAP program marketing, incentives, or staffing may be insufficient to result in substantial net impacts on phosphorus loading; external factors such as higher commodity prices or changing land ownership may make MAEAP enrollment and verification more difficult.
Outreach to the public and farmers	**Task 9:** Improve and increase outreach to the public and farmers to promote understanding of the basin and good conservation practices by initiating new targeted outreach campaigns, workshops, field demonstrations and information sharing	Establishment of external, science-based western Lake Erie basin stakeholder advisory group	Undecided: DAP Team will engage human dimensions experts to develop outreach plan	Not indicated	Insufficient or uneven resources and inconsistency of staffing may interfere with the ability to build needed relationships and commitments; changing administrations can destabilize programs; insufficient transparency may hinder ability or willingness of stakeholders to commit time or provide valuable input. Metrics that can engage stakeholder communities and demonstrate progress toward goals of value to them could energize contributors and create momentum and goodwill to overcome delays, misunderstandings, or inconsistencies in resources.
Wetland restoration	**Task 10:** Promote wetland restoration and land management initiatives to reduce phosphorous loading	Site prioritization selection through criteria and modeling using Landscape Level Wetland Functional Assessment and other tools	Pilot phase EGLE NPS Program grant funded projects - NPS project database MDARD funded projects - MAEAP database Cumulatively track progress using GLWMS	State will seek funding for these efforts	Cost benefits considering total benefits (habitat, phosphorus retention, carbon storage) will be sufficient to justify investments. If restored wetlands do not prove to be a cost-effective means of reducing phosphorus loads, they may still have sufficient co-benefits to justify their creation. Related programs being implemented in Ohio at a larger scale will be important to watch for lessons learned and best practices. Sufficient monitoring will need to be conducted to quantify phosphorus-related benefits over time, and to determine which maintenance practices are necessary to prevent switching of wetlands from sinks to pulsed sources over time.

Table A-6. Adaptive management projects included in Michigan's AM Plan (Michigan Department of Environment, Great Lakes and Energy et al. 2021)

Adaptive Management Project	Description	Hypothesis
Point source loading reduction	Michigan Department of Environment, Great Lakes and Energy will partner with the GLWA to design and fund a study to evaluate soluble reactive phosphorus discharge quality as a function of the level of municipal treatment, including secondary treated, primary treatment, combined sewer overflow Retention Treatment Basins, and untreated combined sewer overflows (Task 4f).	Improving understanding of phosphorus speciation in effluent may make it possible to optimize treatment operations and seasonal approaches to reduce soluble reactive phosphorus versus total phosphorus.
Agricultural inventory	Conduct Agricultural Inventories in priority HU code-12 subwatersheds in the Bean Creek (Task 3i) and River Raisin (Task 6g) Watersheds.	Higher resolution Agricultural Inventories will make it possible to more effectively place and fund BMPs.
BMP effectiveness	Implement a study to evaluate the effectiveness of DWM control practices installed to reduce tile line discharges of nitrates, total phosphorus and soluble reactive phosphorus (Task 5e). Determine the feasibility of implementing a regional commercial biodigester in the western Lake Erie basin (Task 5h). Based on prior evidence of an association between decreased CREP acreage and increased phosphorus loads, MDARD will work with agricultural partners to reinstate CREP in the western Lake Erie basin and look for associated water quality improvements, among other actions to further reduce agricultural nonpoint source issues (Task 5g).	The combination of approaches under investigation will identify multiple cost-effective practices and combinations to further reduce nonpoint source phosphorus loads, including multiple benefits from certain practices (e.g., renewable power generation from biodigesters).
Michigan Agriculture Environmental Assurance Program (MAEAP)	To better understand how MAEAP is being adopted across the western Lake Erie basin priority watersheds, MDARD is proposing to specifically identify and track the number of BMPs implemented in the following: • Bean Creek Watershed (Task 3f) • St. Joseph River Watershed (Task 3g) • River Raisin Watershed (Task 6e) Focusing on tracking progress made in these watersheds will assist the MDARD with setting quantifiable MAEAP goals and focus additional MAEAP efforts in areas of greatest environmental risk.	Using the MAEAP model in a more targeted effort will improve the adoption rate that results in improved water quality.
Outreach	The DAP Team will establish an external western Lake Erie basin stakeholder advisory group to provide input and feedback on the adaptive management process. • Establish an external, science-based western Lake Erie basin stakeholder advisory body to provide input and feedback on the adaptive management process (Task 9e). • Develop social-based metrics with assistance from social science experts to better understand public and farmer perception (Task 9d).	An improved external advisory structure for DAP implementation and evaluation will increase trust, collaboration, investment, and sustained adoption of practices.
Wetland restoration	Develop innovative strategies to enhance wetland restoration, green infrastructure, and other land management planning and implementation efforts in Southeast Michigan (Task 10a). • Construct agriculture wetland restoration pilot in the western Lake Erie basin (Task 10e). • Implement a Saline River Watershed Drain Easement Purchase pilot to incentivize drain setbacks (Task 6k).	Wetland and buffer restoration sites of sufficient size to achieve substantial phosphorus reductions and other benefits (habitat, carbon storage) can be identified, appropriate land can be acquired, and sufficient funds for construction/ maintenance/monitoring will be available, and restored sites will consistently capture and retain phosphorus as expected.

The DAP and AM Plan note that nonpoint source reductions will be necessary from the River Raisin and Upper Maumee River Watersheds to meet 2025 load reduction goals, as well as provide estimates as to the nature, extent and combination of BMPs needed to meet load reduction targets, and reductions that may be attainable across different combinations of BMP practices.

Adaptive Management: The AM Plan as proposed formalizes a planning, assessment, governance, and reporting implementation framework for the AM process (**Figure A-4**). This framework includes joint annual progress reports, two-year work plans across the quality of life agencies, and DAP updates every five years. These updates will incorporate learning from the previous DAP and specify commitments of the agencies and other stakeholders. The DAP also provides updates to the public through a "Taking Action on Lake Erie" website.

