Annex 4: Nutrients

Reducing excess phosphorus inputs to Lake Erie remains the highest priority for action under this Annex. Government agencies and their partners are implementing on-the-ground actions identified in the Domestic Action Plans to slow phosphorus inputs from municipal and agricultural sources. There are signs of progress, but significant and sustained effort is still needed to meet targets. Researchers continue to monitor the impact of phosphorus load reductions on the lake ecosystem to assess progress and inform future management actions.

Key Achievements

- Implemented new and enhanced programs to reduce phosphorus loads to Lake Erie in support of Domestic Action Plans.
- Published the Binational Lake Erie Nutrient Adaptive Management Framework and the 5-Year Binational Adaptive Management Evaluation for Lake Erie (2017-2021) to assess changes in phosphorus loads and progress towards achieving the Lake Ecosystem Objectives outlined in the GLWQA, which include minimizing the impact of excessive phosphorus loading and maintaining healthy aquatic ecosystems.
- Published binational Lake Erie phosphorus loads annually on the Great Lakes Commission's Lake Erie Algae (ErieStat) website.
- Canada and the United States agreed to retain the existing interim binational phosphorus targets for Lake Ontario based on the completion of a scientific assessment of nutrients and engagement with partners and the public.

Purpose and Overview

The purpose of Annex 4 (Nutrients) of the Great Lakes Water Quality Agreement (Agreement or GLWQA) is to coordinate binational actions to manage phosphorus concentrations and loadings, and other nutrients if warranted, in the Waters of the Great Lakes.

Harmful and nuisance algal blooms continue to be of concern in localized areas of the Great Lakes, with Lake Erie experiencing the most significant impacts. In warm, nutrient-rich water, cyanobacteria (also known as blue-green algae), can multiply quickly and create blooms that form at or just below the water's surface. These algal blooms can use up the oxygen and nutrients in the water that other organisms need to live. Some algae create toxins, called cyanotoxins, that can harm people, pets, and wildlife.

The Nutrients Annex guides Canadian and U.S. efforts to meet objectives related to algal growth in each of the Great Lakes, which includes: (1) keeping levels of blue-green algae low enough to prevent formation of harmful toxins, (2) reducing areas of low dissolved oxygen water, (3) maintaining levels of algal biomass below nuisance conditions, and (4) ensuring that algae species in nearshore waters are consistent with those found in healthy aquatic ecosystems. To meet these objectives, Canada and the United States have established binational phosphorus concentration and loading targets for each lake, while also continuing to assess and implement programs and measures designed to reduce phosphorus loadings from point and non-point sources.

ANNEX IMPLEMENTATION

Implementation of Annex 4 (Nutrients) is supported by a Subcommittee, which is co-led by Canada Water Agency (CWA) and U.S. Environmental Protection Agency (EPA). Other Annex 4 Subcommittee members include Agriculture and Agri-Food Canada (AAFC); Chiefs of Ontario; Conservation Ontario; Environment and Climate Change Canada (ECCC); Ontario Ministry of Agriculture, Food and Agribusiness (OMAFA); Ontario Ministry of the Environment, Conservation and Parks (MECP); Ontario Ministry of Natural Resources (MNR); Indiana Department of Environmental Management; Indiana State Department of Agriculture; Michigan Department of Agriculture and Rural Development (MDARD); Michigan Environment, Great Lakes, and Energy (EGLE); New York State Department of Environmental Conservation (NYSDEC); Ohio Department of Agriculture; Ohio Environmental Protection Agency (Ohio EPA); Ohio Lake Erie Commission; Pennsylvania Department of Environmental Protection; Wisconsin Department of Natural Resources; U.S. Army Corps of Engineers (USACE); U.S. Department of Agriculture (USDA); U.S. Geological Survey (USGS); and U.S. National Oceanic and Atmospheric Administration (NOAA).

- Produced a preliminary estimate of binational Lake Ontario phosphorus loads to address a significant knowledge and data gap.

Binational Actions and Achievements

Priority for Action: Lake Erie - All jurisdictions continue to take action and make progress towards achieving phosphorus load reduction targets for Lake Erie.

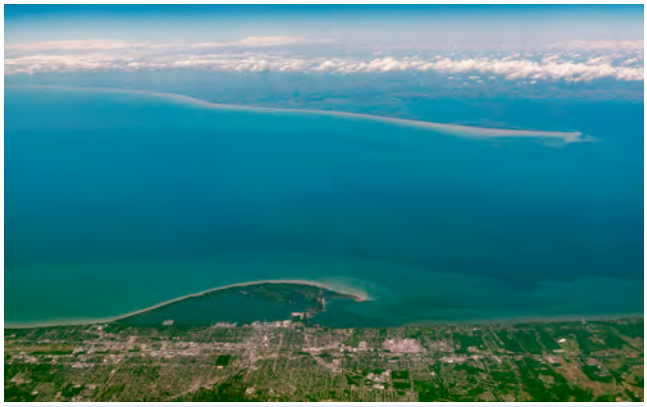
- Each jurisdiction in the Lake Erie basin is taking actions to reduce phosphorus through domestic programs and initiatives. In Canada, this includes projects supported by the CWA's Great Lakes Freshwater Ecosystem Initiative and MECP's Great Lakes Program. In addition, the Sustainable Canadian Agricultural Partnership includes programs funded by Canada and Ontario such as the Resilient Agricultural Landscape Program, which has co-benefits for water quality, and the Agricultural Stewardship Initiative, which provides enhanced funding for phosphorus reduction projects in the Lake Erie and Lake St. Clair watersheds. In the U.S., major funding programs like the Western Lake Erie Basin Initiative, Great Lakes Restoration Initiative (GLRI), H2Ohio and the Western Lake Erie Basin Partnership's Regional Conservation Partnership Program have increased projects to reduce non-point source runoff through wetlands and farmer conservation. Specific actions and progress are described in the Domestic Actions and Achievements section of this report.
- Jurisdictions evaluated the implementation of their Domestic Action Plans over the past five years toward achieving Lake Erie's phosphorus targets. Updated Domestic Action Plans for Ohio, Indiana, Michigan, and Canada-Ontario have been released.

Priority for Action: Lake Erie - Improve communication and engage stakeholders on progress towards achieving Lake Erie phosphorus load reduction targets and Lake Ecosystem Objectives (LEOs).

- The Annex 4 Subcommittee's Lake Erie Adaptive Management Task Team, led by CWA and the EPA, completed an evaluation to assess changes in phosphorus loads and progress towards achieving the Lake Ecosystem Objectives, which was published in 2024.
- CWA and the EPA co-host an annual public "GLWQA Nutrients Webinar: Lake Erie update" webinar to share information and discuss Lake Erie harmful algal blooms and the activities being undertaken to achieve Lake Erie phosphorus load reductions.
- Progress in Lake Erie is also reported through the Great Lakes Commission's Lake Erie Algae (ErieStat) website, Lake Erie Lakewide Action and Management Plan Annual Reports, EPA's Lake Erie Nutrients webpage, the Ohio Lake Erie Commission's Annual Water Monitoring Summary, Ontario's website regarding the Canada-Ontario Lake Erie Action Plan (LEAP), NOAA's Lake Erie Harmful Algal Bloom Forecast/ Seasonal Assessment, scientific conferences (e.g.,

International Association for Great Lakes Research), and the Great Lakes Executive Committee meetings.

