United States Environmental Protection Agency

Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water

Strategy Submitted to Congress to Meet the Requirements of P.L. 114-45

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Table of Contents

List of Sections Responsive to P.L. 114-45

Drinking Water Protection Act – Elements Necessary for the Strategic Plan	**Section of EPA's Strategic Plan**
§1459(a)(1)(A)- *"evaluate the risk to human health from drinking water provided by public water systems contaminated with algal toxins;"* §1459(a)(1)(B)- *"establish, publish, and update a comprehensive list of algal toxins which the Administrator determines may have an adverse effect on human health when present in drinking water provided by public water systems, taking into account likely exposure levels;"* and §1459(a)(1)(C)(i)- *"summarize - the known adverse human health effects of algal toxins included on the list published* [by EPA] *when present in drinking water provided by public water systems."*	Algal Toxins and Their Human Health Effects (Section II, A)
§1459(a)(1)(D)(i)- *"publish health advisories pursuant to section 1412(b)(1)(F) for such algal toxins in drinking water provided by public water systems."*	Health Advisories (Section II, B)
§1459(a)(1)(C)(ii)- "*factors that cause toxin-producing cyanobacteria and algae to proliferate and express toxins."*	Factors Likely to Cause Harmful Algal Blooms (Section II, C)
§1459(a)(1)(D)(ii)- *"establish guidance regarding feasible analytical methods to quantify the presence of algal toxins."*	Analytical Methods (Section II, D)
§1459 (a)(1)(D)(iii)- *"establish guidance regarding the frequency of monitoring necessary to determine if such algal toxins are present in drinking water provided by public water systems."*	Frequency of Monitoring (Section II, E)
§1459(a)(1)(E)- *"recommend feasible treatment options, including procedures, equipment, and source water protection practices, to mitigate any adverse public health effects of algal toxins included on the list published* [by EPA]*."*	Treatment Options (Section II, F) Source Water Protection Practices (Section II, G)
§1459(a)(1)(F)- *"enter into cooperative agreements with, and provide technical assistance to, affected States and public water systems, as identified by the Administrator, for the purpose of managing risks associated with algal toxins included on the list published* [by EPA]."	Cooperative Agreements and Technical Assistance (Section II, H)
§1459(b)(1)- *"identify gaps in the Agency's understanding of algal toxins, including—(A) the human health effects of algal toxins included on the list published* [by the EPA]*; and (B) methods and means of testing and monitoring for the presence of harmful algal toxins in source water of, or drinking water provided by, public water systems".*	Information Gaps (Section III, A)
§1459(b)(2)- *"consult, as appropriate, (A) other Federal agencies that—(i) examine or analyze cyanobacteria or algal toxins; or (ii) address public health concerns related to harmful algal blooms; (B) States; (C) operators of public water systems; (D) multinational agencies; (E) foreign governments; (F) research and academic institutions; and (G) companies that provide relevant drinking water treatment options."*	Stakeholder Involvement (Section III, C)
§1459(b)(3)-*"assemble and publish information from each Federal agency that has—(A) examined or analyzed cyanobacteria or algal toxins; or (B) addressed public health concerns related to harmful algal blooms.*"	Information from Other Federal Agencies (Section III, B)

List of Abbreviations and Acronyms

ARS	Agricultural Research Service
ART	Analytical Response Team (NOAA's)
ASDWA	Association of State Drinking Water Administrators
AWWA	American Water Works Association
BMAA	Beta-methylamino-L-alanine
BMP	Best Management Practices
CCL	Contaminant Candidate List
CDC	Centers for Disease Control and Prevention
CEAP	Conservation Effects Assessment Project
CHRP	Coastal Hypoxia Research Program
CRMs	Certified Reference Materials
CWA	Clean Water Act
CyAN	Cyanobacteria Assessment Network
CYN	Cylindrospermopsin
DBP	Disinfection byproducts
DHHS	Department of Health and Human Services
DNA	Deoxyribonucleic acid
DOC	Department of Commerce
DOD	Department of Defense
DOE	Department of Education
DOI	Department of Interior
DWMAPs	Drinking Water Mapping System for Protecting Source Water
DWPA	Drinking Water Protection Act
DWSRF	Drinking Water State Revolving Fund
DWTP	Drinking water treatment plant
ELISA	Enzyme-linked immunosorbent assay
EPA	United States Environmental Protection Agency
ESA	European Space Agency
FDA	Food and Drug Administration
GAC	Granulated Activated Carbon
GAO	Government Accountability Office
GAP	General Environmental Assistance Program
GIS	Geographic Information Systems
GLRI	Great Lakes Restoration Initiative
HA	Health Advisory
HABHRCA	Harmful Algal Bloom and Hypoxia Research and Control Act
HAB	Harmful algal bloom
HESD	Health Effects Support Document
HHWQC	Human Health Water Quality Criteria
IWG	Interagency Working Group
LC/MS/MS	Liquid chromatography tandem mass spectrometry
LPS	Lipopolysaccharides
MMPB	2-methyl-3-methoxy-4-phenylbutyric acid
NARS	National Aquatic Resource Surveys
NASA	National Aeronautics and Space Administration
NCCOS	National Centers for Coastal Ocean Science

NCER	National Center for Environmental Research
NDWAC	National Drinking Water Advisory Council
NERL	National Exposure Research Laboratory
NGO	Non-Governmental Organization
NHC	National HABs Committee
NIEHS	National Institute of Environmental Health Sciences
NIFA	National Institute of Food and Agriculture
NLA	National Lakes Assessment
NOAA	National Oceanic and Atmospheric Administration
NORS	National Outbreak Reporting System
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRC	National Research Council
NRCS	Natural Resources Conservation Service
NRWQC	Nationally Recommended Water Quality Criteria
NSF	National Science Foundation
NWFSC	Northwest Fisheries Science Center
NWIS	National Water Information System
NWP	National Water Program
OCE	Division of Ocean Sciences (NSF)
Ohio EPA	Ohio Environmental Protection Agency
OKDEQ	Oklahoma Department of Environmental Quality
ORD	Office of Research and Development (EPA)
OST	Office of Science and Technology (EPA)
OW	Office of Water (EPA)
PAC	Powdered Activated Carbon
PMN	Phytoplankton Monitoring Network
PSP	Paralytic Shellfish Poisonings
PWS	Public Water System
qPCR	Quantitative Polymerase Chain Reaction
RARE	Regional Applied Research Effort
RPS	Recovery Potential Screening
SDWA	Safe Drinking Water Act
SEATT	South East Alaska Tribal Toxins network
SWP	Source Water Protection
TMDLs	Total Maximum Daily Loads
UC	University of Cincinnati
UCMR	Unregulated Contaminant Monitoring Rule
USACE	United States Army Corp of Engineers
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WBPs	Watershed-Based Plans
WHO	World Health Organization
WQT	Water Quality Trading
WRF	Water Research Foundation

I. Executive Summary

The prevalence and duration of harmful algal blooms (HABs) in freshwater is rapidly expanding in the United States and worldwide. The water quality, human health and socioeconomic impacts of HABs can be significant. Some HABs can produce toxins that are toxic to liver, kidney and nervous system functions in humans and animals. These toxins, when found in source waters, can contaminate drinking water supplies if that water is not adequately treated. The challenges that HABs pose to public drinking water systems include an incomplete understanding of how to prevent, predict, analyze, monitor and treat toxins in drinking water; determining how to effectively communicate risk to stakeholders; and developing and implementing resource-efficient methods to reduce the risks posed by HABs in source waters.

The United States Environmental Protection Agency (EPA) developed this document in accordance with Section 1459 of the Safe Drinking Water Act, as amended by the Drinking Water Protection Act, which requires that the Administrator of the EPA develop a strategic plan for assessing and managing risks associated with algal toxins in drinking water provided by public water systems. This plan presents examples of recently completed and ongoing HAB-related activities and provides steps and timelines for intended future EPA activities. These ongoing and future activities outline EPA's plan for the next few months through the next five years and beyond. This plan addresses:

Algal Toxins and Their Human Health Effects
Evaluating the risk to human health from drinking water contaminated with algal toxins provided by public water systems; establishing, publishing and updating a comprehensive list of algal toxins that may have an adverse effect on human health when found in drinking water provided by public water systems; and summarizing those health effects.
<u>Steps include:</u> 1) Building on the existing work of compiling information on mechanisms of toxicity in human and animals for the toxins microcystins, cylindrospermopsin and anatoxin-*a*; 2) evaluating information gaps and analyzing the human health risk posed by other toxins of human health concern; and 3) determining whether sufficient information is available to develop health advisories for additional toxins.

Health Advisories
Determining whether to publish additional health advisories for the algal toxins represented on the comprehensive list of algal toxins that may have an adverse effect on human health when found in drinking water provided by public water systems.
<u>Steps include:</u> 1) Determining if adequate occurrence, toxicology and epidemiology data are available to develop health advisories for the listed toxins other than those established in June 2015 for the cyanotoxins microcystins and cylindrospermopsin; 2) evaluating the toxicity of these listed toxins including the toxico-dynamics and toxicokinetics of microcystin congeners; and 3) analyzing the adverse effects to the reproductive system from exposure to microcystins.

Factors Likely To Cause Harmful Algal Blooms
Summarizing the factors that cause toxin-producing cyanobacteria and algae to proliferate and express toxins.
<u>Steps include:</u> 1) Building on research to better understand HAB ecology; 2) developing tools to quantify HABs in U.S. freshwater lakes and reservoirs using satellite color data; 3) evaluating, interpreting and linking existing data on algal toxins and the factors that impact their occurrence, including nutrient

loading and climate change; and 4) identifying areas where more monitoring is necessary to support scientific understanding.

Analytical Methods
Establishing additional guidance regarding feasible analytical methods to quantify the presence of algal toxins.
<u>Steps include:</u> 1) Building on efforts to evaluate the comparability of rapid screening methods and more specific analytical methods; 2) evaluating methods to fill knowledge gaps and provide improved analytical methods for algal toxins in drinking water; and 3) providing standardized and validated detection and analysis methods, as needed, for emerging algal toxins of concern.

Frequency of Monitoring
Evaluating the frequency of monitoring necessary to determine if such algal toxins are present in drinking water provided by public water systems.
<u>Steps include:</u> 1) Engaging with states and public water systems to update and refine the existing guidance on monitoring frequency as more information becomes available; and 2) using emerging science on factors affecting HABs and algal toxins to inform monitoring frequencies.

Treatment Options
Evaluating feasible treatment options, including procedures and equipment to mitigate any adverse public health effects of algal toxins included on the published algal toxin list.
<u>Steps include:</u> 1) Summarizing the state of knowledge regarding water treatment optimization and identifying approaches to assist with treatment challenges related to HAB events; 2) researching the removal effectiveness of unit operations for various toxins and developing better predictive tools/models; and 3) investigating how to implement treatment process and operational changes for maximum protection and cost-effectiveness under a variety of site-specific constraints.

Source Water Protection Practices
Evaluating and recommending feasible source water protection practices to mitigate any adverse public health effects of algal toxins included on the published list.
<u>Steps include:</u> 1) Expanding computerized mapping and water quality modeling for HAB detection and prediction at the watershed scale; 2) monitoring nutrients across watersheds to both target and assess protection activities; 3) working with states to prioritize nutrient-impacted waterbodies for water quality improvements and developing targets for clean-up; and 4) collaboratively working across the EPA's regional offices to promote awareness amongst the public drinking water systems on the monitoring, screening techniques and source water protection practices.

Additionally, this plan outlines a strategy for continuing to utilize cooperative agreements and provide technical assistance to states and public water systems to address HABs.

II. Introduction

On August 7, 2015, Public Law 114-45, titled the Drinking Water Protection Act, amended the Safe Drinking Water Act (SDWA) by adding Section 1459, Algal Toxin Risk Assessment and Management (see Appendix 1 for the text of P.L. 114-45). Section 1459 directs the Administrator of the United States Environmental Protection Agency (EPA) to submit to Congress, no later than 90 days after the date of enactment, a strategic plan for assessing and managing risks associated with algal toxins in drinking water provided by public water systems (PWSs). The plan must include steps and timelines to:

- Evaluate the risk to human health from drinking water contaminated with algal toxins provided by PWSs;
- Establish, publish and update a comprehensive list of algal toxins that may have an adverse effect on human health when found in drinking water provided by PWSs, accounting for the levels of likely exposure;
- Summarize known adverse human health effects of the listed algal toxins when present in drinking water provided by PWSs and summarize factors that cause toxin-producing cyanobacteria and algae to proliferate and cause cells to express toxins (i.e., produce and release toxins);
- For the listed algal toxins, determine whether to publish health advisories, establish guidance on feasible analytical methods to quantify the presence of algal toxins, recommend the frequency of monitoring necessary to determine if algal toxins are present and recommend feasible treatment options including source water protection practices; enter into cooperative agreements with, and provide technical assistance to, affected states and PWSs, as identified by the Administrator, for the purpose of managing risks associated with algal toxins included on the algal toxin list developed by the EPA; and update the strategic plan as appropriate.

Section 1459 also directs the EPA to identify information gaps in the understanding of algal toxins, including the human health effects and the methods and monitoring for algal toxins in source water or in drinking water provided by PWSs. The new amendment directs the EPA, as appropriate, to consult with other federal agencies (that evaluate cyanobacteria or algal toxins or that address public health concerns related to cyanobacteria and algal toxins), states, PWS operators, multinational agencies, foreign governments, research and academic institutions and companies providing treatment options. In addition, Section 1459 also directs the EPA to assemble and publish information from each federal agency that has evaluated cyanobacteria or algal toxins or addressed public health concerns related to HABs.

This document presents to Congress a strategic plan for the assessment and management of the risk associated with algal toxins in drinking water provided by PWSs. This strategic plan outlines steps and timelines for currently planned EPA activities and the activities that could occur in the future, contingent upon available resources and funding, to address specific items in Section 1459. Nothing in this document, in and of itself, obligates EPA to expend appropriations or incur other financial obligations that would be inconsistent with the Agency's statutory authority, its budget priorities, or the availability of appropriated funds. This document also does not create any right or benefit, substantive or procedural, enforceable by law or equity against EPA, its officers or employees, or any other person.

The strategic plan also includes ongoing activities of the Interagency Working Group (IWG) that was established as part of the Harmful Algal Bloom and Hypoxia Research and Control Act (HABHRCA) Amendments of 2014 (HABHRCA 2014; P.L. 113-124). The IWG on HABHRCA is chaired by the EPA and National Oceanic and Atmospheric Administration (NOAA), and includes representatives of the U.S.