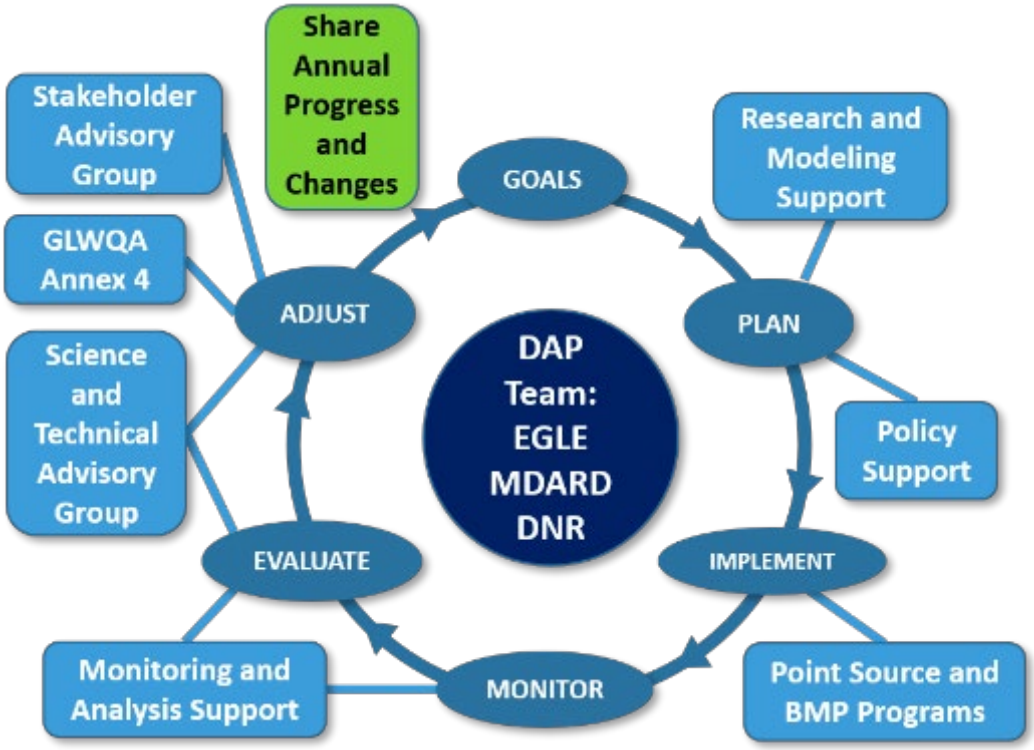

Figure A-4. Proposed conceptual governance and support structure for Michigan DAP adaptive management cycle (Michigan Department of Environmental Quality 2018)

State-Level Stakeholders

- **Michigan Department of Environment, Great Lakes, and Energy, Water Resource Division:** Responsibility for permitting point sources, monitoring tributary nutrient loads, and assisting partners with the watershed planning and implementation efforts.

- **Michigan Department of Agriculture and Rural Development:** Oversees or facilitates agricultural conservation programs that contribute to nonpoint source nutrient load reductions under a variety of federal and state programs, including Michigan Agricultural Environmental Assurance Program.

- **Michigan Department of Natural Resources**: Monitors fish and wildlife habitats and populations and works with partners to protect and restore them in Lake Erie and associated tributaries.

The DAP team also plans to form an external, science based western Lake Erie basin stakeholder advisory group and consult other experts as well for the AM process.

Ohio

Summary

The Ohio DAP[8] brings together goals, strategies, management actions, and funding sources under one umbrella to meet the goals of the Agreement using an AM approach. The DAP and associated AM process is managed and facilitated by the Ohio Lake Erie Commission, an umbrella organization composed of six state agencies and private citizens. The DAP follows the Lake Erie Collaborative Agreement (Collaborative) commitments by Ohio, Michigan and Ontario to reduce phosphorus loadings by 40 percent (signed in 2015 and 2019). The DAP provides a comprehensive inventory of strategies and actions, data monitoring efforts and modeling, indicative of the extensive planning and implementation efforts underway. However, while the DAP references AM, it does not specify how AM actions will be governed and implemented.

Ohio AM framework elements

Objectives: The objectives of the DAP have been established by Annex 4 of the Agreement as follows:

- Achieve 40 percent load total spring load reduction in total and dissolved reactive phosphorus entering Lake Erie's western basin from the Maumee River by the year 2025
- Achieve a 40 percent total spring load reduction in total phosphorus and dissolved reactive phosphorus entering Lake Erie's western basin from the Portage and Toussaint Rivers by 2025
- Achieve a 40 percent total spring load reduction in total phosphorus and dissolved reactive phosphorus entering Sandusky Bay from the Sandusky River
- Achieve a 40 percent total annual load reduction in total phosphorus entering Lake Erie's central basin by 2025, applying to priority tributary watersheds to the central basin of Lake Erie in Ohio: the Maumee, Toussaint, Portage, Sandusky, Huron, Vermilion, Cuyahoga, and Grand Rivers.

Management actions: To meet these objectives, the Ohio DAP specifies four strategies with corresponding priority management actions that have been established based on evolving research into the major sources of phosphorus in Ohio. The DAP also specifies primary state implementing agencies and stakeholders, and funding sources associated with the strategies and actions (**Table A-7**).

[8] Ohio Lake Erie Commission 2020a

Table A-7. Strategies and management actions in the Ohio DAP (Ohio Lake Erie Commission 2020a)

Strategy	Management Actions	Implementing Agencies and Stakeholders	Funding Sources Indicated
Agricultural land management BMPs	10 cost-effective BMPs identified by Ohio Department of Agriculture and Ohio Environmental Protection Agency across three categories: **Category 1:** • Nutrient management • Soil testing and nutrient management plan • Variable rate fertilization • Subsurface fertilizer placement • Manure incorporation **Category 2:** • Erosion management • Conservation crop rotation • Cover crops **Category 3:** • Water Management • Drainage water management • Edge-of-field buffers • Two stage ditch construction • Wetlands	Ohio Department of Agriculture (primary) Soil and Water Conservation Districts Ohio Agriculture Conservation Initiative Watershed coordinating groups Private agribusiness firms	H2Ohio – HB 166 Senate Bill 299 US Farm Bill (CREP) US Clean Water Act Section 319 GLRI Public-Private Partnerships
Wetland restoration	Investment in natural infrastructure following Ohio Department of Natural Resources strategic approach	Ohio Department of Natural Resources (primary)	
Community sources (home sewage treatment systems and wastewater facilities)	Identification and repair of failing how sewage treatment systems Wastewater infrastructure	Ohio Environmental Protection Agency (primary)	H2Ohio – Home Sewage Treatment Systems remediation and water treatment technologies and wastewater infrastructure Federal funding to Ohio Environmental Protection Agency (and then to local health departments in the state) for repair/replacement of failing home sewage treatment systems Ohio Environmental Protection Agency Water Pollution Control Loan Fund
Watershed Planning	Identify most effective locations for agricultural BMPs, stream restoration, and home sewage treatment systems Implementing nine element watershed plans	Joint between Ohio USEPA, Ohio Department of Agriculture, soil and water conservation districts and other watershed coordinating groups	