- Through the Canadian Environmental Sustainability Indicators program, Canada provides information on the state of the phosphorus loadings to Lake Erie.



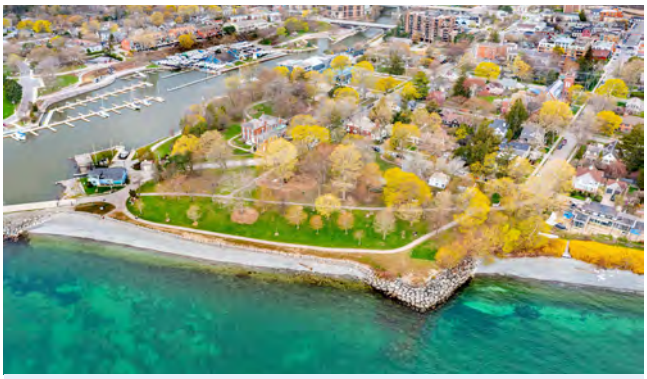
Aerial view over Lake Erie, Presque Isle State Park, Pennsylvania. Credit: Alex Potemkin @ iStock.

Priority for Action: Priority for Action: Lake Ontario - By the end of 2023, complete the review of interim phosphorus targets for Lake Ontario.

- During 2023, the Annex 4 Subcommittee completed the review of interim phosphorus targets and conducted broad-based engagement on the findings and outcomes. Following the 2023 review, Canada and the U.S. agreed to retain existing binational phosphorus targets for Lake Ontario and continue to implement nutrient management and science programs to better understand and mitigate the impacts of nutrients in offshore and nearshore waters of Lake Ontario.

Priority for Action: Lake Ontario - By the end of 2025, identify locations where management actions may be needed to address nearshore algae issues in Lake Ontario.

- Initial areas where nearshore algae is an issue have been identified. The Subcommittee is developing a comprehensive approach to build on this action using satellite observations of cyanobacteria and targeted sampling and mapping of nuisance benthic algae (e.g., *Cladophora*) and using input from shoreline users to assess the spatial and temporal extent of nuisance and harmful algae impacts in Lake Ontario's nearshore.



Lake Ontario shoreline with in-lake algae growth. Credit: jimfeng @ iStock.

Priority for Science: (General to all Lakes) - Improve our understanding of factors affecting nuisance and harmful algae growth in the Great Lakes, particularly in nearshore areas.

- The Lake Erie Adaptive Management Task Team's Nuisance Algae Working Group, led by USGS and MECP, is coordinating monitoring approaches and tracking the extent and severity of nuisance algae growth and washup. ECCC, MECP and USGS continue implementing binational *Cladophora* research, modeling and monitoring at multiple sentinel sites around the Great Lakes to track status and trends in biomass and better define at what point submerged aquatic vegetation constitutes a nuisance condition.

Priority for Science: Lake Erie - Improve tracking and reporting on phosphorus loads to Lake Erie and the extent of harmful algal blooms..

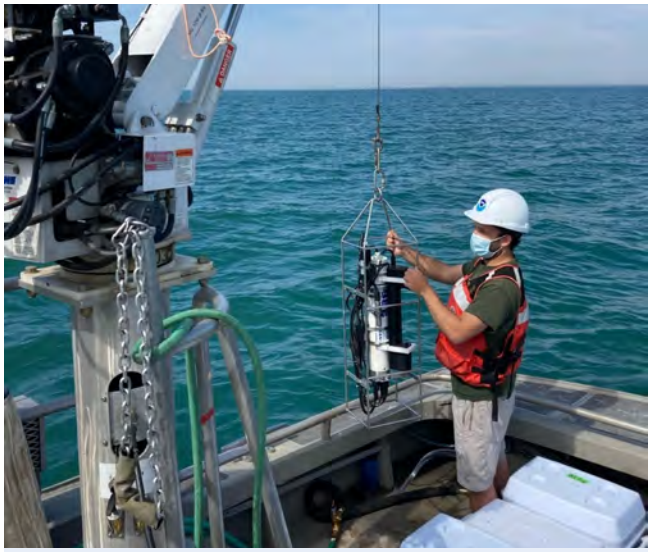
- The Lake Erie Adaptive Management Team's Loadings Working Group, led by ECCC and the EPA, updates and publishes binational phosphorus loads annually on the Great Lakes Commission's Lake Erie Algae (ErieStat) website. They are continuing to assess the best methods to estimate binational phosphorus loads and trends that account for changes in annual data collection and fluctuations in precipitation, including flow-normalized loads.
- In 2024, the Lake Erie Adaptive Management Task Team published the 5-Year Binational Adaptive Management Evaluation for Lake Erie (2017-2021), which reports on phosphorus loading and resulting lake ecosystem conditions related to harmful algal blooms (HABs), hypoxia, and nuisance algae. This is

the first evaluation conducted since the adoption of phosphorus load reduction targets in 2016 and the implementation of nutrient management Domestic Action Plans in 2018 and will be repeated every 5 years.

- To further improve phosphorus load estimates to Lake Erie's western basin, ECCC established a new nutrient monitoring site on the Detroit River in 2024 to complement USGS Detroit River monitoring.
- In 2024, the Lake Erie Adaptive Management Task Team published the Binational Lake Erie Nutrient Adaptive Management Framework and established five Working Groups comprised of U.S. and Canadian agency and academic experts. The HABs, Hypoxia, Nuisance Algae, Data and Modeling, and Loadings Working Groups will support reporting in the next 5-year Binational Adaptive Management Evaluation (2022-2026).

Priority for Science: Lake Erie - Improve hypoxia assessment methods.

- The Lake Erie Adaptive Management Task Team's Hypoxia Working Group, led by CWA and the EPA, tracks and maintains a directory of hypoxia research and monitoring efforts in Lake Erie to identify data gaps and improve assessments of hypoxia in the central basin.



Scientist aboard a NOAA research vessel preparing to deploy an instrument to measure water quality in Lake Erie. Credit: University of Michigan Cooperative Institute for Great Lakes Research @ flikr.

Priority for Science: Lake Erie - Explore the feasibility of a toxicity prediction model for harmful algal blooms.

