UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON D.C. 20460

OFFICE OF THE ADMINISTRATOR
SCIENCE ADVISORY BOARD

June 25, 2015

EPA-SAB-15-010

The Honorable Gina McCarthy
Administrator
U.S. Environmental Protection Agency
1200 Pennsylvania Avenue, N.W.
Washington, D.C. 20460

Subject: Early Advice on an Ensemble Modeling Approach for Developing Lake Erie Phosphorus Objectives

Dear Administrator McCarthy:

The U.S. Environmental Protection Agency's Region 5 requested a consultation with the Science Advisory Board (SAB) regarding the development of preliminary phosphorus objectives, loading targets and allocations for Lake Erie. An SAB consultation provides expert advice on a technical question at an early stage in a science activity. The SAB augmented the Ecological Processes and Effects Committee with subject matter experts to form the Lake Erie Phosphorus Objectives Review Panel to provide advice, through the Chartered SAB, on the agency's initial efforts to develop the preliminary phosphorus objectives.

The binational phosphorus objectives are being updated to achieve the nutrient objectives for Lake Erie, pursuant to Annex 4 of the 2012 Great Lakes Water Quality Agreement (GLWQA). The SAB reviewed the methodology presented in EPA's Draft *Technical Approach for Lake Erie Phosphorus Load-Response Modeling* (2014) to provide early advice on the agency's approach. The document describes the framework that the EPA will use to model indicators of eutrophication, the ensemble of models relevant to Lake Erie, and the available data to develop, calibrate and validate the models.

The SAB was asked to comment on the eutrophication response indicators, the models chosen to evaluate the eutrophication response in Lake Erie, the ensemble modeling approach and the efficacy of setting phosphorus loads and concentration targets. The charge questions are attached. The SAB Lake Erie Phosphorus Objectives Review Panel met in Chicago on December 10, 2014, to receive briefings from EPA Region 5 staff, presentations by invited technical experts from Canada, and comments from the public. The draft EPA Technical Approach describes the agency's initial efforts to develop the preliminary phosphorus objectives and in some parts does not provide sufficient information for robust responses to the charge questions. The SAB provides responses to the charge questions and recommendations below and notes where the agency needs to provide additional information.

Eutrophication Response Indicators

The SAB was asked whether the proposed eutrophication response indicators provide a scientific foundation for the Lake Erie Ecosystem Objectives. The EPA identified four eutrophication indicators and selected models that will provide an ensemble of results to compare the indicators and phosphorus levels in Lake Erie. The four indicators are:

1. phytoplankton as represented by chlorophyll-*a*,
2. cyanobacteria blooms in the western basin of Lake Erie,
3. hypoxia in the central basin of the lake, and
4. phosphorus content stored in *Cladophora.*

The SAB found that the first three indicators are reasonable choices, have a foundation in the available science concerning Lake Erie nutrient dynamics, and can be estimated from the models. In contrast, the SAB found that there may not be a sufficient history of reliable data collection to develop models based on the, fourth indicator, phosphorus content of *Cladophora*.

The traditional indicators of eutrophication (focusing on phosphorus concentrations, total phytoplankton biomass and chlorophyll-*a*) should be supplemented by monitoring changes in the composition of the biological communities in the ecosystem, focusing on the relative abundance of phytoplankton, changes in the oxidation state of sediments, and changes in the form and isotopic composition of nitrogen and phosphorus. The agency should also be mindful that factors such as nutritional status and physical environment can add uncertainty to approaches that use chlorophyll-*a* to predict planktonic biomass.