In addition to the priority strategies and actions summarized in **Table A-7**, development of a far-field total maximum daily load, actions to reduce phosphorus by nongovernmental organizations and private sector stakeholders, and prohibition of dumping harbor dredge material in Lake Erie will all work to achieve phosphorus reduction targets under the Ohio DAP.

Monitoring and modeling: The DAP discusses how monitoring data will be leveraged and restructured to guide assessment of these priority strategies and actions under adaptive management for the DAP. For example, the mass balance report quantifying phosphorus and nitrogen loads and sources that is required every two years was planned to include all Annex 4 priority watersheds; wetland monitoring in the western Lake Erie basin and Sandusky Bay was planned by the Ohio Department of Natural Resources to determine water quality thresholds to prevent HABs and establish a baseline through which to assess wetland restoration projects; and additional water quality sensors are planned by Ohio Department of Natural Resources. These monitoring data are collected by state agencies (e.g., ODA Division of Soil and Water Conservation, Ohio Environmental Protection Agency); county organizations (e.g., soil and water conservation districts); and Federal agencies (e.g., US Department of Agriculture Farm Service Agency). Data will be used to track progress against nutrient reduction targets.

Data collection efforts in Ohio are also supported by the National Center for Water Quality Research at Heidelberg University; it has a long history of collecting data in key Lake Erie watersheds in Ohio, providing the timing and location of phosphorus movement through the watersheds. The Ohio Environmental Protection Agency has used these data to understand the major sources of phosphorus in key watersheds, and a recent effort has provided further granularity of total phosphorus loads from different sources and geographic areas at the HU code-12 level (26-square mile units). Nonpoint sources, especially from agriculture, comprise the major proportion (87 to 93 percent) of phosphorus in most rivers under the DAP, except for the Cuyahoga River, where wastewater plants contribute nearly half.

The DAP discusses the dissemination and reporting of water quality data through several venues, including required annual reporting (e.g., Agreement Triennial Progress report, biannual Ohio Integrated Water Quality Monitoring and Assessment Report); webinars and data platforms such as ErieStat; public forums such as the Great Lakes Public Forum; and public reporting through H2Ohio.

The DAP discusses additional research that is planned to support adaptive management in Ohio by reducing uncertainty associated with water quality dynamics in the priority watersheds. Research will be supported by academic entities such as the Ohio Department of Higher Education, the University of Toledo, the Ohio State University, and Ohio Sea Grant through projects such as the Harmful Algal Bloom Research Initiative, funded by the Ohio Department of Higher Education Uncertainties that persist include the effectiveness of certain practices, dissolved reactive phosphorus, fate and transport of pollutants, nutrient cycling in Lake Erie, and the time lag between management actions and system response (e.g., lower phosphorus levels in Lake Erie).

The DAP also includes information on watershed modeling that has been conducted to support the AM process in making predictions around expected outcomes from management actions. The DAP cites two papers by researchers that model the expected phosphorus reductions from

conservation practices affecting the Maumee River and Lake Erie: these models showed the need for a diverse set of conservation practices reflecting the diversity of farms and farmer preferences across a wide area of the priority watersheds to achieve phosphorus reduction goals.

Adaptive Management: The overall planning and implementation of the DAP occurs in an informal process managed by the Ohio Lake Erie Commission. The planning and implementation process overseen by the Ohio Lake Erie Commission is not detailed in the DAP, and the state does not have a separate AM framework document detailing a process. For this reason, the research team contacted a key member of the Ohio Lake Erie Commission team to learn about the planning, learning, and implementation process followed in Ohio.

The Ohio Lake Erie Commission leads an annual monitoring and data reporting cycle driven by algal blooms in the summer. Data are collected and assessed on the algal blooms in winter; spring sees delivery of monitoring data reports on data points such as the intensity of the algal bloom, the HAB index, phosphorus loadings, and aerial imagery that helps track total maximum daily load targets. These data are used to assess progress. A working group composed of staff from US Geological Survey, Ohio Environmental Protection Agency, Heidelberg University, and Ohio Lake Erie Commission assess the data and develops a water quality monitoring summary from these data; Heidelberg University and NOAA use these data to forecast conditions for the next year that are released in the summer.

AM will be reflected in Ohio's DAP updates. DAP updates are driven by programmatic changes, such as new funding becoming available to drive new actions, and by seasonal data that call for adjustments to program activities. The DAP will also be updated to reflect total maximum daily load development.

State-Level Stakeholders:

- **Ohio Department of Agriculture:** Agricultural nonpoint source nutrient loads.
- **Ohio Environmental Protection Agency:** Point source and water quality monitoring.
- **Ohio Lake Erie Commission:** Serves as the overall coordinating entity working in conjunction with the various state, federal agencies, and other partners to achieve the Domestic Action Plan and western Lake Erie basin Collaborative goals.
- **Ohio Department of Health:** Home Sewage Treatment Systems
- **Ohio Department of Natural Resources:** Private lands wildlife habitat management and Lake Erie fisheries