- The Lake Erie HAB forecasts continue to be refined with the latest technologies available and researchers are getting closer to being able to predict whether blooms are likely to be toxic. In 2023 and 2024, the NOAA Great Lakes Environmental Research Laboratory deployed a network of sophisticated instruments in Lake Erie that can collect and analyze water samples in situ to provide near-real time measurements of the dangerous toxin often present in these blooms, microcystin. NOAA is planning to expand their bloom forecasts to include a prediction on the probability of exceeding toxin threshold levels in 2026.

Priority for Science: Priority for Science: Lake Erie Conduct edge-of-field and in-stream research and monitoring to improve our understanding of phosphorus retention on the landscape and techniques for controlling and trapping phosphorus.

- Edge of field and in-stream research and monitoring continues to be advanced by various Annex 4 member agencies and enhanced through Canada – United States discussion of domestic progress and lessons learned. Research projects include for example:
- In Canada and Ontario, the On-Farm Applied Research and Monitoring (ONFARM) program is an initiative funded by the Sustainable Canadian Agricultural Partnership that implements select agricultural beneficial management practices (BMPs) on participating commercial farms and measures how these practices impact soil health, water quality and productivity. Results from ONFARM investigations can be found in the ONFARM Reports.
- AAFC continued to research ways that farmers can improve nutrient efficiency and reduce nutrient losses off-farm, including an edge-of-field monitoring project investigating the stacking of cover crop and controlled drainage BMPs. It also supported the Environmental Change OneHealth Observatory to fully integrate ecohydrogeological watershed models for both water quantity and quality (nitrogen and phosphorus) and fecal indicator bacteria (*E. coli*).

Lake Erie BMPs-Lower Thames Valley – cover crop field verification conducted in Lower Thames Valley Conservation Authority (LTVCA) watershed in winter 2025. Credit: LTVCA.

Lake Erie BMPs-Middlesex Centre – project example of overwinter cover 2025. Credit: Upper Thames River Conservation Authority.

- MECP continues to analyze and publish findings related to nutrient dynamics in agricultural headwaters from the Multi-Watershed Nutrient Study conducted between 2015 and 2020. More than 10 peer-reviewed manuscripts have been published, including new findings on the impacts of seasonal (including winter) stream flow events, extreme events, enhanced water quality models, and nutrient balances including phosphorus losses and additions in Ontario's agricultural watersheds.
- USGS is integrating edge-of-field and headwater tributary data at several sites in the Great Lakes basin, to evaluate links in timing and concentrations of nutrient and sediment loads.
- USDA Natural Resources Conservation Service (NRCS) partners with the USDA Agricultural Research Service to operate approximately 20 pairs of edge-of-field water quality monitoring sites to evaluate conservation practice effects in the western Lake Erie watershed. These data document small watershed outcomes of conservation efforts under the USDA Conservation Effects Assessment Project and are also leveraged to support projects such as the Western Lake Erie Basin Legacy Phosphorus Assessment Study and a National Legacy Phosphorus Assessment Project, research efforts that aim to advance the understanding of legacy phosphorus mitigation strategies in a variety of watersheds.

Lake Ontario Tributary. Credit: jimfeng @ iStock.

Priority for Science: Lake Ontario - Conduct coordinated monitoring and modeling to improve understanding of phosphorus inputs, fate, and transport in Lake Ontario.

- Agencies are collaborating on monitoring and research to improve understanding of the nature of phosphorus delivery to the lake and to support updated estimation of phosphorus loads.
- Building on the information compiled previously by the Annex 4 Lake Ontario Objectives and Targets Task Team, Canadian researchers completed an inventory and assessment of Lake Ontario models in 2024.
- The USGS and NYSDEC conducted the 4th Lake Ontario Nearshore Nutrient Study during the 2023 CSMI year and included additional contaminant and biological analysis including PFAS and cyanobacterial toxins. These data inform an improved understanding of nearshore nutrient dynamics and the relationship to nuisance and harmful algal blooms.

Nuisance algae shoreline accumulation in Port Hope. Credit: Gary Bowen, 2023.

Priority for Science: Lake Ontario - By 2025, update binational estimates of annual phosphorus loads to Lake Ontario.

- Produced preliminary estimates of annual binational phosphorus loads for Lake Ontario for 2018-2023.
- In 2024, the Annex 4 Subcommittee established a multijurisdictional Lake Ontario Loadings Work Group to develop a coordinated and standardized binational process to calculate and report updated phosphorus loads. The work group conducted an inventory of available information for various source types, gathered and assessed the coverage and usability of data from Canadian and U.S. partners, evaluated approaches to estimating loads, and implemented a process consistent with that in use for Lake Erie.

Progress Towards Phosphorus Load Reduction Targets in Lake Erie

Since the mid-1990s, Lake Erie has experienced harmful and nuisance algal blooms resulting from excess nutrients, specifically phosphorus, which is the primary nutrient limiting algal growth in the lake. In 2016 the Parties agreed that phosphorus loads to the western and central basins of Lake Erie need to be reduced on the order of 40 percent from 2008 baseline levels, which is a reduction from the U.S. and Canada of 3,316 tonnes and 212 tonnes, respectively. The U.S. and Canada subsequently developed a binational phosphorus reduction strategy, coupled with Domestic Action Plans, describing their approach to meet this goal. The Domestic Action Plans were assessed and updated in the 2023-2025 timeframe.

Lake Erie continues to exhibit eutrophic conditions and the largest sources of phosphorus to the lake, the major tributaries, routinely exceed target levels. In addition, smaller tributaries can still contribute at times high concentrations of phosphorus leading to smaller, but still significant, localized algal blooms. The fact that there is not yet a discernible improvement in Lake Erie as a whole reflects the challenges of undertaking collective efforts in a large geographic area and the time required for the ecosystem to respond.

The good news is that there are indications that the actions being taken by the U.S. and Canada are on the right track. First, compared to the early 2000s, Lake Erie conditions (i.e., presence of HABs and hypoxia) have not further deteriorated. Second, in the Maumee River, where actions in the watershed are well underway, there is a sign of improvement in terms of the amount of soluble phosphorus being delivered during the spring months. When we take flow into account, the spring soluble phosphorus appears to have declined by 10 percent from 2008 to 2024. Despite a divergent trend in the particulate type of phosphorus entering Lake Erie, the reduction in soluble phosphorus is a sign of success because it is more bioavailable to algae, and the single best predictor of the chronic and massive harmful algal blooms that span the western half of the lake each summer.

The U.S. and Canada systematically monitor and evaluate progress as part of an adaptive management approach. An evaluation by the Annex 4 Subcommittee's Lake Erie Adaptive Management Team in 2023 reaffirmed that phosphorus remains the primary and most manageable driver of HABs and hypoxia in Lake Erie, and an observable response in water quality will require substantial reductions in phosphorus loads across the basin. Significant efforts are underway in Canada and the U.S. to reduce phosphorus loads that, when sustained, targeted and given time to be effective, will provide major improvements to Lake Erie water quality.