Centers for Disease Control and Prevention (CDC), Food and Drug Administration (FDA), U.S. Department of Agriculture (USDA), U.S. Army Corps of Engineers (USACE), United States Geological Survey (USGS), National Aeronautics and Space Administration (NASA), National Institutes of Health (NIH) and the National Science Foundation (NSF). The IWG develops action plans, reports and assessments in coordination with federal agencies to advance the scientific understanding of and ability to predict, detect, mitigate, control and respond to HABs and hypoxia events. This strategic plan specifically focuses on toxins associated with cyanobacteria (cyanotoxins).[1]

[1] There are toxins associated with some other algae as well. While cyanotoxins are technically not produced by algae, this document describes cyanotoxins as algal toxins to be consistent with the common, synonymous usage of these terms. Similarly, the document at times uses the terms cyanobacterial blooms and harmful algal blooms synonymously.

III. Strategic Plan

a. Algal Toxins and Their Human Health Effects

This section is responsive to §1459(a)(1)(A), §1459(a)(1)(B) and §1459(a)(1)(C)(i) of the SDWA directing the EPA to develop a strategic plan to *"evaluate the risk to human health from drinking water provided by public water systems contaminated with algal toxins*;*" "establish, publish, and update a comprehensive list of algal toxins which the Administrator determines may have an adverse effect on human health when present in drinking water provided by public water systems, taking into account likely exposure levels*;*"* and *"summarize - the known adverse human health effects of algal toxins included on the list published* [by the EPA] *when present in drinking water provided by public water systems."*

Cyanobacteria can produce a wide range of bioactive compounds, some of which may have beneficial or therapeutic effects (Jensen et al., 2001). Other cyanobacteria can produce bioactive compounds that may be harmful, called cyanotoxins. The most commonly recognized bioactive compounds produced by cyanobacteria fall into four broad groupings: cyclic peptides, alkaloids, amino acids and lipopolysaccharides (LPSs).

Cyanotoxins present a unique challenge. The same cyanotoxins can be produced by more than one species of cyanobacteria and some cyanobacteria can produce more than one toxin at a time, resulting in blooms with multiple cyanotoxins (Funari and Testai, 2008). The toxicity of a particular bloom is complex, determined by the mixture of cyanobacteria species present and the variation in strains with toxic and nontoxic genotypes involved (WHO, 1999). Toxin production can vary between blooms and within an individual bloom over time (Duy et al., 2000).

Drinking water is a source of potential exposure to cyanotoxins. The occurrence of cyanotoxins in drinking water depends on their levels in the raw source water and the effectiveness of treatment methods for removing cyanobacteria and cyanotoxins during the production of drinking water. The SDWA, as amended in 1996, requires the EPA to publish a list of contaminants every five years that are known or anticipated to occur in PWSs and which may require regulation under the SDWA. This list is called the Contaminant Candidate List (CCL). Cyanobacteria and their toxins were included in the CCL 1 and the CCL 2. The CCL 3 and the draft CCL 4 also identify cyanotoxins as a priority, highlighting three particular toxins of interest: microcystin-LR, cylindrospermopsin and anatoxin-*a* (U.S. EPA, 2015a). As part of the CCL processes, health and occurrence information were evaluated in establishing the lists. Under the SDWA, the EPA uses the Regulatory Determination process to evaluate available data to determine whether contaminants require regulation or if additional information is needed. The EPA has not addressed cyanobacteria or cyanotoxins in any of the previous Regulatory Determination cycles due to the limited occurrence and health effects information. The contaminants listed on the CCL generally represent priorities for the Unregulated Contaminant Monitoring Rule (UCMR) program. Under UCMR, occurrence data are collected to allow the Agency to evaluate contaminants that currently do not have drinking water standards and to support subsequent Regulatory Determinations (U.S. EPA, 2012b). Cyanotoxins have not been included on previous UCMRs due to a need for improvements in cyanotoxin analytical methods.

Cyanobacteria are the primary harmful algal group in freshwater environments and have been documented throughout the country. Many species of cyanobacteria are able to produce toxins. Microcystins, cylindrospermopsin and nodularins are known to impact the liver (hepatotoxins); anatoxin-*a*, anatoxin-*a(s)* and homoanatoxin-*a* are known to impact the nervous system (neurotoxins).

These toxins pose potential risk to human health via exposure to contaminated water. Other common toxins produced by cyanobacterial species are LPS endotoxins, saxitoxin and beta–methylamino–L–alanine (BMAA). Saxitoxins, a large toxin family also known as paralytic shellfish poisoning (PSP) toxins, are common in marine waters but have also been reported in freshwater systems in the United States. The data on freshwater saxitoxins occurrence are limited, and toxicity data from exposure in drinking water is not available. BMAA, a recently discovered neurotoxin, also has limited data on toxicity and environmental fate and transport.

In 2012, the EPA developed an online resource, the EPA Cyanobacterial HABs Website (http://www.epa.gov/cyanohabs) to provide information to stakeholders on cyanotoxins. The website also includes available health effects information on these toxins.

Completed Activities

The EPA has compiled information on mechanisms of toxicity including acute, short-term, subchronic, chronic and cancer in humans and animals, as well as toxicokinetic information for microcystins, cylindrospermopsin and anatoxin-*a*. To view the Health Effects Support Documents (HESDs) for these cyanotoxins in drinking water, visit the EPA's Health Advisory Web page: http://water.epa.gov/drink/standards/hascience.cfm (U.S. EPA, 2015b, c, d). The toxicity of cyanotoxins can vary, even within a specific type of toxin (for example, the microcystins). Symptoms reported after acute recreational exposure to cyanobacterial blooms (including microcystin-producing genera) include skin irritations, allergic reactions or gastrointestinal illnesses. Effects reported in humans following acute or short-term exposure to cyanotoxins in drinking water include gastroenteritis, and liver and kidney damage. Animal studies have shown that long-term adverse effects from cyanotoxins include liver and kidney effects. A few available epidemiological studies suggest an association between liver and colorectal cancers and some cyanotoxins. However, the epidemiology studies are limited by their study design, including poor measures of exposure, potential co-exposure to microbial and/or chemical contaminants and, in most cases, failure to control for known liver and colorectal risk factors. More information is needed to determine the carcinogenicity of these toxins.

Ongoing Activities

The EPA anticipates gathering additional information going forward to determine whether additional HABs or toxins should be included on the list required by §1459(a)(1)(B). The EPA also expects to determine what human health effects information is available for these HABs and toxins, particularly with regard to drinking water exposures. This information, coupled with available information on occurrence in freshwater, would be used to refine the list of HABs and toxins to consider for future development of Health Advisories (HAs). This list of HABs and toxins would be included on the EPA Cyanobacterial HABs website (http://www.epa.gov/cyanohabs).

The EPA will determine if adequate occurrence, toxicology and epidemiology data are available to develop HAs for additional listed cyanotoxins. The EPA also will continue assessing toxicity data on microcystins, cylindrospermopsin and anatoxin-*a* as appropriate. Research activities to assess the human health effects of cyanotoxins in drinking water include monitoring of cyanotoxins in U.S. waters and conducting toxicological and epidemiology studies to further understand the effects of cyanotoxins. Additional ongoing activities can be found in Appendix 2.

Intended Future Activities

The EPA plans to assess new information as it becomes available on current and emerging cyanotoxins to determine if future HAs are needed. Additional information on EPA's proposed activities can be found in Appendix 3. Furthermore, as it evaluates human health effects of HAB exposures, EPA intends to continue collaborating with public health partners.

Timelines for Ongoing and Future Activities
EPA has recently completed activities to evaluate the risk to human health from drinking water contaminated with algal toxins (§1459(a)(1)(A)) for three algal toxins: anatoxin-*a,* microcystins and cylindrospermopsin. Going forward, EPA will continue to evaluate additional toxicity data that may become available for these three algal toxins, as appropriate. During FY 2016, EPA plans to evaluate the available information on human health risk associated with other cyanotoxins to determine whether sufficient information is available to develop HAs for additional cyanotoxins. These efforts will also continue in the years ahead.

b. Health Advisories

This section is responsive to §1459(a)(1)(D)(i) of the SDWA directing the EPA to develop a strategic plan to *"publish health advisories pursuant to section 1412(b)(1)(F) for such algal toxins in drinking water provided by public water systems."*

SDWA provides the authority for the EPA to publish HAs for contaminants not subject to any national primary drinking water regulation. HAs describe non-regulatory concentrations of drinking water contaminants at which adverse health effects are not anticipated to occur over specific exposure durations (e.g., one day, ten days, several years and a lifetime). They serve as informal technical guidance to assist federal, state and local officials, as well as managers of public or community water systems in protecting public health when emergency spills or contamination situations occur. They are not legally enforceable federal standards.

There are currently no U.S. federal guidelines, water quality criteria, standards or regulations for cyanobacteria or cyanotoxins in drinking water under SDWA, or in surface waters under the Clean Water Act. However, the EPA identifies cyanobacteria and cyanotoxins as a priority, highlighting three particular toxins of interest—microcystin-LR, cylindrospermopsin, and anatoxin-*a*—on previous CCLs and the current draft CCL, which identify contaminants that may need regulation under SDWA. The EPA found there are adequate health effects data to develop HAs for microcystins and cylindrospermopsin but found the data inadequate to develop an HA for the cyanobacterial toxin anatoxin-*a*.

Completed Activities
On June 17, 2015, the EPA published two HAs in drinking water for the cyanotoxins, microcystins and cylindrospermopsin (U.S. EPA, 2015e, f). The HAs for microcystins and cylindrospermopsin provide states, drinking water utilities and the public with information on health effects of microcystins and cylindrospermopsin, analytical methods to test for cyanotoxins in water samples, and treatment technologies to remove cyanobacterial toxins in drinking water. These documents are available at: http://water.epa.gov/drink/standards/hascience.cfm.

Ongoing Activities
The EPA intends to determine whether adequate occurrence, toxicology and epidemiology data are available to develop HAs for the cyanotoxins to be included in the list developed under §1459(a)(1)(B). The EPA also plans to continue assessing toxicity data on microcystins, cylindrospermopsin and anatoxin-*a* to determine whether the existing health advisories should be updated. Additional ongoing activities can be found in Appendix 2.

Intended Future Activities
EPA is evaluating whether additional studies to evaluate the toxicity, including the toxico-dynamics and toxicokinetics, of microcystin congeners are feasible within existing resource constraints. In addition, the NIH National Toxicology Program intends to conduct toxicity studies to address the adverse effects to the reproductive system from exposure to microcystins. The EPA also plans to continue evaluating the health effects of cyanobacteria, including determining the toxicity and allergenic roles of purified cyanobacteria lipopolysaccharide. Additional information on EPA's proposed activities can be found in Appendix 3.

Timeline for Ongoing and Future Activities
The EPA published HAs for microcystins and cylindrospermopsin in June of 2015. If the EPA finds that additional information is sufficient to develop HAs for cyanotoxins other than microcystins or cylindrospermopsin, completion of HAs for additional cyanotoxins is expected to take approximately one to two years per assessment.

c. Factors Likely to Cause Harmful Algal Blooms

This section of the strategic plan is responsive to §1459(a)(1)(C)(ii) of the SDWA, which directs the EPA to develop a strategic plan to summarize the "*factors that cause toxin-producing cyanobacteria and algae to proliferate and express toxins*".

Cyanobacteria, also known as blue-green algae, naturally occur in marine and fresh waters. Under certain conditions cyanobacteria can grow rapidly, producing cyanobacterial blooms (AWWA and WRF, 2015). Some cyanobacteria are capable of producing toxins, called algal toxins or cyanotoxins, which can pose health risks to humans and animals (U.S. EPA, 2014). Blooms producing toxins are often referred to as HABs. The conditions that cause cyanobacteria to produce cyanotoxins are not well understood. For example, even when cyanobacteria capable of producing toxins are present, they may not actually produce toxins under all environmental conditions (U.S. EPA, 2012b). Also cyanotoxins can occur in the absence of a visual bloom as not all blooms are visual. It is also not possible to determine solely upon visual observation if a bloom is producing toxins. When blooms occur, the risk of cyanotoxin contamination of the surface water increases, thus increasing potential risk to drinking water sources (U.S. EPA, 2014).

Excess nutrient (nitrogen and phosphorus) loadings and concentrations are a leading cause of increased occurrence of cyanobacterial bloom formation in water bodies (Yuan and Pollard, 2015). These excess nutrients can originate from agricultural, industrial and urban sources as well as from atmospheric deposition (Paerl and Otten, 2013; Conley et al., 2009; Glibert et al., 2014). Factors influencing the occurrence of cyanobacterial blooms can include:

- excess nutrient (nitrogen and phosphorus) loadings and concentrations,
- slow-moving surface water,
- high water temperature,
- high intensity and duration of sunlight,
- water column stratification,
- changes in water pH, and
- occurrence of trace metals.

Many of these factors play a greater role during shifts in wind and/or precipitation patterns (Izydorczyk et al., 2005; Ohio EPA, 2010). Rapid swings between drought and flooding can increase levels of nutrients in adjacent and downstream water bodies that have accumulated on the land during the drought. Increased temperatures and changes in frequency and intensity of rainfall associated with climate change can also favor bloom formation (Paerl and Huisman, 2009). In addition, Doblin et al. (2007) demonstrated that cyanobacteria can be transported in ballast water from ships at a port where active blooms occur to other locations when ballast water is discharged.

Completed Activities

The EPA has taken several steps to better understand cyanobacterial HAB ecology. In particular, the EPA is conducting research to evaluate and summarize contributors to cyanobacterial HAB development and toxin production. This research program also includes the use of molecular methods to characterize risk in reservoirs due to algal blooms and toxin production.