There is evidence that the total phosphorus loading in Lake Erie has not changed markedly during the past couple of decades, but the response of the lake's biology has changed in ways that are undesirable (e.g., toxic blooms and hypoxia), poorly understood, and difficult to predict. Specifically, the biological communities in the lake have changed and thus altered the patterns, rates, and amounts of phosphorus cycling internally in the ecosystem, including its regeneration from sediments. The agency should consider this rapid recycling of phosphorus between the bacterial and phytoplankton communities and release from sediments. The regional climate is changing. Sediment and nutrient loading, the temperature of the lake waters, degree of stratification, and length of the ice-free season have increased. Also, there appears to be an increase in the fraction of total phosphorus that is dissolved and therefore more bioavailable. Thus, the traditional dose-response assumptions of models, based solely on total phosphorus, may be insufficient to develop the phosphorus objectives. The SAB notes that there is limited detail in the draft technical approach addressing spatial and temporal scales and recommends that the agency increase the discussion of spatial-temporal variations (i.e., spatial distribution, spatial resolution, sampling timelines, and seasonal variation) and rationale used to develop the preliminary phosphorus objectives.

Selection of Models and the Ensemble Modeling Approach

The SAB was asked whether the models chosen to evaluate the eutrophication response in Lake Erie are appropriate and reflect the best available science. The SAB finds that ecosystem simulation models and an ensemble modeling approach are appropriate and powerful tools to address the problem of phosphorus pollution in Lake Erie and to make predictions for the future state of the Lake Erie ecosystem. However, some of the models chosen for the ensemble assume that the productivity of Lake Erie is limited solely by available phosphorus. The direct relation of phosphorus concentration in lake waters to the productivity of phytoplankton is probably still robust but other factors in addition to phosphorus (i.e., possible co-limitation by nitrogen) may need to be considered to minimize hypoxia and algal blooms. Increased loading of nitrogen has shifted the available nitrogen in lake water, the nitrogen-to-phosphorus ratio, and the nutrient uptake from the changing composition of the biota.

Although the ensemble approach is reasonable, there are questions about how the models will be combined. Providing more detail on this topic should be a priority for the EPA. Also, there are questions about the efficacy of the specific models included in the ensemble, some of which do not include much of the lake's biology. The SAB notes that recent published literature in ecology speaks of major changes in the biology of ecosystems as representing a "regime shift." Regime shifts are associated with changes in the species composition in ecosystems that alter the pathways and rates of biogeochemical cycling and make a return to the prior state impossible. It is possible that Lake Erie has undergone such a regime shift that will be better addressed in the process models, but not easily captured in the empirical or statistical models.

The SAB notes that the current response indicators are relatively simple and easy to measure. The agency will need to determine if they are sufficient to address the eutrophication problems of Lake Erie. The draft *Technical Approach* did not provide sufficient detail to assess how the agency will evaluate the similarities and differences among the models to develop preliminary phosphorus loadings to Lake Erie. The SAB notes that there are methods to conduct uncertainty and sensitivity analyses individually and across the models, yet at this stage, there was insufficient information available to the SAB to provide specific recommendations about the efficacy of individual models. The SAB will need to receive a fuller discussion on the precision and validation of various alternative models in subsequent reports.

Developing Preliminary Phosphorus Loads and Concentration Targets

The SAB was asked whether the models included in the ensemble, used singly or in combination, provided a scientifically grounded basis for the required update of phosphorus load targets for Lake Erie. The SAB notes that monitoring the loading of nitrogen and phosphorus to Lake Erie is appropriate to understand the lake's nutrient regime and implement management practices. However, the biology in the lake responds to concentrations, not loadings. The agency needs to consider both loads and concentrations. Concentrations of available phosphorus developed from modeled load estimates are based on complex physical and biological processes as discussed in the other charge question responses. Therefore, the agency will need to periodically assess the models and their projected target loadings to assess the relevance between loads and available phosphorus concentration in meeting management objectives.

According to the draft Technical Approach, the EPA and the GLWQA Annex 4 work group will "apply an adaptive management approach in which the phosphorus concentrations and loading targets are revisited periodically" to develop the phosphorus objectives. The SAB agrees that the modeling approach must be flexible given the complexity, changing biology and shifts in the physical dynamics of Lake Erie. The SAB encourages the EPA to expand the explanation of its plans to implement adaptive management. For example, the 2011 *Lakewide Action and Management Plan for Lake Erie* includes a plan to revisit nutrient management actions and targets on an annual basis and integrate revision into the five-year Lake Erie LaMP management, work planning, and reporting cycle. The EPA should include more detail on the monitoring, data, and analyses needed to implement an adaptive management strategy for the phosphorus objectives.