Sources of funding: The DAP specifies specific funding sources in Ohio that have been leveraged for continued support of priority strategic actions under the plan. For example, H2Ohio is a state-specific funding source launched in 2019 by Ohio Governor DeWine that will

be leveraged to conduct the activities under the Ohio DAP.[9] H2Ohio allocates the state's budget surplus to improve water quality in the state through land protection, restoration and monitoring and research. While funding is available statewide, water quality goals for Lake Erie that use funding from H2Ohio are specifically addressed through the DAP, where it will be used for agriculture BMPs, wetland restoration activities and wastewater infrastructure. While H2Ohio is an important state funding source, sustainability of this funding is reliant on the existence of a state budget surplus following the two-year budget cycle. Another source of funding identified in the DAP is Ohio's budget bill 166 (2020-2021), which authorized USD$172 million in funding to water quality activities under the DAP in the Lake Erie basin as well as in other areas. The DAP notes that additional funding will be requested in future budget requests. Finally, the DAP notes that Senate Bill 299 (2021-2022) provides USD$36 million to various programs, including support for soil and water conservation districts in the western Lake Erie basin for staffing and activities and USD$20 million for the Ohio Department of Agriculture to support programs that will help meet DAP agricultural management activities.[10]

[9] H2Ohio delivers funding through collaboration with the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, Ohio Department of Agriculture and the Ohio Lake Erie Commission.
[10] These activities include the Ohio Working Lands Small Gains Program, the Voluntary Nutrient Management Plans through Certified 4R Retailers, and the Ohio Working Lands Hay Buffers Program.

Pennsylvania

Summary

The Pennsylvania Lake Erie Phosphorus Reduction DAP[11] was led by the Pennsylvania Department of Environmental Protection. The DAP does not mention other agencies, organizations or stakeholders that participated in the development of the DAP. The DAP notes that only one Lake Erie LEO is applicable to Pennsylvania—minimizing the extent of hypoxic zones—because Pennsylvania does not have a watershed that contributes to the western basin. Further, Pennsylvania does not have Priority 1 or 2 tributaries that contribute to cyanobacteria blooms in nearshore waters. With no recommendation on *Cladophora* in the eastern basin from the Annex 4 Objectives and Targets Task Team, the Pennsylvania DAP concludes that the only target applicable to the state is associated with tributaries that connect to the central basin. The DAP estimates that Pennsylvania contributes only an average of 0.51 percent to total phosphorus loading in the central basin.

Pennsylvania AM framework elements

Objectives: The Pennsylvania DAP identifies data limitations on tributary loadings and sources that contribute to the central basin. The DAP summarizes the watershed area, including characteristics of the significant and smaller tributaries that drain to the central basin, point source facilities in these watershed areas, and nonpoint source loading characteristics. Data limitations on phosphorus and nutrient-related data for central basin tributaries exist, although data that are available suggest that Pennsylvania may already have met the 40 percent reduction in total phosphorus goal over the 2008 baseline.

Management actions: Management actions contained in the Pennsylvania DAP, termed "tactics," focus on implementing water quality-related actions to support nutrient reduction goals in the central basin. Two categories of action are detailed: (1) conduct work to increase confidence of Pennsylvania tributary loadings to the central basin by 2021; and (2) focus nutrient reduction programs to the central basin tributaries. **Table A-8** summarizes the components of the two categories. Funding for these actions is noted in the DAP as contingent on the availability of future federal funding.

Monitoring and Modeling: In the DAP, the Pennsylvania Department of Environmental Protection commits to several phosphorus reduction tracking and reporting activities. This includes compiling and evaluating National Pollutant Discharge Elimination System discharge monitoring reports for regulated facilities in the central basin tributaries; working with nonpoint source pollution reduction grant recipients within the central basin to quantify and report nutrient reductions from constructed BMPs; ensuring that new nonpoint source pollution reduction grant recipients within the central basin in Pennsylvania annually report nutrient reductions from constructed BMPs; and participating in ErieStat.

[11] Pennsylvania Department of Environmental Protection 2017

For reporting, the Pennsylvania Department of Environmental Protection commits to developing a report that quantifies known phosphorus contributions and reductions on a schedule determined jointly with the USEPA. The Pennsylvania Department of Environmental Protections also commits to submitting these data to the USEPA (or another third-party entity on a mutually determined schedule) to track and account for total lakewide phosphorus reductions.

Table A-8. Pennsylvania DAP management actions (Pennsylvania Department of Environmental Protection 2017)

Category	Proposed Actions	Funding
Provide greater assurance of Pennsylvania phosphorus loading estimates	Research and assemble all available water quality data for central basin tributaries Evaluate and assess applicability of existing data and reports Conduct tributary land use assessment and geographic information systems-based nutrient modeling	DAP notes that these actions will rely on the future availability of federal grant funding
Prioritize delivery of nutrient reduction programs to central basin tributaries	Pennsylvania Department of Environmental Protection will examine existing programs to identify opportunities to focus resources on Central Basin tributaries. Existing programs are: Pennsylvania Department of Environmental Protection Clean Water Program: National Pollutant Discharge Elimination System permitting for point sources, Municipal Separate Storm Sewer System, Erosion and Sediment Control; sewage facilities, manure and nutrient management, agricultural erosion and sediment. Pennsylvania Department of Environmental Protection Coastal Resources Management Program: Coastal Zone Management Program. Pennsylvania Department of Environmental Protection Partnerships with County/Local Governments: PA Vested in Environmental Sustainability Program with the Erie County Conservation District; Erie County Small Flow Treatment Facility Program with the Erie County Department of Health; Urban Stormwater Management and Green Infrastructure Initiative with multiple program partners.	DAP notes that Pennsylvania Department of Environmental Protection partnership activities rely exclusively on continuation of the GLRI Pennsylvania State Capacity Grant.

Adaptive management: The DAP contains a short paragraph on AM that identifies the main components of AM. As discussed in the DAP, AM actions include revising the plan every five years to incorporate new information and lesson learned and describe the Pennsylvania Department of Environmental Protection's participation in Agreement activities.

State-level stakeholders: Unlike other states, stakeholders are not identified in the Pennsylvania DAP. However, the DAP notes it was a major contributing factor to the formation of the Pennsylvania Lake Erie Environmental Forum, which informs the public about Great Lakes environmental issues.

Appendix B: Survey Results

Q1 In which state(s) or province in the Great Lakes basin do you primarily work? (check all that apply)

Answered: 36 Skipped: 0

ANSWER CHOICES	RESPONSES	
Indiana	11.11%	4
Michigan	19.44%	7
New York	2.78%	1
Ohio	47.22%	17
Ontario	25.00%	9
Pennsylvania	0.00%	0
All on US side	13.89%	5
All on Canadian side	11.11%	4
All, on BOTH sides	16.67%	6
Other (please specify)	0.00%	
Total Respondents: 36		

Q2 Do you work in the Lake Erie watershed?