The EPA provides nationally consistent and scientifically robust assessments of aquatic resources through the National Aquatic Resource Surveys (NARS), with a variety of indicators including cyanotoxins and cyanobacteria abundance (U.S. EPA, 2010). Other physical, chemical and biological indicators such as chlorophyll-*a*, pathogens, nutrients and sediments are also surveyed. Information from these surveys is available at: http://water.epa.gov/type/watersheds/monitoring/aquaticsurvey_index.cfm. The NARS dataset provides information useful for vulnerability assessments for risks of cyanotoxin exposure for drinking water sources. The EPA evaluated data from the 2007 National Lakes Assessment (NLA) on cyanotoxin co-occurrence with other environmental variables. A model was developed associating concentrations of microcystins with concentrations of chlorophyll-*a* and total nitrogen. This model can be used for predicting the occurrence of high concentrations of microcystins, and to identify watershed management thresholds for total nitrogen and chlorophyll-*a* to reduce the risks of increased cyanotoxin concentrations in source water (Yuan et al., 2014). The 2012 NLA data were used to describe a statistical approach for deriving numeric targets for concentrations of total phosphorus and total nitrogen in lakes and reservoirs that reduce the probability of excess growth of cyanobacteria in source water (Yuan and Pollard, 2015). This analysis classified different lakes into groups in which the relationships between cyanobacterial biovolume and nutrient concentrations were similar, improving the strength of association between nutrient concentrations and cyanobacterial biovolume over the entire dataset. Then relationships between total nitrogen, total phosphorus and cyanobacterial abundance were estimated within different lake classes using hierarchical Bayesian statistical models.

In June 2015, the EPA released a step-by-step assessment guidance to help drinking water systems conduct a system-specific evaluation to determine if and when their source water is vulnerable to cyanotoxin occurrence (part of a recommendations document released to assist PWSs in managing risks from cyanotoxins (U.S. EPA, 2015g)). The EPA also released HESDs for the cyanobacterial toxins microcystins, anatoxin-*a*, and cylindrospermopsin (http://water.epa.gov/drink/standards/hascience.cfm) that contain information on the factors likely to cause cyanobacterial blooms and toxin production, in addition to health effects information.

Ongoing Activities

The EPA is working collaboratively with NASA, NOAA and the USGS on the Cyanobacteria Assessment Network (CyAN) to detect and quantify cyanobacterial blooms in U.S. freshwater lakes and reservoirs using satellite color data. These efforts will allow for more frequent observations over broader areas than can be achieved by taking traditional water samples. Researchers are developing a mobile application (app) to inform water quality managers of changes in water quality using satellite data on cyanobacteria algal blooms (Schaeffer et al., *Accepted*). This network can assist freshwater systems in incorporating satellite ocean color technologies into U.S. fresh and brackish water quality management decisions. The overarching project goal is to support the environmental management and public use of

U.S. lakes, reservoirs and estuaries by providing the capability to detect and quantify cyanobacterial blooms using satellite data (Lunetta et al., 2015; U.S. EPA, 2015h). This tool can help states, PWSs and others obtain efficient and timely information about source water conditions.

The EPA is working on monitoring projects to improve identification and removal of cyanotoxins in drinking water and is also evaluating the impact of increasing water temperatures and nutrient loads on bloom development and toxin production. The EPA is currently conducting research on HABs ecology and the development of watershed and source water management techniques, including the development of models for nutrient loadings, increasing efficiency of watershed placement of phosphorus and sediment best management practices (BMPs) to reduce nutrient loadings, and the use of water quality trading (WQT) to cost-effectively reduce nutrient loadings delivered to a watershed. The EPA is also assessing the impact of land use and infrastructure on watershed changes and evaluating ecological contributors to HAB development and toxin production. EPA-led monitoring projects are also underway to improve identification and removal of cyanobacterial toxins in drinking water and to identify and characterize the development of blooms in Lake Erie.

The EPA continues to analyze NARS datasets to determine if national recommendations can be made on the concentrations of total nitrogen and total phosphorus in source waters that would most likely not lead to formation of HABs. For additional ongoing activities see Appendix 2: EPA's Current Activities Directly Related to Freshwater HABs.

Intended Future Activities

The ongoing efforts detailed above are expected to continue to completion. In addition, EPA released its Strategic Research Action Plans for the 2016-2019 timeframe in October 2015. The EPA's Office of Research and Development's Safe and Sustainable Water Resources Research Program has included a project focused on HABs, with multiple tasks that are described in EPA's Intended Future Activities Directly Related to Freshwater HABs (Appendix 3), including further development of satellite remote sensing capabilities for freshwater HABs that can be utilized in monitoring and management programs.

The EPA plans to work with its federal, state and local partners to make full use of existing cyanobacteria and cyanotoxin information from a variety of sources. State and regional investigators have conducted a number of surveys of cyanotoxins that could be explored for inclusion into a central database. This information could come from both field monitoring stations and supporting laboratory experiments. Information on factors affecting bloom occurrence should also be compiled.

The EPA plans to work with state and federal partners to incorporate cyanotoxin monitoring into routine source water and ambient monitoring programs to better understand the conditions that trigger bloom occurrence and toxin production. The EPA also intends to develop HAB indicators, sampling designs and protocols for use in national scale assessments. The EPA intends to also work with state and federal partners to develop a domestic action plan for meeting the updated nutrient load targets for Lake Erie established under Annex 4 of the Great Lakes Water Quality Agreement. The Great Lakes Water Quality Agreement provides a case study of a framework the EPA could use to develop and implement nutrient load targets on a large scale.

The EPA intends to evaluate existing data from case studies and modeling efforts to identify the factors relating bloom occurrence and toxin production. EPA also intends to develop improved approaches to understanding the interactive effects of increasing water temperatures and nutrient loads on HAB development and toxin production as well as improved models to predict risks of HABs under climate change scenarios. A summary of findings is anticipated to be shared broadly and incorporated into predictive tools. Also of interest is an improved understanding of the temporal dynamics of the relationship between increased nutrients and HABs. Intensive sampling, over time, of a sub-set of the sites included in the NARS will provide the data that could be analyzed in combination with existing national datasets. This would allow the EPA to more accurately characterize the contributions of temporal changes to observed relationships between nutrients and ecological effects in order to make scientifically sound numeric nutrient criteria recommendations that are protective of the nation's drinking water sources.

Additionally, the EPA intends to evaluate the links between changing temperatures and changing risk of blooms on a national scale. Potential studies include relating air temperature to photic-zone temperature with the intention of modelling this at a broader scale, evaluating how cyanobacteria or indicators respond to changes in photic-zone temperature, including how this can be predicted over large spatial extents, and studying how forecasted changes in air temperature impact the likelihood and extent of bloom events. Additional information on EPA's proposed activities can be found in Appendix 3.

The contaminants listed on the CCL (including cyanotoxins) generally represent priorities for the UCMR program. Under UCMR, occurrence data are collected to allow the EPA to evaluate contaminants that currently do not have drinking water standards and to support subsequent regulatory determinations (U.S. EPA, 2012b). EPA is currently evaluating whether to include certain cyanotoxins in UCMR 4, which is scheduled for proposal by early 2016.

The EPA's goal is an improved understanding of the factors that are responsible for cyanobacterial growth and bloom formation as well as an improved ability to predict when cyanobacteria are likely to produce toxins. Additionally, the EPA hopes to develop an improved understanding of the relationship between nutrient loading and cyanotoxin concentrations across a range of temporal and spatial scales. This information is expected to be summarized and incorporated into tools that would help predict and prevent algal toxin occurrence in drinking water sources.

An important approach to reducing potentially toxic cyanobacterial blooms is to develop and implement cost-effective and scientifically sound nutrient reduction strategies to achieve healthy water quality in drinking water sources. The EPA's research will inform tools that can predict downstream water quality impacts, including cyanotoxin concentration, associated with various nutrient management decisions in watersheds. This information will be useful for drinking water managers and others in comparing cost-effective source water control practices to treatment activities at the utility. These tools are anticipated to help predict source water responses to nutrients in the context of other drivers (e.g., climate change, coastal acidification and hydrologic changes).

Timeline for Ongoing and Future Activities

Efforts to better understand the factors that cause toxin-producing cyanobacteria and other algae to proliferate and express toxins are ongoing, and planned research activities are expected to require one to five years to complete, dependent upon the project and contingent upon available resources. For example, the capability of satellite detection of algal blooms is estimated to require up to three years to complete. As another example, the evaluation of NARS data is an ongoing process, with the most recent NARS lake assessment data with an anticipated publication date of spring 2016.

The EPA plans to publish the final UCMR 4 by late 2016 or early 2017. If cyanotoxins are monitored as part of that effort, cyanotoxin national occurrence information in raw and finished drinking water will be collected from 2018 to 2020.

d. Analytical Methods

This section of the strategic plan is responsive to §1459(a)(1)(D)(ii) of the SDWA directing the EPA to develop a strategic plan to *"establish guidance regarding feasible analytical methods to quantify the presence of algal toxins."*

Accurate and scientifically validated methods to detect algal toxins are critical to assessing and managing risks associated with algal toxins in drinking water. The EPA is actively collaborating with states, utilities, and commercial laboratories to develop and validate analytical methods for algal toxins in drinking water.

Completed Activities
With the CCL and UCMR in mind, EPA scientists developed and recently published two liquid chromatography tandem mass spectrometry (LC/MS/MS) methods for cyanotoxin analysis in drinking water: EPA Method 544 for determination of select microcystins and nodularin-R (U.S. EPA, 2015i) and EPA Method 545 for determination of anatoxin-*a* and cylindrospermopsin (U.S. EPA, 2015j). In developing the HAs for total microcystins and cylindrospermopsin, the EPA reviewed a variety of additional analytical methods available for measuring these toxins in drinking water (U.S. EPA, 2015e, r). Based on the Agency's understanding as of June 2015, the EPA provided recommendations for water utilities on the use of enzyme-linked immunosorbent assays (ELISA) as a rapid, cost-effective screening and monitoring tool and the LC/MS/MS methods to determine the concentration of a number of specific toxins (U.S. EPA, 2015g).

Ongoing Activities
The EPA is continuing to develop and validate improved analytical methods for algal toxins in drinking water, and evaluating other methods to fill knowledge gaps. Current efforts include further evaluating the comparability of results from rapid screening methods and more specific analytical methods. The EPA is also investigating a new LC/MS/MS method for microcystins based on analysis of an oxidative product (2-methyl-3-methoxy-4-phenylbutyric acid or "MMPB") which may serve as a surrogate for the total concentration of microcystins present in a sample. This method is an alternative to the ELISA method, providing confirmatory data utilizing a more sophisticated, albeit more time-consuming, complex and expensive method. Another concurrent effort involves adapting drinking water analytical methods EPA Methods 544 and 545 for use in ambient water. Analysis of ambient water tends to be more complex due to additional constituents in the water (e.g., organic matter, particulates) that can potentially interfere with the analysis. The EPA plans to standardize and validate the ambient water methods for use by states, utilities and commercial laboratories to measure cyanotoxins in source waters. Additionally, the EPA is evaluating analytical tools such as real-time sensors, qPCR, and fluorescence-based technologies of microspectrophotometry and flow cytometry to detect cyanobacteria in source water. EPA is also planning to develop methods for analyzing toxins in fish/animal tissues. The EPA is also increasing its laboratory capacity for analyzing cyanotoxins; for example, EPA Region 7 enhanced its EPA lab capabilities and conducted microcystin analysis in September 2015 for the Kickapoo Nation of Kansas for the Delaware River (source of water) and finished water at the treatment plant. Additional ongoing activities can be found in Appendix 2.

Intended Future Activities
In addition to the ongoing efforts discussed above, as the EPA continues to evaluate the human health risk from cyanotoxins in drinking water and establishes a list of algal toxins under §1459(a)(1)(B), there will be continued interest in standardized and validated detection and analysis methods for additional

algal toxins. Since it may prove impractical to develop methods to quantify each and every algal toxin in water (as there are multiple classes of algal toxins and potentially more than one hundred variants within one class, e.g., microcystins), it is important to develop effective and targeted methods for algal toxins of concern. A significant challenge to analyzing algal toxins is the limited availability of certified reference materials (CRMs) for many of the toxins that may impact U.S. waters. There is a need for affordable methods for toxin analysis that can be implemented by a variety of user groups, quality-assured with CRMs, and validated through inter-laboratory trials. The EPA plans to continue to collaborate with other federal agencies and stakeholders to develop intra- and interagency methods and approaches. The EPA intends to further investigate alternative ways to assess the impact of the many toxins should quantitation of each and every toxin of interest prove impractical (e.g., due to lack of available CRMs). Additional information on EPA's proposed activities can be found in Appendix 3.

Timelines for Ongoing and Future Activities
The EPA completed the development of EPA Methods 544 and 545 in 2015, as discussed above. Evaluating, and as appropriate developing, an MMPB method is expected to take approximately two years. Developing methods for ambient water is also anticipated to take around two years. As additional algal toxins are identified or prioritized, the EPA plans to continue developing methods as needed, with development of a method typically requiring two to four years.

e. Frequency of Monitoring

This section is responsive to §1459 (a)(1)(D)(iii) of the SDWA directing the EPA to develop a strategy to *"establish guidance regarding the frequency of monitoring necessary to determine if such algal toxins are present in drinking water provided by public water systems."*

Monitoring of algal bloom indicators and toxins in raw water and drinking water can provide early warnings of HAB events and allow water managers to take actions when the HAB events threaten their source water. Toxin concentrations are highly variable with season and time of the day and are impacted by many factors (e.g., bloom dynamics, characteristics of water body, weather, etc.). Currently, no national database on the occurrence of freshwater cyanotoxins is available, and no federal program is in place to monitor for cyanotoxins at U.S. drinking water treatment plants. Therefore, data on the presence or absence of cyanotoxins in finished drinking water are limited. Understanding the factors and conditions that cause bloom formation could lead to better informed and cost-effective monitoring activities, as discussed in Section III, c above. Cyanotoxins can be held within the cell (intracellular) or outside the cell (extracellular). Toxins are released from the cell due to multiple factors and during the normal bloom cycle die off. The relationship between the environmental conditions that trigger the cyanobacteria to produce toxins is poorly understood. This variability and unpredictability of the presence of toxins can make monitoring challenging.

Completed Activities
After consulting with states and other stakeholders, the EPA developed its recommendations on monitoring frequency for microcystins and cylindrospermopsin in raw and finished drinking water based, in part, on conditions in source water and at the treatment plant (U.S. EPA, 2015g). The EPA advised that it is important for PWSs to establish their own monitoring frequency based on their site-specific conditions, available resources, treatment capabilities and other factors (U.S. EPA, 2015g). Additional information regarding monitoring procedures is available on the EPA Cyanobacterial HABs website (http://www2.epa.gov/nutrient-policy-data/cyanohabs), where there are recommended procedures for sampling, preservation, handling and transportation of samples collected to identify the presence of algal toxins in drinking water.