The SAB appreciates the opportunity to provide the EPA with early consensus advice on the modeling approach for developing phosphorus targets for Lake Erie and looks forward to the agency's response. The SAB notes that the *Draft Technical Approach for Lake Erie Phosphorus Load-Response Modeling* (2014) presents the agency's initial plan to develop the preliminary phosphorus objectives and that the

plan likely will evolve. More detailed comments from individual panel members on these major recommendations and additional suggestions are available on the SAB website.

The SAB anticipates a subsequent review of the preliminary phosphorus targets to provide advice on (1) whether the process used to develop the targets was appropriate to meet the nutrient Lake Ecosystem Objectives as defined in the GLWQA and (2) whether the recommended targets are derived from the best available information on the phosphorus sources and trophic status of Lake Erie.

Sincerely,

/S/

Dr. Peter S. Thorne
Chair
Science Advisory Board

/S/

Dr. William H. Schlesinger
Chair
SAB Lake Erie Phosphorus Objectives Review Panel

Enclosures

(1) Roster of Lake Erie Phosphorus Objectives Review Panel Members
(2) Roster of SAB Members
(3) Charge to the SAB for the Consultation of Lake Erie Phosphorus Objectives

NOTICE

This report has been written as part of the activities of the EPA Science Advisory Board (SAB), a public advisory group providing extramural scientific information and advice to the Administrator and other officials of the Environmental Protection Agency. The SAB is structured to provide balanced, expert assessment of scientific matters related to problems facing the agency. This report has not been reviewed for approval by the agency and, hence, the contents of this report do not represent the views and policies of the Environmental Protection Agency, nor of other agencies in the Executive Branch of the federal government, nor does mention of trade names of commercial products constitute a recommendation for use. Reports of the SAB are posted on the EPA website at http://www.epa.gov/sab.

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Charge to the Science Advisory Board for the Consultation of
Lake Erie Phosphorus Objectives
Prepared by the EPA Region 5 Water Division
November 4, 2014

Background

The U.S. Environmental Protection Agency (EPA) Region 5 is co-leading a binational workgroup to develop and implement the Nutrients Annex ("Annex 4") of the 2012 Great Lakes Water Quality Agreement (GLWQA) in accordance with Article 3(b) of the GLWQA. Under Annex 4, the U.S. and Canada (herein referred to as "the Parties") are charged with establishing binational Substance Objectives for phosphorus concentrations, loading targets and allocations for the nearshore and offshore waters of Lake Erie by February 2016. While the Annex applies to all Great Lakes, only Lake Erie has time-bounded commitments, reflecting the Parties' commitment and understanding of the need for prompt action to combat the algae issue there.

Lake Ecosystem Objectives

Pursuant to Article 3(1)(b)(i), the Parties adopted the following Lake Ecosystem Objectives related to nutrients for Lake Erie:

1. minimize the extent of hypoxic zones associated with excessive phosphorus loading,
2. maintain the levels of algal biomass below the level constituting a nuisance condition;
3. maintain algal species consistent with healthy aquatic ecosystems in the nearshore;
4. maintain cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health; and
5. 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.

The Annex 4 workgroup has adopted the following general approach for establishing new/revised Substance Objectives and loading targets for Lake Erie:

1) establish eutrophication response indicators and metrics related to the nutrient Lake Ecosystem Objectives (LEOs);

2) use multiple models to compute appropriate load-response relationships and attribute these to the eutrophication response indicators of concern;

3) synthesize and interpret the results of the ensemble of models to derive phosphorus concentrations and loading targets needed to meet the nutrient LEOs, taking into account the bioavailability of various forms of phosphorous, related productivity, seasonality, fisheries productivity requirements, climate change, invasive species and other factors, such as downstream impacts, as necessary;

4) apply an adaptive management approach in which the phosphorus concentrations and loading targets are revisited periodically.