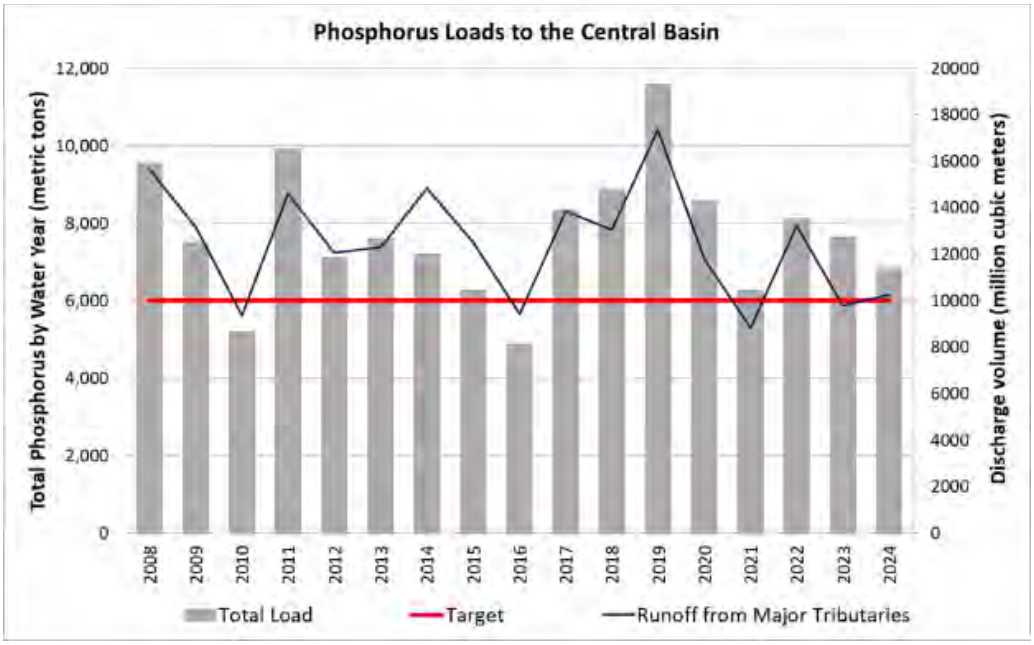


Figure 1: Total phosphorus loading to Lake Erie's western and central basins, 2008-2024. Source: the EPA and ECCC. In 2024, the total phosphorus load to the western and central basins was 6,850 metric tons, higher than the desired target of 6,000 metric tons annually. As shown in Figure 1, this target has only been met twice since 2008. Loads are highly correlated with streamflow discharge, and the years 2010, 2016, and 2021 had drier conditions with less discharge from major tributaries. You can view phosphorus loads to the western and central basins and several priority tributaries in more detail on the Lake Erie Algae (ErieStat) website.

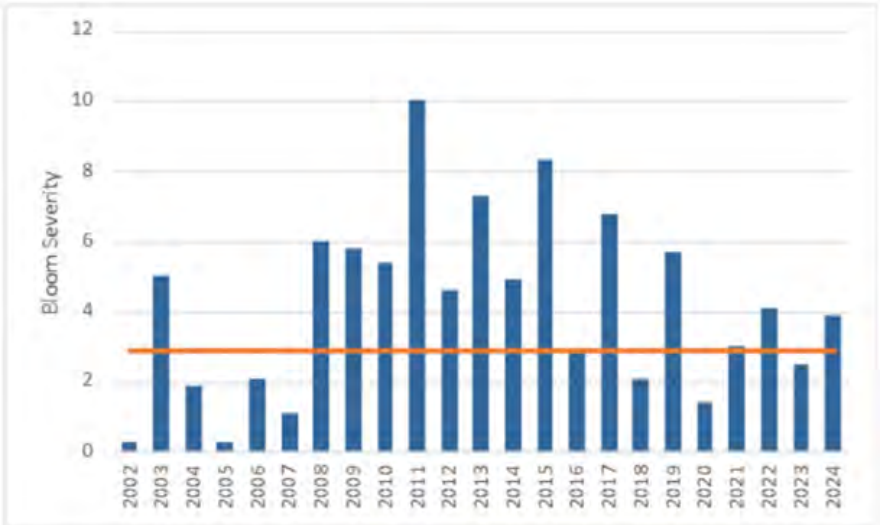


Figure 2: Lake Erie western basin bloom severity, 2002 – 2024. Target threshold depicted with orange line. Source: EPA and NOAA.

The Lake Erie Severity Index (SI) is derived from NOAA's National Centers for Coastal Ocean Science HAB Monitoring Program. The desired threshold not to exceed 9,600 metric tonnes corresponds to a target SI of 2.9. An SI above 5 is considered a "severe" bloom, while blooms over 7 are "very severe." Overall, there is high interannual variability in the severity of the bloom. Between 2017 to 2024, the bloom SI target was met in 2018, 2020, and 2023. The largest blooms to date have occurred in 2011 and 2015. Blooms from 2021-2024 were generally perceived as less intense with fewer "scum" events as compared to 2008-2010 and 2014. NOAA updated the HABs Severity Index time series record for 2002-2024 in May 2025.

Domestic Actions and Achievements

In addition to the actions taken to achieve the binational priorities for science and action, Canada and the United States pursued a variety of domestic projects that also support Annex 4 (Nutrients).

Canada and Ontario-Implementing Canadian Nutrient Reduction Strategies in Lake Erie and Lake Ontario

Reducing phosphorus loads to Lake Erie

- Canada committed to reduce loads from Canadian sources to achieve a 40 percent reduction to Lake Erie (212 tonnes from estimated 2008 levels). Implementation partners are taking action to achieve reductions. In 2018, the Canada-Ontario Lake Erie Action Plan was released, which summarized actions to be taken.
- In 2024, Canada and Ontario released the Canada-Ontario Lake Erie Action Plan Evaluation and Update Report. This report shares accomplishments made by Canada, Ontario and partners since 2018. It also outlines new insights and priorities to guide future actions to reduce phosphorus loads to Lake Erie.
- In 2025, the Canada-Ontario Lake Erie Action Plan Status of Actions was released. This provides the status of each of the 120+ actions under the plan and will be updated on an ongoing basis.
- Through the Great Lakes Freshwater Ecosystem Initiative, the CWA is increasing implementation in the Lake Erie basin through funding of partner efforts to (1) implement on-the-ground phosphorus load reduction measures in critical source areas for nutrient loss, and (2) demonstrate innovative approaches and best management practices that can be used at the broader scale, and filling knowledge gaps through research and science. A total of 13 nutrient-related projects are receiving $53 million over a four-year period, from 2024 to 2028.
- Canada and Ontario have initiated the development of a Canadian Nutrients Strategy for Lake Ontario to meet a commitment in the 2021 Canada-Ontario Agreement on Great Lakes Water Quality and Ecosystem Health to reduce harmful and nuisance algae blooms including in Areas of Concern and other nearshore areas in Lake Ontario. The development of the strategy will continue to be informed by binational initiatives and activities of the GLWQA Nutrients Annex and other domestic initiatives.
- Through the Great Lakes Freshwater Ecosystem Initiative, the CWA is also supporting partner-led projects to advance key nutrient-related priorities in the Lake Ontario watershed to (1) conduct targeted science to generate new information and understanding of key knowledge gaps, (2) develop new watershed-scale nutrient management planning where there is demonstrated risk from known and recurring nearshore toxic or nuisance algal blooms, and (3) implement actions in existing nutrient management plans. A total of 3 nutrient-related projects are receiving over $0.7 million over a two-year period, from 2025 to 2027.