Ongoing Activities
Many of the inter- and intra-agency monitoring programs described in Section III, c , such as the CyAN Project, will provide a better understanding of the appropriate monitoring frequencies of drinking water in addition to helping understand the factors likely to cause HABs. For recreational waters and drinking source waters, continuous, real-time monitoring offers some advantages over traditional water sampling. These efforts can help inform PWS operators and states as to when they should sample their raw and finished waters. The EPA is working with an interagency task force led by NOAA to develop sensitive, quantitative, field deployable assays and sensors for HAB cells, toxins and relevant toxin metabolites; develop remote sensing capabilities for HABs; and integrate HAB and toxin sensors into emerging U.S. and global ocean observation systems.

Other examples of ongoing EPA efforts include a pilot-scale study that EPA Region 8 is conducting with PWSs in Wyoming to monitor and collect samples for cyanotoxin analysis. As another example, with EPA Region 10 support, through the Indian General Environmental Assistance Program, the Sitka Tribe of Alaska formed the Southeast Alaska Tribal Toxins network (SEATT) with seven other tribes to gather HAB baseline information. Additional ongoing activities can be found in Appendix 2.

Intended Future Activities
The EPA plans to continue the ongoing efforts detailed above, engaging with states and PWSs to update and refine the existing guidance on monitoring frequency as more information becomes available. The EPA anticipates that the development of HAB forecasts under the CyAN program will continue during fiscal year 2016 and EPA intends to continue research on determining temporal and spatial variability of blooms (see Section III, c for further discussion). Furthermore, the EPA plans to continue working with NOAA on a systematic approach to provide warnings to states on water quality and occurrence of cyanobacterial blooms, which will allow the states to evaluate patterns and trends in lakes and estuaries that are at risk based on region-specific information. Additional information on EPA's proposed activities is described in Appendix 3.

Additionally, as the EPA continues to evaluate monitoring frequency for UCMR 4, the EPA may suggest possible cyanotoxin monitoring schedules and approaches as part of that effort. The toxins identified as priority in CCL 4 that could be considered in UCMR 4 are: microcystin-LR, cylindrospermopsin, and anatoxin-*a.*

Timeline for Ongoing and Future Activities
The EPA anticipates it will take four to six months to seek public input and analyze available information from the 2015 HAB season (including PWS experience with the current recommendations in the 2015 HAB season). An additional three months is anticipated to update the current monitoring recommendations as appropriate, based on this evaluation. Building of the Cyanobacteria Assessment Network is currently underway and is expected to take an estimated three to five years to complete.

The EPA plans to publish the final UCMR 4 by late 2016 or early 2017. If cyanotoxin monitoring is finalized as part of that rulemaking, any amended or new cyanotoxin-related monitoring schedules or approaches to consider will be included as appropriate.

f. Treatment Options

This section is responsive to §1459(a)(1)(E) of the SDWA directing the EPA to develop a strategic plan to *"recommend feasible treatment options, including procedures, equipment, and source water protection* *practices, to mitigate any adverse public health effects of algal toxins included on the list published* [by the EPA]*."*

Controlling and managing cyanobacteria in source water and treating cyanobacteria and cyanotoxins in drinking water are critical to protecting public health. If operated properly, conventional water treatment designed to reduce turbidity can generally remove intact algal cells and low levels of toxins (AWWARF, 2001; Haddix et al., 2007). More recently, a study conducted in the United States from 2008 to 2010 in five conventional drinking water treatment plants found microcystins and cylindrospermopsin at low concentrations in raw water, but found toxins were removed to levels below detection in any of the finished drinking water samples (Szlag et al., 2015). However, PWSs may face challenges in providing safe drinking water during a severe bloom event, which can increase the cyanobacteria and cyanotoxin levels in source waters. There are various prevention and treatment strategies and approaches at the source, throughout the treatment train, and in the finished water storage and distribution system for a PWS. As with other contaminants, a multiple-barrier approach is useful.

Completed Activities

The EPA has been working collaboratively with regional offices, states and PWSs to characterize the effectiveness of drinking water treatment technologies in reducing algal toxins. In developing the HAs for microcystins and cylindrospermopsin, the EPA reviewed available treatment technologies for treating these toxins in drinking water. These available treatment technologies were published in the HAs for microcystins and cylindrospermopsin (U.S. EPA, 2015 e, f). During the 2013 and 2014 blooms seasons in Lake Erie, EPA researchers conducted sampling at seven drinking water treatment plants. In addition, bench-scale studies on the impact of oxidation and powdered activated carbon (PAC) addition early in the treatment process on toxin removal has been evaluated. Based on this and other experiences, the EPA developed four basic treatment strategies that PWSs can implement to provide immediate response to any cyanotoxins detected in drinking water intakes and included these strategies within the recommendations support document released concurrently with the HAs (U.S. EPA, 2015g).

Ongoing Activities

In order to provide further assistance to utilities, the EPA is developing a document to summarize the state of knowledge regarding water treatment optimization and identify approaches to assist with treatment challenges related to HAB events. The EPA is also undertaking research to better understand the removal effectiveness of unit operations for various toxins and develop better predictive tools/models. For example, it is not known to what capacity a granulated activated carbon (GAC) contactor unit is able to mitigate such compounds in the event of a severe bloom event. Additional ongoing activities are described in Appendix 2.

Intended Future Activities

The EPA plans to continue the ongoing efforts detailed above as well as to undertake a systematic study to evaluate the capacity of GAC to remove cyanotoxins from source water. In addition, the EPA plans to investigate how to implement process and operational changes for maximum protection and cost-effectiveness under a variety of site-specific constraints. Ideally, these changes would minimize capital, maintenance and operational expenses and be scalable across treatment facility size and resource level. In order to address these questions, EPA intends to perform pilot-scale studies at field locations and at in-house facilities. The EPA also plans to continue to engage with water managers and other private and public sector stakeholders to help ensure treatment goals are met, to streamline transfer and adoption of viable management strategies and technologies and to utilize the available treatment research information that is currently available and directly applicable to cyanobacteria and cyanotoxin removal.

Additional intended future activities are listed in Appendix 3, EPA's Intended Future Activities Directly Related to Freshwater HABs.

<u>Timeline for Ongoing and Future Activities</u>
The EPA anticipates the field studies will take approximately four years and the in-house pilot studies will take about two years to complete. The optimization guidance document is estimated to take one year to complete with additional research to be completed in four years. The evaluation of cyanotoxin removal by GAC is estimated to take three years to complete.

g. Source Water Protection Practices

This section is responsive to §1459(a)(1)(E) of the SDWA directing the EPA to develop a strategic plan to *"recommend feasible treatment options, including procedures, equipment, and source water protection practices, to mitigate any adverse public health effects of algal toxins included on the list published* [by the EPA].*"*

Source water protection (SWP) refers to watershed protection measures intended to prevent contaminants such as cyanotoxins from entering or forming in a source of drinking water. SWP serves as an early-stage barrier against drinking water contamination and is a proactive, often cost-effective option to reduce contamination that would otherwise need to be addressed by drinking water treatment technologies. PWSs can effectively reduce cyanobacteria and related contamination by addressing factors likely to cause toxic blooms (hereafter "risk factors"). Numerous risk factors for toxic blooms are discussed in Section III, c. Notably, high loadings of nutrients, like phosphorus and nitrogen, under certain ambient water and climate conditions are drivers of HABs. While other factors like vertical stratification and water temperature may impact HABs, recommended SWP practices address nutrient loading as the most immediate, controllable risk factor.

Nitrogen and phosphorus in source waters can come from point sources of pollution like wastewater treatment plants and/or nonpoint sources of pollution like agricultural or stormwater runoff. Air deposition of nitrogen and legacy from in-stream sediments are also contributors. Effective SWP options to reduce pollution from point vs. nonpoint sources differ; for example, point sources may be addressed through facility-specific actions like Clean Water Act (CWA) permitted effluent limits, while pollution from nonpoint sources may be reduced through broader measures like landscape-scale fertilizer management (by agricultural producers and homeowners) and BMPs such as buffer strips and cover crops on agricultural lands. SWP methods must also be attuned to drainage conditions, soil characteristics and other hydrologic and geologic factors impacting nutrient discharge (Ohio EPA, 2015).

Steps toward recommending the most effective SWP practices to reduce incidents of HABs include:

- **Identify source waters vulnerable to cyanotoxins**, accounting for present, future and seasonal conditions, in order to target early monitoring for cyanotoxins and SWP activities.
- **Develop new and apply existing tools to inventory point and nonpoint discharges of nutrients** in each vulnerable source water to develop the most appropriate matrix of SWP options.
- **Evaluate nutrient contributions**
    - Compare the relative contribution of potential sources of nutrients to in-stream nutrient levels (what are the "root causes" of nutrients in the source water?).
    - Estimate magnitude of HAB risk factors, considering time lags between nutrient load and bloom response.

- Establish the baseline ambient data to measure the impact of SWP activities, once implemented.
- **Assess any institutional factors** (e.g., financing options, policy frameworks and partnership opportunities) that will help stakeholders implement SWP.

Implementing nutrient input control requires the cooperation of many programs and stakeholders. Examples of EPA collaborations to advance the strategies above include:

- A partnership of the EPA, the Association of Clean Water Administrators (ACWA), the Association of State Drinking Water Administrators (ASDWA), the Ground Water Protection Council (GWPC) and their networks worked together to produce *Opportunities to Protect Drinking Water Sources and Advance Watershed Goals through the Clean Water Act*, a toolkit that describes ways PWSs can use the strengths of SDWA and CWA programs to protect drinking water. In the Toolkit, partners describe how programs like point source permitting, water quality standards, listings, Total Maximum Daily Loads (TMDLs) and Section 319 watershed project funding can protect source water, thus alleviating public health risks and treatment costs for downstream PWSs (ASDWA et al., 2014; GWPC, 2012). Several elements of this Toolkit are described below.
- The EPA is working alongside state and utility associations, non-governmental organizations (NGOs), federal agencies like the USDA and other partners in the national Source Water Collaborative (SWC), a group of 26 organizations dedicated to protecting sources of drinking water. The SWC provides planning resources and technical support for local, state and regional source water partnerships with a focus on reducing nutrient pollution. For example, the SWC offers online guides to networking across sectors, accessing funding for SWP and designing specific projects like manure storage systems and GIS scenario analysis for conservation practices (SWC, 2015a). SWC members including USDA and the National Association of Conservation Districts (NACD) also created a Conservation Partners toolkit, which offers a step-by-step guide for understanding conservation programs through Soil and Water Conservation Districts and USDA State Conservationists (SWC, 2015b).
- The EPA is working with states to develop and implement nutrient reduction frameworks to identify their specific sources of nutrient pollution and prioritize watersheds and actions they will take to reduce these sources, as well as measures to track progress in meeting their Clean Water Act goals. These goals include meeting water quality standards for nutrients and preventing HABs. The EPA builds state capacity to reduce nutrient pollution by providing grants for state water pollution control programs and programs for controlling nonpoint sources of pollution. The EPA also makes capitalization grants for state loan programs for municipal wastewater infrastructure and stormwater best management practices. The EPA also provides technical assistance and oversees regulatory programs that states use to reduce nutrient pollution (e.g., National Pollutant Discharge Elimination System (NPDES) permits for point source dischargers, TMDLs that set "pollution budgets" that are the basis for permit limits for point sources and inform financial and technical assistance to nonpoint sources).
- The EPA works with states and other partners in geographically targeted programs to reduce nutrient pollution contributing to harmful algal blooms in the Great Lakes, Chesapeake Bay and its tributaries, and other places. The EPA co-leads the Gulf of Mexico Hypoxia Task Force, a voluntary partnership of five federal agencies and 12 states, that seeks to reduce one of the largest hypoxic zones in the world. Actions by Task Force members to reduce nutrient pollution in the Gulf also have benefits in more local waters, including reduced HABs. The EPA's recently released Report to Congress on the Hypoxia Task Force (U.S. EPA, 2015k) includes numerous examples of collaborative work to control nutrients.

- The EPA and USDA continue to collaborate in multiple geographic programs and in a National Water Quality Initiative to demonstrate the benefits of using systems of conservation practices on vulnerable lands to avoid, control and trap nutrients and maximize the effectiveness of conservation investments.

Completed Activities

SWP and nutrient management planning: The 1996 amendments to the SDWA Section 1453 required state drinking water agencies to complete Source Water Assessments no later than 3.5 years following the Agency's approval of the state's program. Source Water Assessments can help stakeholders identify whether a source water is vulnerable to cyanotoxins. The assessment delineates the Source Water Protection Area of every public water supply, inventories significant potential sources of contamination within the Protection Area, and evaluates the susceptibility of each system to contamination (U.S. EPA, 1997). All states completed Source Water Assessments by 2003. States and local stakeholders often use the assessment as a baseline for proactive source water protection plans and activities. However, since most of these assessments are more than 15 years old and the data used to develop them have improved dramatically, the information may not be accurate today. In addition, many were not made available to the public due to concerns about security. In some cases, because the assessment data were not available to the public, it prevented the data from being used to make planning decisions at the watershed scale. The advent of new sources of contamination (e.g., new urban development) and new, open data sources provide strong incentives to update past assessments to reflect more current information and HABs-specific vulnerabilities.

Additionally, the EPA has worked with states to create and update Nonpoint Source Management Plans and Watershed-Based Plans (WBPs). The CWA requires states to develop Nonpoint Source Management Plans which outline objectives to restore impaired waters and protect healthy waters against nonpoint source pollution. Nonpoint Source Management Plans often form the basis for state regulatory and voluntary initiatives (e.g., conservation programs) to curb nutrient pollution. WBPs, which target specific waterbodies within a state, provide a roadmap to guide cost-effective, well-informed restoration and protection efforts. WBPs serve as the planning framework for CWA §319 watershed projects (ASDWA et al., 2014; GWPC, 2012). At the state level, watershed-specific source water assessments can be compared to Nonpoint Source Management Plans and WBPs to inform SWP planning and activities.

Nutrient monitoring: State water quality agencies monitor and assess waters for nutrients as well as, in some cases, cyanobacteria or microcystins, and share these data through the EPA's Water Quality Data Portal. Another source of monitoring data for HAB information is satellite imaging, such as that used in the Lake Erie HABs Bulletins by NOAA (NOAA, 2015). The United States Geological Survey (USGS) also collects data on nutrients and cyanotoxins through the National Water Information System (NWIS). In addition, cyanobacteria and microcystins are a part of the National Lakes Assessment included in NARS (U.S. EPA, 2013b). However, monitoring for nutrients and cyanotoxins varies in frequency and quality across watersheds and states. Current methods for measuring nutrient loading are expensive and do not fully capture nutrient flux within ecosystems, limiting data availability (see "Ongoing Activities" for additional information).