Due to the complexity of the issue and the need to rely on existing information in the short term, we anticipate refinements in response to peer review and stakeholder feedback. Ongoing monitoring and evaluation will be critical as we track the changes in phosphorus concentrations and loads, in addition to other drivers like hydrology and climate, and the ecological response.

Additional Resources: The EPA identified several reports as supplementary material on the efforts taken in the Lake Erie basin to better understand the background and context of this work. These three reports provide additional background information on the efforts to understand and manage excess nutrients in Lake Erie and the preliminary work on approaches to develop phosphorus objectives:

- Lake Erie Binational Nutrient Management Strategy: Protecting Lake Erie by Managing Phosphorus. Prepared by the Lake Erie LaMP Work Group, 2011.
- Status of Nutrients in Lake Erie Basin. Prepared by the Lake Erie LaMP Work Group, 2009.
- An Approach for Determination of Phosphorus Objectives and Target Loads for Lake Erie. Discussion paper prepared by LimnoTech for Environment Canada, May 2013.

Charge to SAB:

The EPA requests the Science Advisory Board (SAB) provide early advice on the approach (Phase I consultation) and subsequent review (Phase II Peer Review) of preliminary binational phosphorus objectives, loading targets and allocations for the nearshore and offshore waters to achieve the Lake Ecosystem Objectives related to nutrients for Lake Erie, pursuant to the Annex 4 of the 2012 GLWQA.

The objective of the SAB consultation is to obtain early advice on the modeling approach being applied to inform the updated phosphorus targets for Lake Erie. The purpose of the subsequent review of the preliminary phosphorus targets will be to obtain advice on (1) whether the process used to develop the targets was appropriate to meet the nutrient Lake Ecosystem Objectives as defined in the GLWQA and (2) whether the recommended targets reflect the best available information on the phosphorus sources and trophic status of Lake Erie. EPA and Environment Canada are particularly interested in advice pertaining to future applicability of this work as we develop a phosphorus reduction strategy for Lake Erie and begin evaluating phosphorus targets for other Great Lakes.

Document for Review: The SAB will review the methodology presented in EPA's *Draft Technical Approach for Lake Erie Phosphorus Load-Response Modeling*. The document describes the framework approach the EPA will use to model eutrophication response indicators, the ensemble of models relevant to Lake Erie, and the available data to develop, calibrate, and validate the models.

Phase 1 Consultation Questions:

1. Please comment on whether the eutrophication response indicators proposed sufficiently address and provide the scientific foundation for the Lake Ecosystem Objectives for Lake Erie. During your evaluation of the eutrophication response indicators, identify other metrics appropriate for measuring eutrophication response in Lake Erie and other Great Lakes that should be considered, and whether there is a method (model) available to measure this response.

2. Please comment on each of the models chosen to evaluate the eutrophication response in Lake Erie? Are the models appropriate for representing the eutrophication response indicators? Do the models reflect the best available scientific knowledge?

3. Please comment on the appropriateness of the ensemble modeling approach to examine the suite of eutrophication response indicators. Are the models included in the ensemble, when used either singly or combined, sufficient to provide a scientifically grounded basis for the required update of phosphorus load targets for Lake Erie?

4. An anticipated outcome of the modeling exercise is to better understand and quantify what types of conditions would be expected in the lake based upon different levels of phosphorus loading, and to use that information to inform selection of phosphorus loading targets needed to meet the nutrient Lake Ecosystem Objectives. The phosphorus loading targets could be converted to concentration targets, particularly for river mouths/nearshore zones. Please comment on efficacy and value of establishing target values for both phosphorus loads and concentrations in order to meet to the Lake Ecosystem Objectives. How can we ensure the phosphorus concentration and loading targets are internally consistent with respect to the eutrophication response indicators of concern?