Programs to Reduce Phosphorus Loadings from Agricultural Sources

- The 4R Nutrient Stewardship Program©— which refers to using the Right Source of Nutrients at the Right Rate and Right Time in the Right Place— is led by Fertilizer Canada, OMAFA, the Ontario Agri Business Association, the Grain Farmers of Ontario, the Ontario Federation of Agriculture, and the Christian Farmers Federation of Ontario. As of 2023, over 2,500 farms and 384,000 hectares are following the 4R© best management practices to improve on-farm crop productivity and fertilizer efficiency.
- Through the five-year (2023-2028) Sustainable Canadian Agricultural Partnership, Canada and Ontario are committing more than $68 million under the Ontario Agricultural Sustainability Initiative to fund three programs designed to support farmers in making their agricultural lands more productive and resilient:
  - The Resilient Agricultural Landscape Program, a $56.7 million, five-year program that will continue to make funds available to support projects to measurably reduce greenhouse

gas emissions and/or sequester carbon, while addressing other environmental co-benefits like water quality and soil health. This includes $25 million delivered by Ontario Soil and Crop Improvement Association to provide funding directly to farmers, $21.6 million delivered by Conservation Ontario to support organizations working with farmers and $5 million for Ontario Forage Council to support improvements on Community Pastures.

  - The Agricultural Stewardship Initiative (ASI), a supplemental cost-share program that provided $3.5 million in 2023 for farmers to modify and adapt their equipment and operating practices, support soil health, water quality and productivity benefits. ASI provides enhanced funding on a regional basis for projects contributing to phosphorus reductions in the Lake Erie and Lake St. Clair watershed areas.

  - The ONFARM program received $7 million to extend and enhance its work, continuing from the Canadian Agricultural Partnership. The program helps farmers better understand and communicate best on-farm management practices to improve soil health and water quality through paired trials on 30 commercial farms across Ontario.

- Ontario supports research and innovation projects through the Ontario Agri-Food Innovation Alliance to address various priorities of the agri-food sector, including water and soil nutrient use efficiency to reduce the loss of nutrients to streams and lakes. In 2023, OMAFA, the University of Guelph and the Agricultural Research and Innovation Ontario renewed the Ontario Agri-Food Innovation Alliance Agreement.

- The Ontario Greenhouse Environmental Strategy (OGES) is a committee that acts as a forum for Ontario's greenhouse industry and government to collaborate on environmental impacts and risks associated with the greenhouse sector. The committee consists of OMAFA, MECP, and the Ontario Greenhouse Alliance, (including Ontario Greenhouse Vegetable Growers and Flowers Canada (Ontario)). OGES objectives include, but are not limited to, mitigating environmental risks and improving on environmental performance associated with greenhouse production, encouraging compliance, and investigating technology and methods for phosphorus reductions and water efficiencies in the greenhouse sector.

Combine harvester in a wheat field. Credit: AlbertPego @ iStock.

Programs to Reduce Phosphorus Loadings from Municipal Sources

- **Wastewater Optimization.** Ontario is providing funding to support the Grand River Conservation Authority Watershed-wide Wastewater Optimization Program. This program works collaboratively with municipal wastewater treatment plant owners and operators to improve the performance of plants in the Grand River, including reducing phosphorus discharges. Through this program, Ontario worked with municipal wastewater practitioners to increase the uptake of wastewater treatment plant optimization.

- **Municipal Sewage Overflows/By-passes Monitoring and Reporting.** Ontario continues to collaborate with municipal partners to better manage wastewater and stormwater across the province, including $9.5 million funding support for municipal monitoring and public reporting of municipal sewage overflows and bypasses across Ontario. This includes funding to six municipalities (Amherstburg, Leamington, London, Sarnia, Niagara Region and Windsor) in the Lake Erie watershed, to help increase transparency around monitoring and public reporting of municipal sewage bypasses and overflows. Municipalities used this support to install and upgrade monitoring equipment, acquire,

and implement software approaches to model event forecasting and develop user-friendly public reporting systems. This program concluded on March 31, 2025.

- **Increasing Stormwater Best Management Practices.** Ontario supported projects that encourage stormwater best management practices including Low Impact Development (LID) which can help reduce nutrients. For example, a municipal workshop to increase awareness of the benefits of long-term planning for stormwater green infrastructure; Sustainable Technologies Evaluation Program tools to improve awareness and knowledge (e.g., a WIKI); and municipal LID maintenance toolkit and training for over 500 municipal inspectors and asset managers across Ontario.

Watershed-Based Planning and Restoration Efforts

- Conservation authorities have continued to lead the development and implementation of watershed and phosphorus management plans, with funding support from Canada and Ontario, and working in partnership with municipalities, local communities, and Indigenous Peoples.
- Canada, Ontario, and conservation authorities continue to engage Indigenous communities in LEAP implementation activities, including the Thames River (Deshkan Ziibi) Shared Waters Approach, supporting First Nations Youth stewardship programs, participation on the LEAP Implementation Team, Lake Erie/Great Lakes governance, and support of specific projects, including watershed planning initiatives and the development of agricultural land management plans.
- Beginning in 2021, OMAFA supported a collaboration between the Chippewas of the Thames First Nation (COTTFN) and the Lower Thames Valley Conservation Authority to develop and implement a COTTFN Agricultural Management Plan. This Plan includes a 4-year water quality monitoring program of surface waters in the Thames River (Deshkan Ziibi), event-based nutrient loading monitoring, soil sampling of agricultural lands, soil biological health assessments, natural restoration of legacy and non-productive agricultural lands, and education and outreach to farmers, farm leaseholders, and general community members about agricultural BMPs for nutrient management, environmental farm plans, and local restoration organizations.