EPA Region 1 developed a GIS-based approach to identify potential risks from nutrient-related impairments, including cyanobacteria blooms in New Hampshire's drinking water sources. The same analysis and mapping is expected to be conducted for the other five New England states. This effort is helping the region and states to gain a better understanding of the connection between drinking water source waters, CWA 303(d) impaired waters and algal blooms. This is a fundamental step to aligning CWA and SDWA priorities.

Source water standards: The EPA'S Office of Water/Office of Science and Technology (OST) has developed Nationally Recommended Water Quality Criteria (NRWQC) for Total Nitrogen and Total Phosphorus (aquatic life ecoregional criteria) and nitrates (human health criteria) to help states and tribes to develop Water Quality Standards under Section 304(a) of the CWA (U.S. EPA, 1986) (U.S. EPA, 2015l). Additionally, the EPA continues to collaborate with states and tribes to develop and implement region-specific Water Quality Standards that account for site-specific information, current science and implementation flexibilities under the CWA. These standards form the first step toward controlling nutrient discharge from point sources in drinking water. Water Quality Criteria inform Total Maximum Daily Loads (TMDLs), which states can use to define nutrient permit limits for point sources.

To help restore waters that do not meet Water Quality Standards, the EPA has developed the Recovery Potential Screening (RPS) tool, which outlines ecological, geographic and social factors that lead to effective watershed protection. RPS helps watershed programs make decisions on where to invest in protections for the highest chances of success (U.S. EPA, 2012c).

<u>*Ongoing Activities*</u>

New tools for HAB detection and tracking: The EPA is developing new HAB tracking tools and approaches to help states and drinking water utilities identify vulnerable source waters and plan SWP activities that are most suitable to those watersheds. The EPA is in the initial stages of developing mobile apps to help citizen scientists report and analyze new blooms. As discussed in Section III, c, the EPA's ORD, NASA, NOAA and USGS are also developing an early warning indicator system using historical and current satellite data to detect algal blooms. Given additional support for these initial efforts, these tools can help the EPA, states and utilities track and swiftly respond to HAB events nationwide. The EPA is also coordinating with states and water systems to share information about protecting source waters, monitoring for cyanotoxins, and managing cyanotoxins in drinking water.

Nutrient monitoring: Additional monitoring information across watersheds is necessary to both target and assess SWP activities by measuring the most significant sources of contamination. For nonpoint source discharges, real time water quality monitoring sensors for nitrogen and phosphorus could be expanded in strategic locations such as downstream of point sources (see "Intended Future Activities" below).

A coalition of federal agencies, including the EPA, NOAA, National Institute of Standards and Technology (NIST), and USGS, has launched the Nutrient Sensor Challenge—an open-innovation competition to accelerate the development and deployment of affordable sensors that can measure nutrients in aquatic environments. The Challenge aims to spur development of inexpensive sensors that can be commercially available by 2017. Sensors can be used by federal and state agencies, researchers, utilities and watershed managers across the United States to gain a better understanding of nutrient levels and how nutrients move through the environment—improving watershed management decisions (ACT, 2015).

The EPA is partnering with the dairy and swine industries to develop a Nutrient Recycling Challenge to accelerate development and use of technologies that can recover nitrogen and phosphorus from animal manure and generate value-added products. Environmental and economic benefits can become substantial as more efficient ways to manage and transport nutrients are developed. The call for concepts will launch November 16, 2015.

Source water standards: For waters experiencing high nutrient and cyanotoxin levels, states, often with assistance from the EPA, work to prioritize waterbodies for TMDL development and establish waste load allocations and permitted effluent limitations under Section 402 of the Clean Water Act. By lowering nutrient loads from upstream sources, states can reduce the burden on PWSs to remove nutrients and cyanotoxins from raw water. The EPA's mapping tools like the Drinking Water Mapping System for Protecting Source Water (DWMAPS) can identify watersheds critical to drinking water and the impairment status of those waters so that states can easily locate impaired source waters and take protective action (e.g., TMDL development). In addition, the Source Water Collaborative is currently creating an online shared library for states to exchange technical information and Water Quality Criteria for contaminants like nutrients and cyanotoxins, which can help states efficiently establish nutrient criteria. The EPA is also providing NPDES permit writer training for state permit writers to help them translate narrative nutrient criteria into permit limits to control nutrient inputs from point sources.

The EPA is co-leading a binational workgroup to develop and implement the Nutrients Annex ("Annex 4") of the 2012 Great Lakes Water Quality Agreement. Under Annex 4, the United States and Canada are charged with establishing binational phosphorus targets for the nearshore and offshore waters of Lake Erie, needed to meet several ecosystem objectives, including minimizing the extent of hypoxic zones associated with excessive phosphorus loading and maintaining cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health.

The EPA is also working closely with states and encouraging them to develop numeric nutrient criteria for causal (nitrogen and phosphorus) and response (chlorophyll-*a*; water clarity) variables for multiple water body categories (streams/rivers, lakes/reservoirs and estuaries/coastal waters). The increasing frequency of HABs and cyanotoxins in drinking water supplies further underscores the need for the EPA regions and states to strengthen their efforts. This could include developing these criteria or translators of narrative nutrient criteria in a timely fashion and at levels protective of all uses, including the drinking water use.

Regional HABs workshops and information-sharing: Where data on sources of drinking water exist, partnerships between watershed stakeholders can allow pooling and sharing of information to ensure that all stakeholders benefit. The EPA and the national Source Water Collaborative work to promote information-sharing partnerships at the watershed scale through online guides like the Source Water Collaborative's "How to Collaborate" toolkit and site-specific pilot programs. The EPA also encourages or sponsors regional workshops designed to bring together state environmental agencies, health departments, drinking water utility managers, public water supply operators, State Conservationists (USDA-Natural Resources Conservation Service) and other agriculture partners to discuss HAB issues. For example, the EPA hosted a HAB workshop on September 30, 2015 – October 1, 2015 in Rapid City, South Dakota. The EPA plans to support at least two additional workshops of this kind in 2016. Additional ongoing activities are described in Appendix 2.

<u>*Intended Future Activities*</u>

The EPA, along with other federal partners, plans to continue the ongoing efforts detailed above as well as to expand computerized mapping and water quality modeling in order to estimate cyanotoxin risk at the watershed scale. Current tools used by the EPA could benefit from data enhancements, user support and flow-specific modeling capability to help estimate nutrient loading in watersheds. Further resources would also allow the federal government to deploy early warning systems based on satellite imagery and/or citizen scientist reporting to forecast blooms around the country (these technologies are currently under development in discrete pilot sites/regions).

Future work could include working collaboratively with the EPA's regional offices to promote awareness amongst the public drinking water systems on the monitoring, screening techniques and source water protection practices that can identify and reduce cyanotoxins that may impact public drinking water supplies.

Nutrient monitoring is critical to SWP planning to address cyanotoxins. Future work could include EPA and partners increasing the coverage and frequency of monitoring both up and downstream of key sources of point and nonpoint source phosphorus and nitrogen pollution. Monitoring data could also contribute to modeling efforts such as USGS SPARROW or evaluation of ORD's Mississippi River Basin's multimedia system, which estimates the discharge, fate and transport of nutrients (USGS, 2011; U.S. EPA, 2015m).

Contingent upon available resources, the EPA may continue to provide logistical and technical support to the formation and maintenance of state, local and hydrologically based collaboratives of PWSs, scientists, elected officials and citizens such as the Salmon Falls Source Water Collaborative. As noted above, the EPA encourages place-based and issue-specific stakeholder workshops to address source water contaminants of concern to local communities, and hopes to continue this effort. Workshops may leverage planning tools such as Source Water Assessments and Watershed-Based Plans, as well as frameworks like Water Safety Plans from the World Health Organization, to identify nutrient sources and apply cost-effective discharge controls.

Future work could include the EPA conducting an analysis of the economic value of SWP. Analyzing and articulating the economic value of SWP is necessary for PWSs to justify their investment in these measures. While early case studies indicate that SWP is less expensive compared to plant-level treatment methods, more comprehensive research is required (WRI, 2013; Winiecki, 2012).

Objectives for holistic watershed planning, involving a variety of stakeholders at the federal, state, and local level, include:

- Decision-support and GIS mapping tools allow states and PWSs to assess source water vulnerability to HABs.
- Ubiquitous source water monitoring in vulnerable watersheds provides states and PWSs with data necessary to identify the most significant risk factors for HABs and design SWP treatment options accordingly.
- Point sources help monitor for and reduce nutrient loading in source waters, where appropriate.
- Nonpoint sources of nutrients are mitigated through conservation and other SWP practices.
- CWA programs help protect sources of drinking water.

Timelines for Ongoing and Future Activities

Activities related to source water protection are ongoing. EPA hosted one regional HAB-related source water protection workshop in fall of 2015, and plans to host at least two more in 2016. The preliminary deployment for the citizen science tracking mobile app is estimated to take one year to complete and two to three years to complete the nationwide deployment. A preliminary version of DWMAPS is currently available (DWMAPS, 2015); more advanced versions are expected to be available for user testing by a focus group of states and utilities within three to six months. The satellite detection of algal blooms is estimated to take approximately one to three years to complete. The nutrient sensor development and pilots are estimated to take approximately two years and the HABs community workshops are estimated to take one year to complete.

h. Cooperative Agreements and Technical Assistance

This section of the strategy is responsive to §1459(a)(1)(F) of the SDWA directing the EPA to develop a strategic plan to *"enter into cooperative agreements with, and provide technical assistance to, affected States and public water systems, as identified by the Administrator, for the purpose of managing risks associated with algal toxins included on the list published* [by the EPA]."

This section of the strategy identifies past efforts undertaken by the EPA on cooperative agreements and technical assistance, as well as ongoing, planned and potential future activities related to cooperative agreements and technical assistance. This section also describes the goals of this strategy with regard to meeting these provisions.

A key tool that the EPA utilizes to provide states the opportunity for technical assistance is the Drinking Water State Revolving Fund (DWSRF), created under the 1996 Amendments to the SDWA. The program provides financing to water systems for infrastructure improvements needed to achieve the health protection objectives of the SDWA. Through annual appropriations to the EPA, states receive capitalization grants for their state's DWSRF program, which then revolve at the state level. States have the flexibility to take up to 31% of their capitalization grants in the form of set-asides to provide non-infrastructure assistance. There are broad eligibilities under the four set-asides including capacity development, source water protection and technical assistance and training. The four set-asides include small system technical assistance, administrative and technical assistance, state program management, and local assistance and other state programs. Each year, states develop work plans outlining how much in set-asides they plan to take from their capitalization grants and what activities they plan to conduct with those funds. States could also elect to use some of their funds for source water protection and technologies related to the control of HABs.

Other cooperative agreements and technical assistance include utilizing the tools and authorities of both the SDWA and the CWA. For instance, the Clean Water State Revolving Fund program allows a state to provide, in addition to critical wastewater infrastructure financing, funding options for source water protection projects. Performance partnership agreements also occur between the EPA and states. These are two-year agreements that document mutual strategic goals, joint priorities, objectives and commitments. These partnership agreements can provide flexibility in determining how federal grant money can be used at the state level to fund source water protection measures and source water monitoring efforts to help prevent and detect HABs.

The EPA also has tools for cooperative agreements and technical assistance for states that are more informal in nature. These include the EPA's working relationships with state agencies and their associations, drinking water research organizations and the EPA regional efforts in assisting states in efforts to protect the quality of drinking water.

<u>*Completed Activities*</u>
The EPA has had formal and informal cooperative agreements with states and various organizations in the drinking water industry, as well as provided technical assistance states and PWSs. For instance, with regard to formal agreements, states have used DWSRF set-asides to fund the following activities:

- Obtain test kits/laboratory equipment for systems to test for newly recognized contaminants of concern and training to use that equipment;
- Review and approve laboratory protocols to ensure these laboratories meet new/existing drinking water analytical method requirements;

- Provide technical assistance to laboratories related to data management and timely delivery of drinking water quality results;
- Obtain laboratory equipment for conducting drinking water sample tests;
- Plan and implement surface water source assessment and protection activities, including source water management plans, buffer establishment and upkeep, road and storm water management and reconstruction activities, developing public outreach and educational programs and materials;
- Provide a source water protection ordinance template for city and county governments; and
- Support source water protection education and workshops.

Another example is the relationships the EPA has with the state drinking water regulatory agencies and their associations. For instance, the EPA has a long-standing cooperative relationship with the Association of State Drinking Water Administrators (ASDWA), a national professional association of state drinking water programs. Examples of successful cooperation with ASDWA include the sharing of information between the EPA and ASDWA, the participation of ASDWA on the EPA Federal Advisory Committees and input on potential implementation concerns that may arise as a result of regulations developed by the EPA. The EPA benefited greatly from the input of state representatives and ASDWA during a May 11, 2015, public meeting on cyanotoxins, and on the EPA document “Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water.” The technical assistance provided within the document has assisted states and utilities in better preparing for and responding to cyanotoxins in drinking water.

In addition, the EPA has utilized informal relationships with states and provided emergency technical assistance to states in times of crisis. For example, the EPA provided analytical support and technical assistance to the State of Ohio during the Toledo cyanotoxin bloom of 2014.

The EPA has also been an active participant in water industry research planning activities carried out by the Water Research Foundation (WRF) and others. For instance, the EPA has participated on WRF research advisory committees, which lead to an enhanced state of knowledge on a range of drinking water issues, including cyanotoxins. WRF has funded several projects on cyanotoxins, such as “Optimizing Conventional Treatment for Removal of Cyanobacteria and Toxins” (2010).

The EPA co-chairs the Interagency Workgroup on the Harmful Algal Blooms and Hypoxia Research and Control Act, which was tasked by Congress with developing a Report to Congress on Harmful Algal Blooms and Hypoxia Comprehensive Research Plan and Action Strategy. In addition, the IWG continues to coordinate activities within the federal agencies on harmful bloom activities. The EPA is also involved in the collaborative efforts of the National HABs Committee whose mission is to facilitate coordination and communication of activities on a national level between the U.S. HAB community including researchers and government agencies.