Answered: 36 Skipped: 0

ANSWER CHOICES	RESPONSES	
Yes	97.22%	35
No	2.78%	1
TOTAL		**36**

Q3 What sector do you work in?

Answered: 36 Skipped: 0

ANSWER CHOICES	RESPONSES	
Private Sector	2.78%	1
Public Sector - State	22.22%	8
Public Sector - Federal	30.56%	11
Public Sector - Local/Municipal	2.78%	1
Non-Governmental Organization (NGO)	22.22%	8
Other (please specify)	19.44%	7
TOTAL		**36**

[Q3 Continued – responses for “other (please specify)”]

#	OTHER (PLEASE SPECIFY)
1	Academic; some work with NGOs
2	academic and policy
3	Academic
4	Education
5	binational
6	Project Funder
7	retired

Q4 What is your level of engagement in developing the AMF?

Answered: 35 Skipped: 1

	1 (LOW)	2	3	4	5 (HIGH)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
% responses	34.29%	11.43%	20.00%	8.57%	20.00%	5.71%		
# of responses	12	4	7	3	7	2	35	2.67

Please indicate your understanding of the following topics:

Q5 Lake Erie Nutrient Management

Answered: 35 Skipped: 1

	1 (LOW)	2	3	4	5 (HIGH)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
% responses	0.00%	2.86%	8.57%	42.86%	45.71%	0.00%		
# of responses	0	1	3	15	16	0	35	4.31

Please indicate your understanding of the following topics:
Q6 Adaptive Management Frameworks in Theory

Answered: 35 Skipped: 1

	1 (LOW)	2	3	4	5 (HIGH)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
% responses	0.00%	20.00%	8.57%	45.71%	25.71%	0.00%		
# of responses	0	7	3	16	9	0	35	3.77

Please indicate your understanding of the following topics:
Q7 Lake Erie Adaptive Management Framework: Planning &Implementation

Answered: 35 Skipped: 1

	1 (LOW)	2	3	4	5 (HIGH)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
% responses	5.71%	20.00%	28.57%	28.57%	17.14%	0.00%		
# of responses	2	7	10	10	6	0	35	3.31

Please indicate your understanding of the following topics:
Q8 Institutional Arrangements for calculating nutrient loads

Answered: 35 Skipped: 1

	1 (LOW)	2	3	4	5 (HIGH)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
% responses	5.71%	11.43%	37.14%	25.71%	20.00%	0.00%	3	
# of responses	2	4	13	9	7	0	5	3.43

Please indicate your understanding of the following topics:

Q9 Institutional Arrangements for research/monitoring programs

Answered: 35 Skipped: 1

	1 (LOW)	2	3	4	5 (HIGH)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
% responses	2.86%	8.57%	34.29%	40.00%	14.29%	0.00%		
# of responses	1	3	12	14	5	0	35	3.54

Q10 Please suggest a national or international model of an adaptive management framework related to nutrient management, if you are aware, that the LE-AMF could learn from.

Answered: 13 Skipped: 23

NARRATIVE RESPONSES TO Q10 OMITTED

Q11 Are you involved in the LE-AMF?

Answered: 35 Skipped: 1

ANSWER CHOICES	% RESPONSES	# RESPONSES
Yes	45.71%	16
No	54.29%	19
TOTAL	35	

Q12 With your involvement in the LE-AMF, please rate the following:

Q12 Lake Erie nutrient management is well understood.

Answered: 14 Skipped: 22

	1 (DISAGREE)	2	3	4	5 (AGREE)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
Lake Erie nutrient management iswell understood.	14.29% 2	0.00% 0	21.43% 3	35.71% 5	28.57% 4	0.00% 0	14	3.64

Q13 With your involvement in the LE-AMF, please rate the following:

Answered: 14 Skipped: 22

	1 (POOR)	2	3	4	5 (EXCELLENT)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
The level of collaboration amongst various modeling teams within the Lake Erie watershed is:	0.00% 0	7.14% 1	28.57% 4	28.57% 4	14.29% 2	21.43% 3	14	3.64
The level of collaboration amongst various organizations leading these models is:	0.00% 0	7.14% 1	21.43% 3	21.43% 3	28.57% 4	21.43% 3	14	3.91
The level of coordination amongst various organizations leading these models is:	7.14% 1	0.00% 0	42.86% 6	7.14% 1	21.43% 3	21.43% 3	14	3.45
The level of collaboration amongst various research/monitoring teams within the Lake Erie watershed is:	0.00% 0	14.29% 2	14.29% 2	42.86% 6	14.29% 2	14.29% 2	14	3.67
The level of collaboration amongst various organizations leading these research/monitoring programs in the Lake Erie watershed is:	0.00% 0	21.43% 3	7.14% 1	42.86% 6	14.29% 2	14.29% 2	14	3.58
The level of coordination amongst various organizations leading these research/monitoring programs in the Lake Erie watershed is:	0.00% 0	14.29% 2	21.43% 3	35.71% 5	14.29% 2	14.29% 2	14	3.58
The existence of nutrient loading models for Lake Erie is:	0.00% 0	7.14% 1	14.29% 2	64.29% 9	0.00% 0	14.29% 2	14	3.67
The level of sustainable institutional arrangements for research/monitoring program for Lake Erie and its stakeholders is:	7.14% 1	28.57% 4	21.43% 3	21.43% 3	0.00% 0	21.43% 3	14	2.73

Q14 With your involvement in the LE-AMF, please rate the following:

Answered: 14 Skipped: 22

	1 (NOT AT ALL ADEQUATE)	2	3	4	5 (EXTREMELY ADEQUATE)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
Resources being directed to support a collaborative modeling process within the Lake Erie watershed are:	7.14% 1	21.43% 3	35.71% 5	28.57% 4	0.00% 0	7.14% 1	14	2.92
Resources (funding, personnel, technology, etc.) to support a collaborative research/monitoring program are:	7.14% 1	21.43% 3	50.00% 7	21.43% 3	0.00% 0	0.00% 0	14	2.86

Q15 Please share any related comments that you may have on your involvement in the LE-AMF.

Answered: 4 Skipped: 32

NARRATIVE RESPONSES TO Q15 OMITTED

Q16 The adaptive management components of the LE-AMF have resulted in a framework as described in the IJC SAB-RCC report.