Science, Research, and Monitoring

- ECCC, with Ontario's support, provides annual assessments of phosphorus loads entering Lake Erie from Canadian sources.
- ECCC, in collaboration with partners including the University of Waterloo and the Toronto Metropolitan University are undertaking research and modeling to improve understanding of the efficacy of various phosphorus reduction best management practices.
- ECCC is building a network of water quality buoys to provide continuous in-situ monitoring of algal pigments and other sensor-based water quality parameters in priority areas experiencing algal blooms. These data are provided in real-time on the Great Lakes Observing System. The first water quality monitoring buoy was deployed near Leamington in Spring 2024, and four more buoys are set to be deployed by 2026 in Western Lake Erie, Lake St. Clair, Lake Huron and Georgian Bay. Data will be used to validate and improve remote sensing.
- ECCC continues to conduct research and monitoring to further understand the biomass concentrations of toxins that pose a threat to human and ecosystem health in the waters of the Great Lakes. ECCC has worked with the National Laboratory for Environmental Testing to create an Algal Toxin analysis starting with Great Lakes water samples in 2025.
- ECCC implemented whole-lake ecosystem models for Lake Erie and developed and implemented satellite-derived algal bloom products with EOLakeWatch. Information is posted daily to a public web interface that documents seasonal progression of blooms. This information is consolidated annually into summary reports. ECCC scientists have developed and are testing an enhanced EOLakeWatch platform with additional functionality and extended data coverage across

the Great Lakes and to other freshwater systems in Canada.

- AAFC continued to research ways that farmers can improve nutrient efficiency and reduce nutrient losses off-farm. Four trials were conducted looking at sustainable phosphorus levels in soils. Results identified thresholds at which additional fertilizer did not improve crop yield (corn, soybean, wheat) and increased risk of phosphorus loss. Research continues to look at improving 4R commercial fertilizer nutrient stewardship practices for crop production systems receiving manures.
- AAFC has updated background algorithms in the longstanding Indicator of Risk of Water Contamination by Phosphorus, a tool used to assess the risk of phosphorous loss from agricultural lands resulting from agricultural practices. The updated algorithms reflect current research findings, such as improved understanding of flow pathways and associated phosphorous forms through different pathways on the landscape.
- AAFC's Agricultural Climate Solutions – Living Labs accelerates the co-development, testing, adoption, dissemination, and monitoring of beneficial management practices that sequester carbon and/or reduce greenhouse gas emissions, including co-benefits for water quality. To date, 14 living labs have been announced across Canada, each with a nutrient management component.
- AAFC's Agricultural Solutions – On-Farm Climate Action Fund supports farmers in the adoption of beneficial management practices that store carbon and reduce greenhouse gas emissions in three areas: nitrogen management, cover cropping, and rotational grazing. These activities have co-benefits for water quality.
- CWA is advancing precision conservation through field-scale watershed modeling to identify critical source areas of nutrient loss in the Thames River watershed.
- CWA's Great Lakes Freshwater Ecosystem Initiative is funding partner-led projects to demonstrate innovative approaches and agricultural best management practices in priority Lake Erie watersheds to fill knowledge gaps through science. For example, the Upper Thames River Conservation Authority is testing methods to decrease accumulated phosphorus in soil and demonstrate an edge-of-field water recycling system, and Flowers Canada (Ontario) is testing the effectiveness of a novel approach to remove and recover phosphorus using hybrid treatment swales.
- Ontario is undertaking research studies to better understand phosphorus loadings and algal blooms. With partners, MECP completed a Multi-Watershed Nutrient Study, to understand how phosphorus losses from the land surface have changed over the last 50 years. This study confirmed that the largest proportion of phosphorus is lost during major storm events, many of which now occur outside the growing season. Stream phosphorus monitoring conducted in a sub-watershed inflowing to the Thames River also demonstrated evidence of these changing seasonal patterns. OMAFA continues to support research across multiple disciplines, including water quality and soil health. Several such research projects have been completed and are currently underway, specifically focusing on reducing agri-food sector's adverse impact on the health of the Great Lakes and developing solutions to mitigate future adverse impacts on these vital water bodies.

United States

Governmental agencies and their partners implemented conservation activities to reduce nonpoint sources of pollution that threaten Great Lakes nearshore regions. These partners worked collaboratively to target nonpoint sources of excess phosphorus runoff that contribute to HABs around the Great Lakes in priority watersheds, including the Lower Fox River, Saginaw River, and Maumee River. GLRI-funded projects implemented since the program's inception have prevented more than 2.6 million pounds of phosphorus (including over 450,000 pounds of phosphorus in fiscal Years 2023-2025) from leaving farms and entering the Great Lakes. In addition, GLRI federal agencies and their partners worked collaboratively in urban and suburban areas to prevent more than 230million gallons of polluted stormwater from entering the Great Lakes in Fiscal Years 2023 -2025.

Major Cross-cutting Programs & Partnerships to Reduce Phosphorus Loads to Lake Erie

- **Domestic Action Plans.** Strategies that develop and implement phosphorus reduction activities, called Domestic Action Plans, are currently in the process of being updated. Ohio, and Indiana released theirs in December 2023; Michigan's was released in May 2025; and Pennsylvania is in the process of updating theirs. In addition, the EPA, NOAA, NRCS, USACE, and USGS in collaboration with the five Lake Erie states have been working to update the overarching U.S. Action Plan.

The Fruth Wetland Nature Preserve – an 18-acre wetland restoration project in Seneca County, Ohio – filters agricultural runoff from surrounding farm fields and reduces sediment and nutrient loads to western Lake Erie. Source: ODNR.

- **H2Ohio Initiative.** Since Governor DeWine introduced H2Ohio in 2019, Ohio has appropriated over $600 million for this important water quality initiative through 2025. H2Ohio has been incredibly successful to date in expanding the implementation of agricultural best management practices, wetland restoration, and improvements to wastewater infrastructure.
  - Though H2Ohio is a statewide initiative, it has been designed, in part, to address the specific needs of Lake Erie. Approximately half of H2Ohio funds are spent in the western Lake Erie basin (WLEB) watershed.
  - Nearly $250 million in H2Ohio funding has been allocated by Ohio Department of Agriculture support cropland nutrient management in the WLEB. More than 2,600 farmers have enrolled 1.85 million acres of farmland across the 24 counties that make up the WLEB watershed.
  - Additionally, H2Ohio funds are being used to construct and enhance 183 wetland projects in the Lake Erie watershed and established a long-term monitoring program to evaluate the effectiveness of the wetlands at retaining nutrients.
  - Yearly Phosphorus source reduction estimates and other data can be viewed on the Data Ohio Portal and in H2Ohio Annual Reports.
- **Michigan WLEB Community Advisory Group.** Michigan partnered with University of Michigan Water Center to form an external WLEB Community Advisory Group and Science Panel in August 2023. Together these groups provide a broad conduit for public input into the DAP. Michigan held its first State of the Western Lake Erie Basin Conference in 2023 and a second event was held in 2025.
- **WLEB Partnership.** Federal and state partners in Ohio, Michigan, and Indiana collaborate on strategies to maximize the impacts of their projects through the Western Lake Erie Basin Partnership. Participation was hindered during the pandemic, but since then the Partnership has re-engaged with multiple in person meetings and events in 2023-2025.
- **Great Lakes Restoration Initiative.** Phosphorus reduction and HABs are a funding priority under the GLRI. Approximately $22 million in GLRI funding is invested in Lake Erie nutrient reduction efforts each year, with about 85 percent for on-the-ground projects and 15 percent on the supporting science. EPA created a new GLRI funding opportunity to enhance technical assistance and outreach to farmers in the western Lake Erie basin watershed, awarding $3.7 million for state and locally-led projects in 2025.