Ongoing Activities

The EPA has several activities in which the Agency is participating in cooperative agreements and providing technical assistance in areas that may enhance drinking water protection from cyanotoxin risks. These activities include assistance related to water monitoring, sample analysis, treatment and capacity development. For instance, a state could use its DWSRF funds to help tackle cyanotoxin challenges. DWSRF set-asides may be used as part of a state’s strategy to build technical, financial and managerial capacity of public water systems. For example, a state may use set-asides for demonstration purposes to build the capacity of the system for activities such as monitoring and training for analysis of toxins associated with HABs. One example of the use of DWSRF set-asides is from the Ohio

Environmental Protection Agency (Ohio EPA), which established a fund in 2015 of $1 million to award grants to surface water treatment plants to reimburse the purchase of cyanotoxin investigative monitoring equipment (up to $10,000). Having the capacity to analyze samples at the water supply instead of sending samples to an outside laboratory allows flexibility in monitoring and timely response to any potential finished water detections.

Ohio EPA also plans in 2016 to spend another $1 million from its 15% Local Assistance and Other State Programs set-aside to provide technical assistance to PWSs using surface water to help prevent impacts from cyanobacteria. In addition, Ohio EPA is encouraging PWSs to acquire training from the provider on the specific test kit purchased. Ohio EPA staff will also be available to provide guidance and technical assistance on sample collection and analysis.

There are many areas in which the EPA has provided technical assistance and engaged in cooperative agreements that fall outside of the scope of the DWSRF. For instance, the EPA provides technical assistance to states and PWSs on a variety of challenges to drinking water quality, including preventing algal toxin formation and in addressing algal toxins when they occur to mitigate adverse human health risks from PWSs. The EPA has played a key role in the development of analytic and decision support tools for drinking water quality protection. The EPA anticipates continuing to include the development of analytic and decision support tools in future efforts to assist in collecting and analyzing algal toxin data.

As described earlier, the EPA has a sustained and cooperative relationship with the states and state representative associations (e.g., ASDWA). The EPA will continue to participate in the established data and information sharing activities with ASDWA and other state partners as appropriate. These relationships and activities are particularly important with regard to cyanotoxin concerns, as they can facilitate the understanding of the potential risks posed if cyanotoxin blooms occur, as well as provide a quicker and more accurate response to cyanotoxin detections. The EPA also provides logistical and technical support for the formation and maintenance of state, local and hydrologically-based collaboratives of PWSs, scientists, elected officials and citizens such as the Source Water Collaborative as discussed in Source Water Protection Practices (Section III, g).

As an example of the EPA partnering with states to provide technical assistance, the EPA hosted a workshop in South Dakota for Region 8 state SDWA and Clean Water Act program managers and staff to address the formation of algal toxins. This workshop facilitated collaboration between states and federal agencies, including the EPA, by exploring topics including how to prevent HAB occurrence through source water protection and pollution reduction measures, and how to manage HAB occurrence through enhanced ambient water quality monitoring and drinking water treatment. The EPA Region 2 and Environment Canada formed a Lake Ontario nutrients task team under the Great Lakes Water Quality Agreement Annex 4. This task team is preparing a white paper that will, among other things, characterize algal conditions in Lake Ontario and recommend data and information needs. The EPA Region 5 Great Lakes Restoration Initiative (GLRI) provides funding to federal and state agencies to identify collaboration project opportunities to minimize HABs in the Western Basin of Lake Erie. The EPA Region 9 is working to assist tribes in HAB response, including targeted technical assistance, analytical support and resources for infrastructure improvements to tribes. The EPA Region 9 worked with the Hoopa Tribe in response to detection of anatoxin and microcystin in the Trinity River (source water for Hoopa drinking water) to coordinate analyses, and later provided source water protection grant and drinking water Tribal set-aside funds to support ozone treatment for the Tribe's drinking water system.

An area of collaboration with other federal partners includes the EPA's ongoing work with the Natural Resources Conservation Service (NRCS), the Agricultural Research Service, the United States Forest Service, and USGS, among others, to help states leverage federal technical and financial resources in applying the most cost-effective techniques to reduce the pollution of drinking water sources by HAB precursors such as through natural treatment of cropland runoff. Additional ongoing activities are described in Appendix 2.

Intended Future Activities
The EPA plans to continue the ongoing efforts detailed above as well having an active role in filling the information gaps and research needs. In particular, the EPA has specific capabilities for assisting in identifying HAB causes, development of analytical methods, enhancing monitoring and modeling programs and sharing information with the public.

The EPA anticipates that the DWSRF will continue to be a source of funds available for mitigating and preventing cyanotoxins in drinking water. While operation and maintenance are ineligible costs for both the project loan fund and the set-asides, a state may finance one-time monitoring associated with newly-installed equipment to ensure that the equipment is operating properly and meets equipment specifications as part of the equipment delivery and installation process.

The EPA may also be able to provide technical assistance in the following areas:

- Development of watershed models to better predict nutrient loadings.
- Continued collaboration with ASDWA on providing technical assistance to states.
- Technical assistance to systems experiencing HABs.
- Continued input into the development of research recommendations to the WRF and other research organizations.
- Workshops on opportunities to engage systems on the EPA recommendations to prepare for and respond to cyanotoxins in drinking water.
- Pilot studies to provide technical assistance to a limited number of individual systems in preparing for and responding to cyanotoxins in drinking water.
- Revisions to a document the EPA published in June 2015 on recommendations to prepare for and respond to cyanotoxins in drinking water.
- Partnerships between the EPA regional laboratories with the goal of developing HAB analytical capacity and analytical technical points of contact for state or PWS laboratory assistance.
- Coordination of state level information among states and stakeholders.

Additional assistance in these areas is anticipated to greatly enhance the ability of systems and states to prepare for and respond to cyanotoxins in drinking water, as well as strengthen the activities of the EPA's federal partners.

The goal of the EPA's activities on cooperative agreements and technical assistance is to provide mechanisms for assistance to states and utilities to prepare for and, if necessary, respond to cyanotoxins in drinking water. Establishing these agreements and relationships facilitates the responses needed if and when a system is at risk to cyanotoxins in their water. In addition, the research-related activities better positions the EPA to identify the most appropriate means to provide technical assistance. Furthermore, financial assistance mechanisms described in this section enables systems to secure resources to respond to cyanotoxins in cases where systems may lack the necessary expertise or other resources. Utilizing cooperative agreements and providing technical assistance helps reduce the potential health, environmental and economic impacts of cyanotoxins in finished drinking water and drinking water sources. Additional intended future activities are described in Appendix 3, EPA's Intended Future Activities Directly Related to Freshwater HABs.

Timelines for Ongoing and Future Activities

The EPA will continue outreach efforts with states to communicate about possible DWSRF opportunities, including communicating with partners over the next several months about these opportunities prior to the next HAB season. The EPA plans to continue to exploring other partnership options with federal government agencies, states, tribes, PWSs and utility member organizations such as the American Water Works Association, the Association of Metropolitan Water Agencies and the National Rural Water Association.

IV. Information Coordination

a. Information Gaps

This section of the strategy is responsive to §1459(b)(1) of the SDWA directing the EPA, as part of their strategic plan, to *"identify gaps in the Agency's understanding of algal toxins, including—(A) the human health effects of algal toxins included on the list published* [by the EPA]*; and (B) methods and means of testing and monitoring for the presence of harmful algal toxins in source water of, or drinking water provided by, public water systems."*

The EPA has previously worked to identify research gaps in the development of current and future research plans such as the ORD's Safe and Sustainable Water Resources Strategic Research Plans. The EPA finalized its 2016–2019 project plans in October 2015, which proposed several key research questions the Agency intends to address in the coming years. EPA has also previously collaborated in identifying research needs as part of the proceedings of the Interagency International Symposium on Cyanobacterial Harmful Algal Blooms (ISOC-HAB, 2008). Research needs were identified in Harmful Algal Research and Response: A National Environmental Science Strategy for 2005–2015 developed by the Ecological Society of America, supported by NOAA (HARRNESS, 2005).

The EPA has also worked to develop research needs and challenges as part of the IWG, on the HABHRCA Amendments of 2014. Public Law 113-124, §603A(e)(6) directs the IWG to identify additional needs and priorities relating to HABs. The IWG developed a report on a comprehensive research plan and action strategy that includes information gaps. The IWG, co-chaired by the EPA and NOAA, developed a Comprehensive Research Plan and Action Strategy to address marine and freshwater HABs and hypoxia. This plan will be submitted to Congress in 2015 and includes research gaps as described below. For more information on information gaps discussed in the IWG, please see http://coastalscience.noaa.gov/research/habs/habhrca.

Information gaps exist regarding the impact of drinking water contaminated with algal toxins on human health. Additional research is needed on human health effects of existing and emerging cyanotoxins for which no health data currently exist. Further research is also needed on the human health impacts for which limited health effects data are available, and to better understand the various exposure pathways of cyanotoxins, including ingestion, inhalation and dermal exposures, that occur through household use of tap water provided by PWSs. For example, in June 2015, a Health Advisory document and Health Effects Support Document (U.S. EPA, 2015f, 2015d) were released for microcystins. Microcystin-LR was used as a surrogate for all the other microcystin congeners. More than 100 microcystin congeners exist, which vary based on amino acid composition. Microcystin-LR may be one of the most potent congeners and the majority of toxicological data on the effects of microcystins are available for this congener; however the potential health risks from exposure to mixtures of microcystin congeners is unknown. Thus, additional research is needed to understand the human health impacts of the other congeners, both existing and emerging, as new congeners continue to be isolated and identified.

At present, limited health effects information is available to derive guideline values for the broader range of cyanotoxins that may be present in drinking water. Other research gaps include information from both short- and longer-term studies and carcinogenicity bioassays in experimental animals. One of the challenges in conducting toxicological studies on cyanotoxins is the difficulty and cost of obtaining the individual purified toxins that are needed to conduct the toxicological studies. Human health effects information from cyanotoxin exposures in sensitive populations is needed, for example individuals with preexisting liver conditions, individuals on dialysis, the elderly, pregnant women, and nursing mothers.

There is an information gap regarding toxin transfer through the placental wall as well as through breast milk. There is also a need to establish a rapid sample collection and response protocol for detecting HAB toxins in humans and animals, specialized so that preparation procedures are compatible with analytical methods for detecting HAB toxins in humans and animals.

Where and when HABs will occur remains an information gap that prevents us from fully understanding the human exposure risks from cyanotoxins in drinking water provided by PWSs. There is a knowledge gap regarding the occurrence and formation of blooms in surface waters, including rivers. Occurrence information in all surface waters could be collected using planned and event response monitoring for HABs, cyanotoxins and HAB predictors, such as nutrients. Understanding the factors leading to HAB and cyanotoxin formation can help provide insight into occurrences of HABs and cyanotoxins, provide information for recommendations for monitoring frequency, and better inform HAB prevention strategies. For example, although research has shown nutrients, specifically phosphorous and nitrogen, play key roles leading to HAB formation (WHO, 1999; Jacoby et al., 2000) additional information is needed to fill information gaps on understanding the relationships among nutrient levels, bloom formation, toxin release and other factors such as temperature and precipitation. This information could be used to determine threshold values for various indicators.

Information gaps regarding analytical methods include the need for comparing the results obtained using various cyanotoxin methods and developing cost-effective screening and monitoring methods. As identified by stakeholders, better understanding of current methods and development of new methods is a near-term need. At present, the standardized analytical methods that can be used in a national monitoring program are limited to analyses of a few specific cyanotoxins or cannot speciate groups of related cyanotoxins, such as the microcystins. Analytic standard production is limited, which, in turn, limits capacity for monitoring and research, even when there are measurement methods available. The methods also differ fundamentally in their detection capabilities, and additional research is warranted to better understand the quantitative ability of immunological assays (that measure the interactions of cyanotoxins with antibodies) versus that of LC/MS/MS techniques (that measure the mass-to-charge abundances of ionized cyanotoxin fragments). Each technique has a unique set of advantages and limitations. Additional methods will be needed in the future to measure new and emerging toxins for which there are currently no methods. Methods that are more cost-effective and less lab-intensive would allow for more widespread use in event response and screening. Developing methods for all analyses, screening and monitoring needed to holistically confront the HAB challenge exceeds the scope of any one agency, and may be best served by continued interagency partnerships and establishment of a network of several reference laboratories for standardized and validated methods.

Additional research is needed to better understand congener-specific cyanotoxin removal capabilities of currently available water treatment processes. It is also necessary to evaluate the potential consequences that cyanobacteria and cyanotoxin treatment techniques have on the ability of a treatment facility to comply with existing drinking water quality regulations. For example, the application of high oxidant concentrations to high concentrations of bloom material may negatively impact the ability of a facility to comply with the disinfection byproduct rules. Other information gaps exist regarding cyanobacteria and cyanotoxin treatment such as absorption capacity of powdered activated carbon, contact time (CT) tables for cyanotoxins removal and the effects of permanganate. Application of source water treatments, such as algicides, is also an area where information gaps exist with respect to the impacts of these treatments on treatment efficacy, source water quality, environmental impacts and the efficiency of downstream treatment infrastructure. Prevention and treatment activities can involve a multi-barrier approach as well as adaptive management to fully address the HABs issue. Information is needed to provide support to states and PWSs on developing and incorporating these activities at the PWS level to ensure the best course of action is tailored specifically to the PWSs specific circumstances.

Source water protection information gaps involve better understanding of the causes of blooms as well as better understanding of how source water protection activities can prevent or reduce them. Understanding the impacts of current source water protection practices (both short-term and long-term practices) can help with the development of future protection practices and best management practices within a source water's watershed.

The relationship among factors that promote algal bloom and subsequent toxin production are not well understood. Those factors include both environmental conditions such as water clarity, meteorological conditions, alteration of water flow, vertical mixing, temperature and water quality conditions such as pH changes, nutrient loading (principally in various forms of nitrogen and phosphorus) and trace metals. Developing approaches for open communication and engagement between specific stakeholders is also needed for cooperation and support for SWP practices.

More information is also needed to better understand how climate change will affect the geospatial and temporal distribution of HABs. For example, studies have shown that increases in temperature, altered rainfall patterns, and anthropogenic nutrient loading may lead to an increase in bloom frequency, intensity, duration and geographic distribution (O'Neil et al., 2012; Paerl and Huisman, 2009; Paerl et al., 2011). Another information gap is understanding how the interactions of multiple future climatic changes will impact HAB and cyanotoxins in fresh water systems. Given the potential increase in cyanobacterial blooms due to both the direct and indirect effects of climate change, understanding the effects at a regional scale can help water systems prepare for potential blooms that could occur due to changes in regional climate.