Answered: 12 Skipped: 24

	1 (DISAGREE)	2	3	4	5 (AGREE)	DO NOT KNOW	TOTAL	WEIGHTED AVERAGE
% responses	0.00%	0.00%	16.67%	16.67%	25.00%	41.67%		
# of responses	0	0	2	2	3	5	12	4.14

Q17 What regulatory tools do you feel have had a positive effect on nutrient management in the Lake Erie watershed?

Answered: 25 Skipped: 11

NARRATIVE RESPONSES TO Q17 OMITTED

Q18 Please list any best management practices (BMPs) that have had a positive effect on nutrient management in the Lake Erie watershed.

Answered: 26 Skipped: 10

NARRATIVE RESPONSES TO Q18 OMITTED

Q19 Please suggest ways to strengthen long-term, sustainable institutional arrangements that foster collaboration across government agencies and jurisdictional lines.

Answered: 21 Skipped: 15

NARRATIVE RESPONSES TO Q19 OMITTED

Q20 Please identify relevant stakeholders that could or should be engaged in the LE-AMF process.

Answered: 17 Skipped: 19

NARRATIVE RESPONSES TO Q20 OMITTED

Q21 Please identify any sustainable funding sources to support the work of the LE-AMF.

Answered: 16 Skipped: 20

NARRATIVE RESPONSES TO Q21 OMITTED

Q22 Please identify ways to bring in more resources (funding, personnel, technology, etc.)

Answered: 13 Skipped: 23

NARRATIVE RESPONSES TO Q22 OMITTED

Q23 How can various jurisdictions work together?

Answered: 18 Skipped: 18

NARRATIVE RESPONSES TO Q23 OMITTED

Q24 How does your division/department is/will inform, consult, involve, collaborate, empower others in the decision-making for the LE-AMF?

Answered: 16 Skipped: 20

NARRATIVE RESPONSES TO Q24 OMITTED

Q25 Please provide any data gaps you may be aware of needed to evaluate progress in meeting phosphorus reduction goals in the Lake Erie watershed.

Answered: 18 Skipped: 18

NARRATIVE RESPONSES TO Q25 OMITTED

Q26 Please provide any research needs you feel are necessary to evaluate progress in meeting phosphorus reduction goals in the Lake Erie watershed.

Answered: 21 Skipped: 15

NARRATIVE RESPONSES TO Q26 OMITTED

Q27 What do you feel are the top three ways to improve the LE-AMF institutional framework to advance the Lake Erie nutrient management goals?

Answered: 17 Skipped: 19

ANSWER CHOICES	% RESPONSES	# RESPONSES
1)	100.00%	17
2)	100.00%	17
3)	88.24%	15

Q28 I am confident that the nutrient management goals (shown below) of the LE-AMF will be met in:

Answered: 24 Skipped: 12

	0 TO 5 YEARS	5 TO 10 YEARS	10 TO 25 YEARS	25 TO 50 YEARS	MORE THAN 50YEARS	N/A	TOTAL	WEIGHTED AVERAGE
% responses	0.00%	0.00%	54.17%	29.17%	8.33%	8.33%		
# of responses	0	0	13	7	2	2	24	3.50

Q29 Please provide any additional comments you may have.

Answered: 1 Skipped: 35

NARRATIVE RESPONSES TO Q29 OMITTED

Q30 If willing to identify yourself, please provide your contact information below.

Answered: 11 Skipped: 25

ANSWER CHOICES	%RESPONSES	# RESPONSES
Name	90.91%	10
Company	72.73%	8
Address	54.55%	6
Address 2	0.00%	0
City/Town	72.73%	8
State/Province	81.82%	9
ZIP/Postal Code	54.55%	6
Country	0.00%	0
Email Address	90.91%	10
Phone Number	63.64%	7

Q31 Are you willing to participate in a follow-up discussion on this matter?

Answered: 14 Skipped: 22

ANSWER CHOICES %	RESPONSES	# RESPONSES
Yes	78.57%	11
No	21.43%	3
TOTAL		14

Appendix C: List of Interview Questions and Interviewees

Interviewing Annex 4 Task Team Members

List of Interview Questions

General Background

1. What is your current role in the LE-AMF process? How regularly and in what capacity do you engage with the process?
2. What do you see as the greatest strengths and areas of need for the LE-AMF process?

Progress on establishing LE-AMF

3. Where do you see collaboration across jurisdictions around the LE-AMF happening currently?
4. What funding sources for projects/programs that feed into the LE-AMF do you know of? What is the relative risk of these funding sources continuing to support these project/programs into the future?
5. Please provide your thoughts on the adaptive management process of the LE-AMF. Are modeling and monitoring being used to inform management actions? Are management decisions changing based on modeling and monitoring inputs?

Coordinated planning & implementation

6. Are there personnel and/or program needs that could help the adaptive management process of the LE-AMF?
7. What is the cycle for planning, assessment, and reporting that you are engaged with through your work/role in the LE-AMF? Do you think the planning, assessment, and reporting cycle is regular/predictable?

Sustainable institutional arrangements for modeling/monitoring

8. What nutrient modeling activities and programs are you aware of in the Lake Erie watershed (e.g., nutrient flows into Lake Erie, the impact of management practices on these flows, and the impact of flows on Lake Erie ecosystem conditions)? What is the geographic scope of these activities? How are the modeling activities you know of integrated with other modeling activities occurring in the Lake Erie watershed? Are these modeling activities funded from sustainable funding sources?

9. What nutrient monitoring activities and programs are you aware of in the Lake Erie watershed? What is the geographic scope of these activities? How are the monitoring activities you know of integrated with other monitoring activities occurring in the Lake Erie watershed? Are these monitoring activities funded from sustainable funding sources?
10. Do you think there is enough data available to inform the LE-AMF process on progress towards phosphorus reduction goals? What data gaps exist and how could they be filled?