Programs to Reduce Phosphorus Loadings from Agricultural Sources

- **Widespread farmer engagement in western Lake Erie.** Federal and state agencies in the U.S. have significantly increased conservation assistance to

farmers over the past several years, with new and enhanced programs focused on improving nutrient management practices in priority watersheds (such as the H2Ohio Initiative described above). As of 2025, about half of the 4 million acres of cropland in the western Lake Erie watershed is or was recently enrolled in a federal or state conservation program. This is an outstanding adoption level, that if maintained will significantly reduce phosphorus contributions from agricultural sources to Lake Erie.

- **USDA Conservation Efforts to Reduce Phosphorus Loads to Lake Erie.** From 2018-2023, the USDA's Natural Resources Conservation Service doubled the amount of financial assistance available to farmers in the Lake Erie watershed. The Agency executed more than 3,000 cost-sharing contracts with private landowners, covering over 742,000 cropland acres. Approximately 30 percent of the contracts went to nutrient management practices, 41 percent to cover crops, and 20 percent to animal waste storage and management.
- **Ohio Agriculture Conservation Initiative (OACI).** OACI is a partnership of the agriculture, conservation, environmental, and research communities, which conducts statistical surveys to better understand current on-farm conservation and nutrient management efforts. OACI's recent surveys indicate enrollment in cost-sharing programs is high, the majority of farmers routinely test their soils, and more advanced precision agriculture is widely used in much of northwest Ohio.
- **Expanding Agricultural Programs in Michigan.** MDARD has expanded work with agricultural producers in the WLEB. Implementation of conservation practices has largely been driven by the Michigan Agriculture Environmental Assurance Program and the tri-state Regional Conservation Partnership Program (RCPP). During Fiscal Year 2025 the RCPP signup saw 25 applications submitted totaling approximately $3 million, which exceeded the available funding by nearly $2 million. Currently, there are 115 Cropping System verifications in the WLEB. This totals 59,154 acres, which is approximately six percent of the farmland in Michigan's portion of the WLEB.
- **Michigan's Conservation Reserve Enhancement Program (CREP).** CREP is a formal partnership between MDARD and USDA Farm Service Agency (FSA) to further incentivize implementation of voluntary conservation in priority areas in Michigan, specifically the WLEB, Saginaw Bay and Lake Macatawa watersheds. In exchange for cost share, land rental, and incentive payments landowners agree to install conservation practices on eligible farmland and maintain those practices for 15 years. Michigan's CREP was revived in 2022 with $4.4 million in onetime funds to MDARD for program administration, promotion, and implementation. At the end of Fiscal Year 2024, Michigan's CREP had a total of 1,523 new and existing contracts equaling 17,433 acres enrolled, including 7,031 acres in the WLEB. For the WLEB, conservation practices established on this acreage resulted in the reduction of approximately 14,439 tons of sediment, 19,622 pounds of phosphorus, and 57,444 pounds of nitrogen from entering rivers and streams.
- **Farmers mentoring other farmers.** An EPA GLRI grant to The Nature Conservancy supported a pilot project that successfully recruited 26 farmers to train and mentor others on conservation practices. From 2020-2024, the mentors, who manage 28,590 acres themselves, directly engaged over 11,680 farmers in the Maumee River watershed through workshops, field days, and one-on-one interactions. The goal is to expand the program across Ohio to train 1-3 farmers in each county and continue building a culture of conservation in the region.

Aerial of farm on Lake Erie. Credit: DarrensProFotos @ iStock.

Programs to Reduce Phosphorus Loadings from Municipal Sources

- **Michigan lowers permitted effluent limits to more facilities in the western Lake Erie basin.** Michigan has continued making significant reductions in phosphorus loading to Lake Erie as the result of major improvements in facility operations and stricter permit requirements. These reductions are especially attributable to the Great Lakes Water Authority (GLWA), the Detroit region's primary municipal wastewater service provider, where annual total phosphorus (TP) loads have been reduced by over 55 percent. Building on this success, EGLE established a framework for achieving a 0.5 mg/L TP effluent limit (i.e., a growing season average) at all 25 major publicly owned wastewater treatment facilities located within the western Lake Erie basin. To help facilities meet the lower TP effluent limits, EGLE published Phosphorus Removal Guidance for Wastewater Utilities in Michigan's Western Lake Erie Basin, a document that describes low-cost, practical methods to optimize phosphorus removal, in October 2024.
- **Fort Wayne Deep Tunnel.** In Indiana, 5 miles of the Fort Wayne Deep Tunnel project, an essential part of its Combined Sewer Overflow (CSO) long-term control plan, became operational in 2024, one year ahead of schedule. The final phase, a pumping station, is currently under construction and will mark the official completion of the project. The Deep Tunnel project will reduce CSOs into the St. Marys and Maumee rivers from 72 per year to four per year or fewer.
- **New York Updates Phosphorus Guidance.** In December 2024, New York State Department of Environmental Conservation released draft water quality guidance values for phosphorus that will advance the state's regulation of phosphorus in ambient freshwaters. Because phosphorus is naturally occurring and an essential nutrient for most aquatic systems, linked biological response variables that aid in identifying when phosphorus concentrations have become excessive have also been developed. The water quality guidance values are supplemented by updated draft guidance for inclusion of total phosphorus requirements in permits for existing and new facilities discharging sanitary wastewater to lakes, lake watersheds, and flowing waters of New York State, including Lake Erie and Lake Ontario, which should result in decreased phosphorus loads and subsequent improvements to water quality.

Watershed-Based Planning and Restoration Efforts

- **New expanded water quality monitoring network and field inventories.** Michigan is implementing a strategic and targeted approach to accelerate progress towards nonpoint source reductions. Five subwatersheds within Michigan's portion of the western Lake Erie basin were selected for more focused and accelerated activities including completing agricultural inventories, finer-scale water quality monitoring, and prioritized conservation practice implementation. This ongoing effort is informed by a 2024 report, *The Magnitude and Cost of BMP Implementation: Strategic Planning for Michigan's Priority Subwatersheds*, which was used to assess and estimate the impact of conservation practice scenarios in the five priority subwatersheds.
- **Maumee River Total Maximum Daily Load (TMDL).** Ohio EPA finalized and submitted the Maumee Watershed Nutrient TMDL to the EPA in June 2023. The TMDL identifies phosphorus load allocations for point source and nonpoint source pollution occurring throughout Ohio's portion of the Maumee drainage basin to meet the reduction goals established under Annex 4. It includes an implementation strategy which identifies several mechanisms and funding programs that state and local entities can utilize to reduce phosphorus loads. The first Biennial report on progress was issued in 2024.
- **Wetlands for nutrient reduction.** The EPA continues to prioritize GLRI nonpoint source activities on the restoration of wetlands, floodplains and riparian buffers along agricultural drainage ditches and other areas that receive agricultural runoff. As an example, one EPA GLRI grant will restore over 50 acres of cropland and 15 acres of floodplain, add floodplain to at least 2 miles of agricultural ditches, which will reduce phosphorus loads to the Maumee River by 2,000 pounds annually.