A better understanding of risk communication in the context of risk management is also needed for cyanotoxins and HABs. The HAs for microcystin and cylindrospermopsin established two advisory levels, one for bottle-fed infants and young children of pre-school age and one for all other ages. This can create confusion for the public, and additional tools would support water systems in communicating this risk. The advisory levels are based on 10 days of exposure, which may also create difficulty in risk communication. Additional support would help PWSs handle various scenarios such as short duration exposures or low levels of exposures. The EPA has released recommendations regarding communication language that can be found in the recommendations document (http://www2.epa.gov/nutrient-policy-data/guidelines-and-recommendations) based on varying levels cyanotoxins found in the finished water. The EPA will update this language and develop other tools as appropriate. Currently the EPA is also working with the CDC and other stakeholders on updating the Drinking Water Advisory Communication Toolkit to include cyanotoxins specific information (http://www.cdc.gov/healthywater/emergency/toolkit/drinking-water-outbreak-toolkit.html).

Developing training tools to assist in answering the key questions specific to PWSs are warranted. Although systems have been dealing with algal blooms for some time, additional training is needed regarding the cyanotoxin-producing blooms, on preventing the toxins from reaching finished water as well as training on how to handle communication situations as described above once cyanotoxins occur in finished water. PWS training can also help systems understand the impacts of the management cost consequences to the PWS for preparation and response measures to cyanotoxin occurrence.

Additional development is also needed on how HABs data and information are managed and shared. Many systems are collecting HABs and cyanotoxin information and it would be beneficial to have commonalities among the data being generated such as all relevant metadata would need to be included. Using available tools such as the EPA's Water Quality Exchange or the Water Quality Portal, a cooperative service that is jointly sponsored by USGS and the EPA, can be used to assist the data management of cyanotoxin information. Stakeholders identified needs to develop and use other resource friendly information sources such as creating monitoring networks for sharing data.

b. Information from Other Federal Agencies

This section of the strategy is responsive to §1459(b)(3) of the SDWA directing the EPA, as part of its strategic plan, to *"assemble and publish information from each Federal agency that has—(A) examined or analyzed cyanobacteria or algal toxins; or (B) addressed public health concerns related to harmful algal blooms.*"

The HABHRCA IWG coordinates and convenes with relevant federal agencies to discuss HABs and hypoxia events in the United States, and to develop a number of reports and assessments of these situations. For more information on HABHRCA and the Interagency Workgroup please visit http://coastalscience.noaa.gov/research/habs/habhrca.

Since 2013, the EPA is an ex-officio member of the National HABs Committee (NHC). The NHC is an elected body with members representing the HAB research and state and local management community with non-voting ex-officio members from the EPA, NOAA, USGS and CDC.

In addition to the ongoing EPA efforts described in Appendix 2 and on the EPA's website that details EPA activities on cyanotoxins (http://www2.epa.gov/nutrient-policy-data/cyanohabs), several federal agencies are conducting activities and projects to advance the research on toxin-producing cyanobacteria and algal toxins in drinking water. Federal agencies, such as USDA, are collaborating to address nonpoint sources of nutrients that can contribute to the rise of HABs. Other agencies support research to better understand HABs, including ways to prevent, control and mitigate them. Health and food safety agencies at the federal and state levels are studying and monitoring the health effects on people and pets. In some cases, government agencies at all levels are engaging the public to conduct citizen science to monitor water quality and the occurrence of HABs in local waters. These activities are listed in the HABHRCA Comprehensive Research Plan and Action Strategy and in Appendix 4 of this strategic plan. Appendix 4 was compiled from interagency efforts based on input and feedback from other federal agencies. This information will be further explored with the release of the HABHRCA Report to Congress anticipated to be released by the end of 2015.

Timeline
EPA intends to publish information on federal agency efforts on HABs in late 2015 through its collaboration on the HABHRCA Congressional Report.

c. Stakeholder Involvement

This section of the strategy is responsive to §1459(b)(2) of the SDWA directing the EPA, as part of its strategic plan, to *"consult, as appropriate, (A) other Federal agencies that—(i) examine or analyze cyanobacteria or algal toxins; or (ii) address public health concerns related to harmful algal blooms; (B) States; (C) operators of public water systems; (D) multinational agencies; (E) foreign governments; (F)* *research and academic institutions; and (G) companies that provide relevant drinking water treatment options."*

Completed Activities

The EPA held a public listening session on September 16, 2015, to provide an opportunity for stakeholders to present their views on the key issues that may inform the strategic plan on assessing and managing risks from cyanotoxins to drinking water. Over 300 people participated and 13 individuals provided written or oral input. Registrants of that session included members and stakeholders of the drinking water community, such as PWS operators, state and local governments, academic institutions, federal agencies, industry representative groups, environmental groups, technology manufacturers and developers (see Appendix 5 for Summary of Stakeholder Input). Comments submitted during the listening session were considered in the development of this strategic plan. On September 17, 2015, the EPA heard clarification of input provided by states and water utilities in a meeting with ASDWA and AWWA and several of their members. Participants provided additional input regarding key information gaps related to our understanding of managing algal toxins in drinking water. The consultation focused on discussions of activities to include in the strategic plan.

In April 2015, the EPA sought input on the most recent draft Contaminant Candidate List (CCL) 4. The list contained cyanotoxins including anatoxin-*a*, cylindrospermopsin and microcystins. In May 2015, the EPA held a public meeting to provide an opportunity for public input on potential actions states and PWSs could take to prepare for and respond to cyanotoxin health risks in drinking water. The EPA engaged with stakeholders on what information the Agency could provide to best support states and PWSs in addressing their risks to cyanotoxins.

The IWG also conducted a series of webinars in all major regions of the United States and a public meeting in Ohio to initiate a conversation with stakeholders on topics related to HABs and hypoxia. Input received was used by the IWG to inform the development of the comprehensive research plan and action strategy for dealing with and responding to HABs and hypoxia that will be published in fall 2015.

Intended Future Activities

As part of future efforts to evaluate risks to drinking water from cyanotoxins, the EPA will continue to engage stakeholders, including states, ASDWA, AWWA, PWSs, the environmental community and others as appropriate to ensure timely, useful and valid products. The EPA also intends to participate in additional public meeting(s) after the current algal bloom season ends to obtain feedback on the EPA's recommendation document for PWSs.

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VI. Appendix 1. Text of Public Law No: 114-45

[114th Congress Public Law 45]
[From the U.S. Government Publishing Office]

Public Law 114-45
114th Congress

An Act

To amend the Safe Drinking Water Act to provide for the assessment and management of the risk of algal toxins in drinking water, and for other purposes. <<NOTE: Aug. 7, 2015 - [H.R. 212]>>

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, <<NOTE: Drinking Water Protection Act. 42 USC 201 note.>>
SECTION 1. SHORT TITLE.

This Act may be cited as the “Drinking Water Protection Act”.
SEC. 2. AMENDMENT TO THE SAFE DRINKING WATER ACT.

(a) Amendment.--Part E of the Safe Drinking Water Act (42 U.S.C. 300j et seq.) is amended by adding at the end the following new section:
“SEC. 1459. <<NOTE: 42 USC 300j-19.>> ALGAL TOXIN RISK ASSESSMENT AND MANAGEMENT.

“(a) Strategic Plan.--
“(1) <<NOTE: Deadline. Health and health care.>> Development.--Not later than 90 days after the date of enactment of this section, the Administrator shall develop and submit to Congress a strategic plan for assessing and managing risks associated with algal toxins in drinking water provided by public water systems. The strategic plan shall include steps and timelines to--
“(A) evaluate the risk to human health from drinking water provided by public water systems contaminated with algal toxins;
“(B) establish, publish, and update a comprehensive list of algal toxins which the Administrator determines may have an adverse effect on human health when present in drinking water provided by public water systems, taking into account likely exposure levels;
“(C) summarize--
“(i) the known adverse human health effects of algal toxins included on the list published under subparagraph (B) when present in drinking water provided by public water systems; and
“(ii) factors that cause toxin-producing cyanobacteria and algae to proliferate and express

toxins;

"(D) with respect to algal toxins included on the list published under subparagraph (B), determine whether to--

"(i) publish health advisories pursuant to section 1412(b)(1)(F) for such algal toxins in drinking water provided by public water systems;

"(ii) establish guidance regarding feasible analytical methods to quantify the presence of algal toxins; and

"(iii) establish guidance regarding the frequency of monitoring necessary to determine if such algal toxins are present in drinking water provided by public water systems;

"(E) recommend feasible treatment options, including procedures, equipment, and source water protection practices, to mitigate any adverse public health effects of algal toxins included on the list published under subparagraph (B); and

"(F) enter into cooperative agreements with, and provide technical assistance to, affected States and public water systems, as identified by the Administrator, for the purpose of managing risks associated with algal toxins included on the list published under subparagraph (B).

"(2) Updates.--The Administrator shall, as appropriate, update and submit to Congress the strategic plan developed under paragraph (1).

"(b) <<NOTE: Health and health care.>> Information Coordination.--In carrying out this section the Administrator shall--

"(1) identify gaps in the Agency's understanding of algal toxins, including--

"(A) the human health effects of algal toxins included on the list published under subsection (a)(1)(B); and

"(B) methods and means of testing and monitoring for the presence of harmful algal toxins in source water of, or drinking water provided by, public water systems;

"(2) as appropriate, consult with--

"(A) other Federal agencies that--

"(i) examine or analyze cyanobacteria or algal toxins; or

"(ii) address public health concerns related to harmful algal blooms;

"(B) States;

"(C) operators of public water systems;

"(D) multinational agencies;

"(E) foreign governments;

"(F) research and academic institutions; and

"(G) companies that provide relevant drinking water treatment options; and

"(3) assemble and publish information from each Federal agency that has--

"(A) examined or analyzed cyanobacteria or algal toxins; or

"(B) addressed public health concerns related to harmful algal blooms.

"(c) Use of Science.--The Administrator shall carry out this section in accordance with the requirements described in section 1412(b)(3)(A), as applicable.

"(d) Feasible.--For purposes of this section, the term 'feasible' has the meaning given such term in section 1412(b)(4)(D).''.

(b) Report to Congress.--Not later than 90 days after the date of enactment of this Act, the Comptroller General of the United States shall prepare and submit to Congress a report that includes--

(1) an inventory of funds--

(A) expended by the United States, for each of fiscal years 2010 through 2014, to examine or analyze toxin-producing cyanobacteria and algae or address public health concerns related to harmful algal blooms; and

(B) that includes the specific purpose for which the funds were made available, the law under which the funds were authorized, and the Federal agency that received or spent the funds; and

(2) recommended steps to reduce any duplication, and improve interagency coordination, of such expenditures.

VII. Appendix 2. EPA's Current Activities Directly Related to Freshwater HABs

The efforts listed below include efforts by the EPA to manage and research harmful algal blooms in freshwater systems. While extensive, this list is not exhaustive and additional efforts are ongoing at the Agency. Better understanding of the science behind HABs is necessary to protect the public from cyanotoxins in drinking water and their adverse health effects. Resources permitting, the EPA plans to close informational gaps and provide helpful tools through research to better identify, monitor, and manage HABs and toxins.

EPA/ORD Research Activities

- Ohio is the first state in the United States to implement a state-wide program of cyanobacteria toxin monitoring in raw and finished drinking waters. The EPA collaborated with the Ohio EPA and collected water samples at intermediate locations within drinking water treatment facilities. The researchers employed enzyme linked immunosorbent (ELISA) assays for measuring cyanobacteria toxin. The goals of the project were to: (1) provide a baseline estimate of the efficacy of currently installed drinking water treatment infrastructure, (2) provide data to inform cost-effective process upgrades, and (3) provide samples to support the development of a chromatographic/mass-spectrometric method, which is robust enough to handle the matrix variations commonly encountered in a water treatment facility. Preliminary results from the in-plant sampling study indicated the release of intracellular cyanobacterial toxins into aqueous solution during the addition of a powerful oxidizer (potassium permanganate). Potassium permanganate is added early in the treatment process for zebra mussel and taste and odor control. The release of intracellular toxins into a water treatment plant is potentially problematic because the bulk of the existing treatment infrastructure is not designed to remove dissolved chemical contaminants. This study also investigates the impacts of pH, suspended particulate concentration, oxidant dose, oxidant contact time, powdered activated carbon (PAC) type, PAC dose, temperature, and subsequent control of intracellular toxins.

- Four federal agencies (U.S. EPA, USGS, NOAA, and NASA) are participating in the Cyanobacterial Assessment Network (CyAN) project to (1) develop a uniform and systematic approach for identifying cyanobacteria blooms using ocean color satellites across the contiguous United States; (2) create a strategy for evaluation and refinement of algorithms across satellite platforms; (3) identify landscape linkage postulated causes of chlorophyll-*a* and cyanobacteria blooms in freshwater systems; (4) characterize exposure and human health effects using ocean color satellites in drinking water sources and recreational waters; (5) characterize behavioral responses and economic value of the early warning system using ocean color satellites and mobile dissemination platform; and (6) disseminate satellite data through an Android mobile application and EnviroAtlas. The EPA anticipates that the use of uniform satellite data products will improve the decision-making ability of managers. In addition, satellite data products may augment federal, state, tribal, and municipal monitoring and research efforts. At the conclusion of this project, there should be an increase in the applied use of remotely sensed water quality data for water quality management. The use of this technology has tremendous potential owing to the temporal and spatial coverage of the imagery and the current lack of data available for many systems. Using satellite data to monitor and report blooms throughout a region or state would provide a novel robust tool and assist in holistic management of events that may involve significant risk to the public. Ultimately this project will reduce resource needs and potential exposures of the public.

- The EPA Office of Research and Development's National Risk Management Research Laboratory, in partnership with Ohio EPA, USGS and local municipalities, sampled monthly during the 2013 and 2014 summers water throughout the treatment trains of 7 water treatment facilities that use Lake Erie as a drinking water source. Sampling and testing was done for cyanotoxins, chlorophyll-*a*, and other chemical and microbiological markers commonly associated with HABs. The purpose of this project was to evaluate the effectiveness of toxin removal during water treatment, detect cyanotoxins, and try to identify water quality indicators that predict the onset of future HABs.