Table C-1. List of completed interviews

Number	Interviewee	Organization
1	Katie Stammler	Water Quality Scientist/Source Water Protection Project Manager, Essex Region Conservation Authority (Canada)
2	Nicole Zacharda	Program Manager, Great Lakes Commission
3	Michelle Selzer	Lake Erie Coordinator, State of Michigan Department of Environment, Great Lakes, and Energy
4	Craig Stow	Research Scientist, NOAA Great Lakes Environmental Research Laboratory
5	John Hortness	Great Lakes Program Coordinator and GLRI Coordinator, US Geological Survey
6	Laura Johnson	Director, National Center for Water Quality Research, Heidelberg University
7	Julia Rutledge/Jennifer Vincent	Environment and Climate Change Canada
8	Kristen Arnold	Branch Manager, Indiana Department of Environmental Management
	Jennifer Thum	Deputy Director, Indiana State Department of Agriculture
	Kate Sanders	Resource Specialist, Indiana State Department of Agriculture
9	Pamela Joosse	Senior Soil and Nutrient Specialist, Agriculture and Agri-Food Canada
10	Tom Zimnicki	Agriculture and Restoration Policy Director, Alliance for the Great Lakes
11	Sandra Kosek-Sills	Environmental Specialist, Ohio Lake Erie Commission

Appendix D: Lake Erie Tributary Monitoring Locations

Tables are from Ohio Lake Erie Commission 2020b.

Table 1: Western Lake Erie Basin tributary nutrient load monitoring sites by sampling agency and location detail

Site USGS Station Number and Name	Water Quality Sampling Agency	HUC8	Drainage Area (mi²)
River Raisin			
04176500 - River Raisin near Monroe, MI	NCWQR	04100002 (River Raisin)	1,042
Maumee River			
04177080 - E Br St Joseph R NR Waldron, MI	USGS – MI	04100003 (St. Joseph River)	71
04177266 - W Branch St. Joseph R NR Nettle Lk, OH	USGS – MI		102
04178000 - St. Joseph River near Newville, IN	USGS – OH		610
04181049 - St. Marys River at Willshire, OH	USGS – OH	04100004 (St. Marys River)	386
04182000 - St. Marys River near Fort Wayne, IN	USGS – IN		762
04183000 - Maumee River at New Haven, IN	USGS – IN	04100005 (Upper Maumee River)	1,967
04183105 - Maumee R. at SR 101 nr Woodburn, IN	USGS – IN		2,089
04183500 - Maumee River at Antwerp, OH *	USGS – OH		2,129
04183979 - Platter Creek near Sherwood, OH	USGS – OH		20
04184500 - Bean Creek at Powers, OH	USGS – MI	04100006 (Tiffin River)	206
04185000 - Tiffin River at Stryker, OH	NCWQR		410
04185318 - Tiffin River near Evansport, OH	USGS – OH		563
04185440 - Unnamed Tributary to Lost Ck nr Farmer, OH	NCWQR		4
04185935 - (Upper) Auglaize River near Kossuth, OH	USGS – OH	04100007 (Auglaize River)	201
04186500 - Auglaize River near Fort Jennings, OH	USGS – OH		332
04188100 - Ottawa River near Kalida, OH	USGS – OH		350
04188252 - Unnamed Trib. to Blanchard R.(Shallow R)	NCWQR	04100008 (Blanchard River)	8
04188324 - Potato Run near Wharton, OH	NCWQR		17
04188496 - Eagle Creek above Findlay, OH	USGS – OH		51
04189000 - Blanchard River near Findlay, OH	NCWQR		346
04190000 - Blanchard River near Dupont, OH	USGS – OH		756
04191058 - Little Auglaize River at Melrose, OH	USGS – OH	04100007 (Auglaize River)	401
04191444 - Little Flatrock Creek near Junction, OH	USGS – OH		15
04191500 - Auglaize River near Defiance, OH	USGS – OH		2,318
04192500 - Maumee River near Defiance, OH	USGS – OH	04100009 (Lower Maumee River)	5,545
04192574 - West Creek near Hamler, OH	NCWQR		16
04192599 - S. Turkeyfoot Creek near Shunk, OH	NCWQR		116
04193500 - Maumee River at Waterville, OH *	USGS/NCWQR at gage station 4193490)		6,330
04193999 - Wolf Creek at Holland, OH	NCWQR		25
Portage River			
04195500 - Portage River at Woodville, OH	NCWQR	04100010 (Cedar-Portage R.)	428

* USGS surrogate (super) gages are also developed for these sites.

Table 2: Sandusky Bay and Central Lake Erie Basin tributary nutrient load monitoring sites by sampling agency and location details

Site USGS Gage code and site name	Water Quality Sampling Agency	Surrogate Gage	HUC 8	Drainage Area (mi^2)
Sandusky River				
04197100 - Honey Creek at Melmore, OH	NCWQR	No	04100011	149
04197152 - Rock Creek near Republic, OH	NCWQR	No		15
04197170 - Rock Creek at Tiffin, OH	NCWQR	No		35
04198000 - Sandusky River near Fremont, OH	NCWQR	No		1,251
Huron – Vermillion HUC 8				
04199000 - Huron River at Milan, OH	NCWQR	Yes	04100012	371
04199155 - Old Woman Ck near Huron, OH	NCWQR	No		22
04199500 - Vermilion River near Vermilion, OH [1]	USGS	Yes		262
Black River				
04200500 - Black River at Elyria, OH [1]	USGS	Yes	04110001	396
Cuyahoga River				
04208000 - Cuyahoga River at Independence, OH	NCWQR	Yes	04110002	707
Grand River				
04212100 - Grand River near Painesville, OH [1]	USGS	Yes	04110004	685

[1] No water quality results are presented in this report for these stations as samples currently collected are only to support the surrogate gage development.