- **Conservation Easements.** NRCS efforts under the GLRI recently expanded to include wetland and floodplain easements, as well. By 2029 NRCS estimates that 30 acres of restored wetland easements and 500 acres of floodplain easements will be secured in the western Lake Erie watershed with NRCS GLRI funding. In addition, FSA and the State of Ohio are implementing a new CREP agreement that will expand the amount of land in permanent vegetative cover adjacent to rivers and streams in the WLEB. So far, they have enrolled nearly 50,000 acres of their 67,000 acre goal.
- **Watershed modeling in the eastern basin.** The USGS and NYDEC developed new SWAT models for 9 watersheds in the eastern basin of Lake Erie to evaluate the effects that conservation practices, point source discharges, and green infrastructure can have on nutrient and sediment loads. Model results were used to inform the 9 Element Plan for NY's Lake Erie Watershed, one of New York's major efforts identified in the U.S. Action Plan for Lake Erie, and were published in 2024; Monitoring and Simulation of Hydrology, Suspended Sediment, and Nutrients in Selected Tributary Watersheds of Lake Erie, New York. Scientific Investigations Report 2024-5022.

Science, Research, and Monitoring

- **Supporting science under GLRI.** From 2023 to 2025, NOAA, USGS, and USACE conducted over $15 million in critical science activities to support Lake Erie nutrient-reduction goals. GLRI supports critical HABs monitoring and decision-support tools, including the Lake Erie HABs Tracker tool and biweekly forecasts; tributary and edge-of-field monitoring and nutrient load computations; and ecosystem and watershed modeling.
- **HABs Forecasting.** NOAA's Great Lakes Environmental Research Laboratory leads efforts to track and forecast blooms in Lake Erie, Saginaw Bay, Green Bay, and Muskegon Lake (eastern Lake Michigan). NOAA has continued to improve the Lake Erie HABs forecasting tools with cutting edge technology and research. The Lake Erie Harmful Algal Bloom forecast system currently provides stakeholders critical information including current location, most recent accurate estimate of size (area), and a 5-day forecast of transport, mixing, scum formation, and bloom decline. As noted earlier in this report, NOAA expects the forecasts will be expanded to include algal toxins by 2026. This is made possible through use of sophisticated instruments that can collect and analyze water samples on the spot without human help. Sometimes referred to as a "lab in a can," there are only around 10 of these instruments in use globally and the first to ever be deployed in a freshwater system was in Lake Erie. Reliable and timely detection of HAB location and potential toxicity is vital to protect human health.
- **Ohio Technology Assessment Program.** Several new technologies to help achieve phosphorus reduction goals for Lake Erie are currently being evaluated by Ohio EPA's H2Ohio Technology Assessment Program. The EPA partnered with Ohio EPA to establish GLRI Pilot Projects for three out of ten of them. The first two will test innovative fertilizer technologies including field demonstrations of a slow-release fertilizer. The third project will quantify their phosphorus reduction potential of automated drainage water management systems, which is a proven conservation practice that offers significant potential to improve water quality in regions with tile-drained cropland, as well as enhance farm economic viability via increased crop resiliency and yields.
- **Great Lakes Tributary Water Quality Dashboard.** USGS has been monitoring water quality in 24 U.S. tributaries to the Great Lakes since 2011. A recent analysis found that flow-normalized total phosphorus loads have decreased or remained steady in most (21 of the 24) of the monitored tributaries, indicating widespread progress toward the nutrient reduction goals of the GLRI and the GLWQA. All of the results of this analysis are published on an interactive, web-based dashboard, at https://rconnect.usgs.gov/glritrends/ and will be regularly updated as new data become available.
- **GLRI Demonstration Farm.** A demonstration farm in northeast Wisconsin is providing a unique opportunity to measure the impacts of two innovative practices applied as a system designed to remove dissolved phosphorus and nitrates.

Kinnard Farms will be the first demonstration farm in the nation to have a denitrifying bioreactor and a Phosphorus Removal System built in-line on the same tile system within a field. Over the next several years USGS will monitor the system at three different points, collecting data that will help tell a more complete story about the impact of pairing these two technologies on subsurface water quality.

- **Wetlands research.** The EPA is collaborating with USACE, ODNR and other partners to assess wetlands for nutrient reduction potential in the western Lake Erie watershed. In 2020, USACE built a phosphorus-optimized demonstration wetland in Defiance, Ohio, that is being intensively monitored; and in 2025, USACE began work on a second site with the City of St. Marys. The EPA also partnered with ODNR to expand their H2Ohio Wetland Monitoring Program to provide a more robust monitoring network using autonomous sensors. The aim of both of these projects is to use hydrology and water quality data collected from the wetlands to create meaningful indices of nutrient removal, to inform future management decisions.
- **Ohio Department of Higher Education Harmful Algal Bloom Research Initiative (HABRI).** HABRI is a statewide research program created in 2015 in response to the 2014 Toledo HAB toxin drinking water advisory. From 2015 - 2025, Ohio invested $24 million in funds for 115 HABs projects to 15 Ohio-based universities. Projects are selected with input from state agencies, and the program has been extremely successful at providing quick and reliable information to address their needs and knowledge gaps.
- **Ohio EPA Total Maximum Daily Load (TMDL) Program.** The TMDL Program, established under the Clean Water Act, focuses on identifying and restoring polluted rivers, streams, lakes, and other surface water bodies. A TMDL is a written, quantitative assessment of water quality problems in a water body and contributing sources of pollution. It specifies the amount a pollutant needs to be reduced to meet water quality standards, allocates pollutant load reductions, and provides the basis for taking actions needed to restore a water body.
- **HABs Mitigation and Research.** NYDEC continues to collaborate with partners to study, manage, and mitigate HABs in New York. Since releasing the NYDEC HAB Research Guide in 2021, NYDEC has supported $14.4 million in HABs research projects. Recently completed projects include an overview of HABs detected in NY from 2012-2020, an evaluation of a spectral fluorometer for monitoring chlorophyll, an investigation into patterns and impacts of cyanobacteria, and a HAB mitigation pilot project in cooperation with Clarkson University on electrochemical oxidation. NYDEC is currently working with SUNY ESF to characterize occurrence of benthic cyanobacteria and toxin production statewide and investigate the use of high-definition satellite images to estimate HAB pigments in lakes.