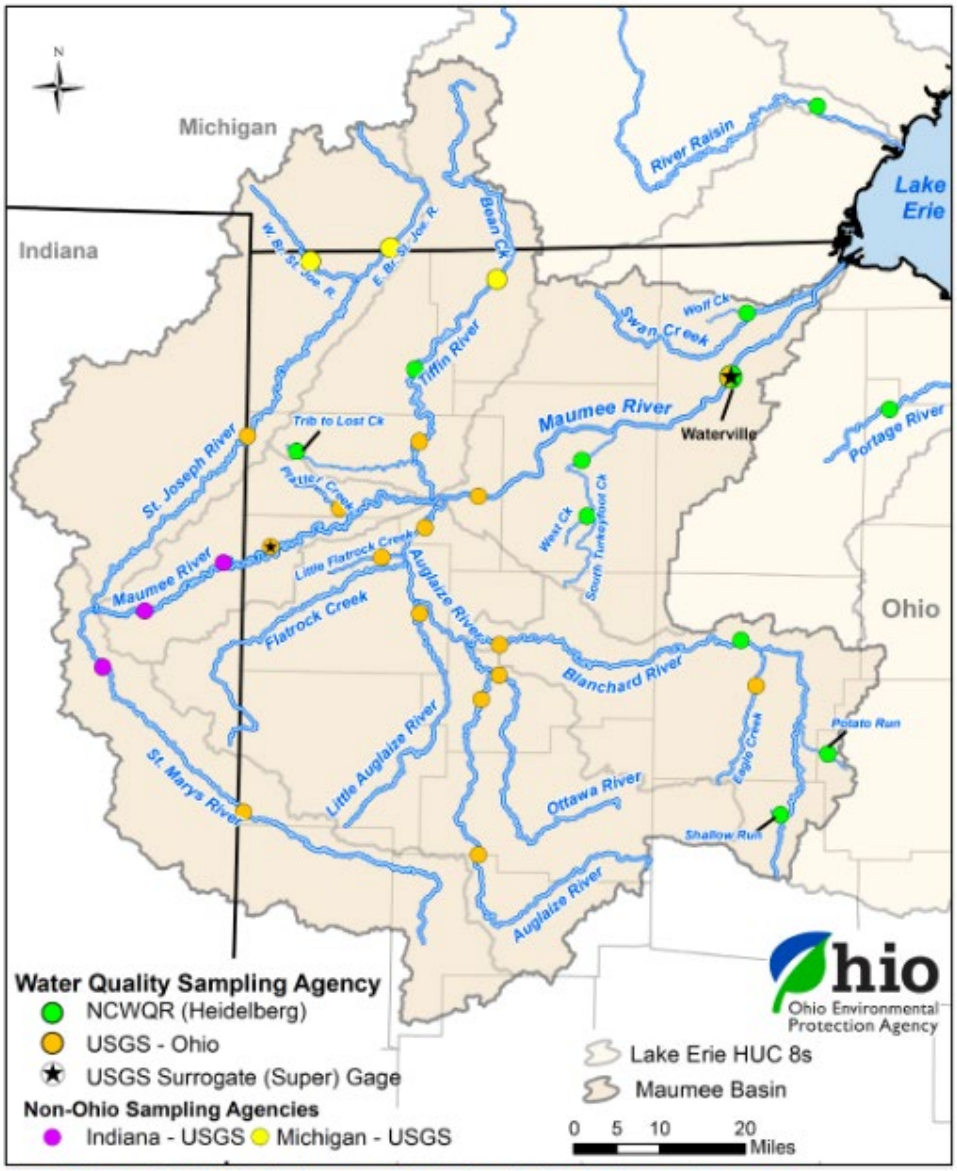

Figure 3. Western Lake Erie Basin tributary nutrient load monitoring sites by sampling agency

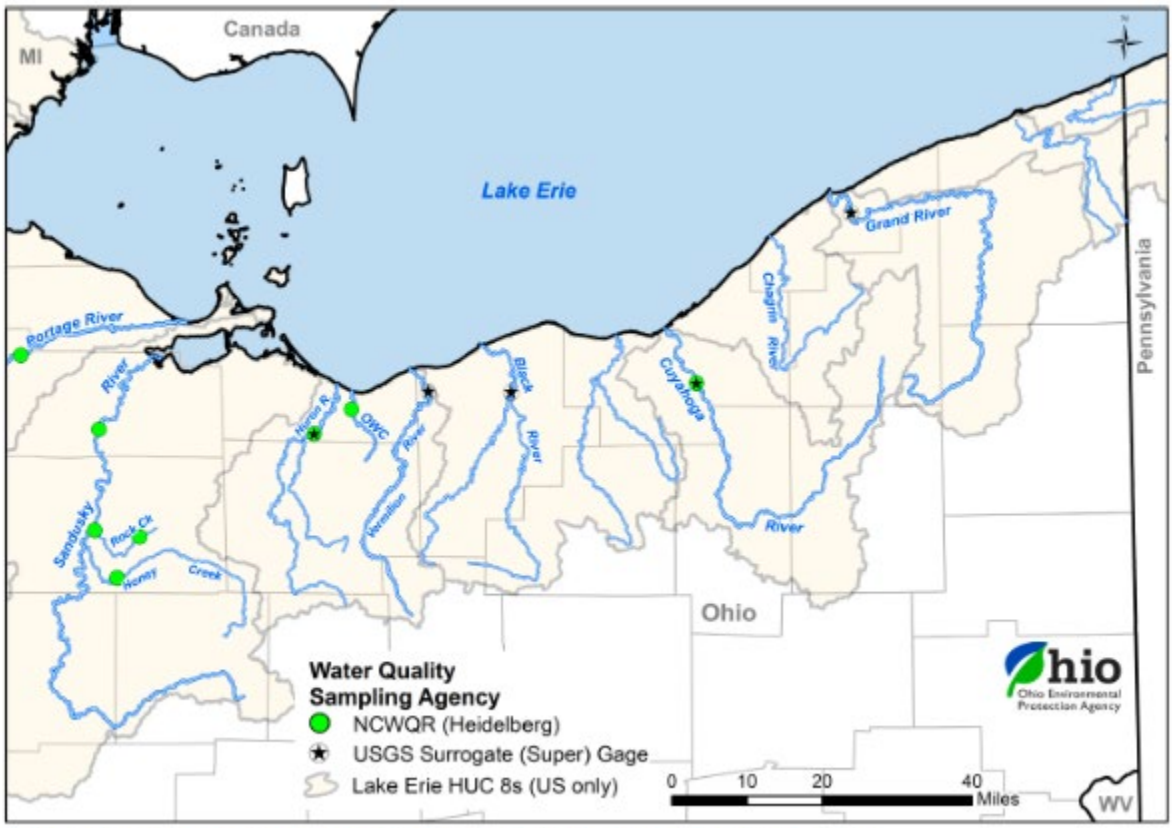

Figure 4. Sandusky Bay and Central Lake Erie Basin tributary nutrient load monitoring sites by sampling agency