- The EPA currently conducts monitoring and modeling research in the East Fork of the Little Miami River Watershed overlaid by five southwestern Ohio counties, including Clermont, Brown, Highland, Clinton, and Warren. This collaborative research supports the Ohio EPA surface water modeling division who is responsible for writing the TMDL for the system. Harsha Lake is a 2000 acre flood control reservoir that bisects the watershed and receives significant loads of nitrogen and phosphorus pollution from the predominant agricultural land use, failing septic systems, and 10 small waste water treatment plants in the upper watershed. But the loading is not static over seasonal or inter annual time periods. While the U.S. Army Corps of Engineers (USACE) has historically funded monthly lake monitoring at six lentic sites within the system, typically from May to August, the EPA's research objectives needed more temporal and spatial coverage to completely understand the controls over the nutrient budgets. The entire lake is now being sampled by EPA-ORD every three weeks throughout the entire year and a continuous water quality sensing buoy is deployed from March through November. The buoy sensing platform is paired with online monitors located within the intake structure to a 12 million gallons per day (mgd) drinking water treatment plant that include a fluoroprobe configured to characterize divisional-level dynamics of the algal community. As a result of the sampling intensity, the U.S. Geological Survey's Ohio Water Science Center has included Harsha in its intensive molecular-based study to characterize HABs at beaches of inland lakes and Lake Erie. The EPA visits the main beach site at Harsha weekly to establish a temporally dense time series for this collaborative effort. Data resources now existing for Harsha Lake serve to help verify remote sensing algorithms that the USACE is promoting for early HAB detection and management in the Ohio River Basin. USACE funded an aerial imaging flyover and supported permanent monitoring of lake inflows and outflows, as well as algal taxonomic analyses for the project. The monitoring buoy is located near the drinking water treatment plant (DWTP) intake but was specifically positioned to pair water quality data with satellite imaging. Synoptic sampling methods are being used at 22 other USACE Louisville District reservoirs and at DWTP intake locations on Lake Erie.

- The EPA's National Center for Environmental Research currently supports research that uses molecular tools and satellite remote sensing to quantify water quality and human health risks of harmful algal blooms and disinfection byproducts associated with extreme weather in Lake Erie drinking water. This research is investigating the impacts of extreme precipitation on urban runoff and urban water quality by integrating a set of models that down-scale climate simulations to spatial scales relevant to urban hydrology and land cover products. Products from this work include molecular tools for quantifying cyanotoxins; remote sensing indicators for modeling water quality and human health; and visualization products that demonstrate future changes in drinking water quality (in both long-term forecasting predictions, and short-term forecasts immediately following an extreme event).

- There are many barriers preventing the success of water quality trading (WQT) in the United States. The EPA research focuses on two major barriers that hinder WQT: uncertainties in modeling the watershed and thin markets (too few participants). The research will determine whether any non-traditional participants would have an incentive to purchase nutrient abatement credits from agricultural producers (traditional participants). Researchers have examined a drinking water treatment plant's incentive, and will now assess the impact of HABs on treatment costs. In addition, recreationalists and local property owners affected by problems of HABs may also have incentive to purchase nutrient abatement credits from upstream agricultural producers. A considerable lake modeling effort will be undertaken to better link HAB dynamics to watershed management scenarios and socioeconomic factors along with the WQT research.

- The EPA currently collaborates with USGS through an interagency agreement to characterize cylindrospermopsin and saxitoxin occurrence in U.S. lakes included in the 2007 National Lakes Assessment. Analyses will include assessing risk to human health via multiple exposure scenarios to recreational and drinking waters.

- The EPA performs research on the detection of unique cyanobacteria organisms using fluorescence-based technologies including micro spectrophotometer and flow cytometry. Different types of algae and cyanobacteria occur in surface water. Occasionally these organisms produce toxins with are harmful to organisms that live in the water or other organisms that are exposed to the water. This research aims to correlate the specific spectra of the organism with its unique morphology. It is anticipated that the specific spectra and changes in the spectra may be an early predictor for toxin production. Initial preliminary research has identified unique cyanobacteria that have distinct spectra in the 650 nm range that are different than the algae that fluoresce in the 690 nm range. It is hoped that a specific signature of different cyanobacteria can be developed to identify the cyanobacteria that may be producing toxins.

- The EPA-ORD works with the OW's National Coastal Condition Assessment (NCCA) program and EPA Region 5. The researchers recently mapped cyanobacteria concentrations across the coastal zone of the Great Lakes. States and the EPA collected whole water samples and analyzed the samples for nutrients, chlorophyll-*a* and phytoplankton species composition, including *Microcystis*. A set of about 400 sites across the coastal zone of the Great Lakes were sampled in 2010. Plans are to repeat the effort in 2015. The research included phytoplankton indicators and mapping of cyanobacteria levels according to WHO thresholds. Phytoplankton will again be included 2015 in the NCCA survey. Results will contribute to the development of empirical models linking water quality and plankton levels in coastal waters to watershed disturbance levels across the Great Lakes Basin, including 762 coastal watersheds.

- The EPA tested cylindrospermopsin (CYN) for mutagenicity in the *Salmonella* (Ames) mutagenicity assay using the standard plate-incorporation method in strains TA98 and TA100 with rat-liver metabolic activation (S9). Because studies in the literature showed the CYN induced chromosomal mutations in vitro only in the presence of S9, and because of the small amount of sample available, the EPA evaluated the mutagenicity of CYN in *Salmonella* with S9 and did not do any experiments without S9. The researchers performed two experiments. The first was exploratory, with a dose range of 1 – 20 µg of CYN per Petri plate; the second experiment had a slightly higher range of 25 – 100 µg/plate. The results were all negative for mutagenicity in both of the strains tested. There was not enough sample to repeat the assays at even higher doses, and EPA's source for the CYN (GreenWater Laboratories, Palatka, FL) could not provide additional sample at the time. The EPA plans to test CYN one time more at higher doses (perhaps 1000 µg/plate) if additional sample can be obtained. Otherwise, at this point, the results show that CYN is not mutagenic in *Salmonella*, which means that it does not induce gene mutations. However, the literature does show that in the presence of S9 or in vivo, CYN can induce chromosomal mutations (i.e., micronuclei) and DNA damage (the comet assay). Thus, it may have carcinogenic potential through these mechanisms of chromosomal DNA damage. Thus, CYN clearly causes chromosomal mutation, but until it is tested at somewhat higher doses, it is unclear if CYN can also cause gene mutation.

- The EPA continues to develop analytical methods for cyanobacterial toxins. The only liquid chromatographic/mass spectrometric (LC/MS) cyanobacterial toxin analytical method currently published by the EPA is intended as a finished water method to support the Unregulated Contaminant Monitoring Rule (UCMR) as appropriate. The EPA is developing chromatographic/mass spectrometric methods that can be applied with equal confidence throughout the treatment process, from raw to finished water. If development proceeds with sufficient speed, ELISA results from the treatment plant sampling study will be compared with LC/MS results, with the ultimate goal of determining the optimum monitoring trade-off between ELISA and chromatographic/mass spectrometric analysis.

- The EPA is exploring the impact of algal blooms, including HABs, on disinfection by-products (DBPs) formation potential in drinking water treatment plants (DWTPs). The EPA began collecting water quality information at a DWTP intake with the intent to examine what water quality parameters are most applicable to predicting the water treatment impacts of HABs. Included in this work are online toxicity monitor testing for HAB toxins and development of treated water testing protocols for toxin detection.

- The overall health effects caused by cyanobacteria remain poorly elucidated. Our current understanding of the individual toxicological, dermatological and allergenic effects of cyanobacterial toxins (cyanotoxins) and their components (including metabolites and by-products) as well as their possible synergistic interactions is lacking. Numerous species of cyanobacteria are capable of producing a wide variety of structurally and biochemically diverse metabolites (some of which have proven to be toxic to other organisms). Animal and cellular studies have shown the presence of toxicity despite the lack of measurable known cyanotoxins. The EPA will identify and characterize cyanobacteria peptide(s) responsible for allergic sensitization in susceptible individuals and to investigate the functional interactions between cyanobacterial toxins and their co-expressed immunogenic peptides. This effort is a collaboration between the EPA, Northern Kentucky University and the University of Cincinnati (UC, Department of Internal Medicine, Division of Immunology and Department of Environmental Health Gene Environmental Interactions Training Program). Data collected from EPA and UC will lead to a better assessment of the toxicological and allergic response potential from cyanobacteria. The outcomes of this study will provide researchers with expertise in (1) the identification of cyanobacteria and their toxins, (2) the isolation and culturing of cyanobacteria from the environment, (3) the purification and characterization of lipopolysaccharides (LPS) and (4) the performance of the *in vitro* beta-hexosaminidase release assay for allergens using sera from atopic patients skin-prick positive for *M. aeruginosa* extract. The data provided by the effort will be used by the researchers to determine if there is a potential allergenic component to the health outcomes using animal models and possibly develop a generic screening method to determine exposure to cyanobacteria. This collaborative study provides the opportunity to characterize cyanotoxins, cyanobacteria-derived allergenic components and their possible roles in the presence or absence of synergistic interactions.

- Immunoassays are widely used biochemical techniques to detect microcystins in environmental samples. The use of immunoassays for the detection of microcystins is vulnerable to matrix components and other interfering substances. The EPA research evaluates the effects of interfering substances commonly found in drinking and ambient water samples using commercially available immunoassay kits for microcystin toxins. The microplate and strip test immunoassay formats were tested in the study. Results of this study may assist in the further refinement of existing assays and the development of practical antibody-based methods to detect cyanotoxins in water.

EPA Regional Activities

- In Region 1, the EPA has convened a region-wide cyanobacteria monitoring and "bloom watch" workgroup consisting of state agencies, tribes, public water suppliers, NGOs, citizen monitoring groups, and academics. During the 2014 pilot, over 100 water bodies were sampled and in 2015 the program was expanded, including 10 public drinking water system sources and additional recreational water bodies. Workgroup members participate in a variety of ways – all designed to ensure sampling and data collection are performed in a uniform and consistent manner for analyzing regional cyanobacteria occurrence. Participants use monitoring kits complete with portable microscopes and smartphone adaptors so samplers can identify cyanobacteria in the field and directly send images to taxonomy experts to confirm their initial identifications. The smartphone app also allows sampling crews to electronically submit monitoring data to a central database. A second app is currently in development for tracking the occurrence of blooms across the region and the mid-west. Portable fluorometers are available on loan as a rapid assessment tool to detect changes in cyanobacteria. 2016 project enhancements will include refining data collection and analysis efforts, formatting designs for relaying information to the general public, enhancing the citizen science program components and recruitment of drinking water systems. Funding is, in part, through a recently awarded the EPA-ORD Ideation grant.

- EPA Region 1 staff developed a GIS-based method to identify potential risks from nutrient related impairments, including cyanobacteria blooms in New Hampshire's drinking water sources. Information was gathered on drinking water intakes that were in close proximity to surface waters that have been listed as impaired on the state's 303(d) list for nutrient related parameters such as total phosphorus, total nitrogen, chlorophyll-*a*, dissolved oxygen, excess algal growth, algal toxins and turbidity. Nine drinking water intakes were identified using geospatial analysis where at least one nutrient related impairment existed in a waterbody that was within 200 feet of the intake. A map was produced that shows the identified water systems along with nutrient impaired water bodies. The same analysis and mapping will be conducted for the other five New England states. This effort is helping the region and states to gain a better understanding of the connection between drinking water source waters, CWA 303(d) impaired waters and algal blooms and is a fundamental step to aligning Clean Water Act and Safe Drinking Water Act priorities.

- EPA Region 1's Regional Laboratory established in 2010 monitoring buoys in the Charles and Mystic Watersheds to track cyanobacterial blooms and water quality conditions. The buoys measure for chlorophyll and use fluorescence sensors to measure for phycocyanin. Field samples are collected for chlorophyll-*a* and cyanobacterial cells to correct and evaluate data.

- Renegotiation of the Great Lakes Water Quality Agreement requires that the Parties (EPA and Environment Canada) re-examine and establish phosphorus loading targets and associated in-lake endpoints and metrics associated with hypoxia, hazardous algal blooms, and *Cladophora* for each of the Great Lakes. In addition, phosphorus load allocations must be determined by country, state and province, and for priority watersheds. Because of the severe symptoms being experienced in Lake Erie, it has been designated as the first and lead lake for evaluation; it is anticipated that Lakes Ontario and Michigan will follow. The EPA is managing phosphorus and nutrient loading data to ensure consistent use and interpretation for the purposes of setting loading and other associated targets in Lake Erie. Work is being conducted linking watersheds with coastal receiving waters. The loading datasets are by source category including municipal point sources, industrial point sources, atmospheric and nonpoint sources. Preliminary results indicate that the phosphorus loads of the Maumee and Detroit Rivers are among the largest for all of the Great Lakes and are high priority watersheds requiring attention to abate the various symptoms being observed in western Lake Erie. Total phosphorus and dissolved phosphorus both are greatest from these major sources. The phosphorus loading dataset will be used for satisfying other requirements of the Agreement through various empirical and statistical assessments and modeling applications. An ensemble modeling approach is being used by the Parties consisting of federal and academic partners and is beginning a Science Advisory Peer Review on December 2014. For the Interagency Task Force, responses from Region 5 and the Great Lakes National Program Office are pending.

- EPA Region 5 co-leads a binational workgroup to develop and implement the Nutrients Annex ("Annex 4") of the 2012 Great Lakes Water Quality Agreement. Under Annex 4, the United States and Canada are charged with establishing binational phosphorus targets for the nearshore and offshore waters of the Great Lakes needed to meet several ecosystem objectives, including minimizing the extent of hypoxic zones associated with excessive phosphorus loading and maintaining cyanobacteria biomass at levels that do not produce concentrations of toxins that pose a threat to human or ecosystem health. This effort is focused on Lake Erie in the near term, with specific milestones in the next 3-5 years (see below). In addition, EPA Region 2 has begun working with Annex 4 to develop strategies to address phosphorus targets for Lake Ontario, which is the next Great Lake that will receive focused attention by Annex 4. Region 2 is conducting a nutrient monitoring protocol that will provide baseline monitoring and modeling data to help establish phosphorus loading targets for Lake Ontario.

- On September 3, 2014, the EPA Administrator Gina McCarthy announced that the Great Lakes Restoration Initiative (GLRI) will provide nearly $12M to federal and state agencies for projects identified as a result of an August 2014 meeting held by Region 5 to identify collaboration opportunities to minimize HABs in the Western Basin of Lake Erie. These projects include:
    - Farmer incentives
    - Soil testing and fertilizer recommendations
    - Planting of winter crops
    - Upgrades to controlled drainage systems
    - Funding of best management practices (BMP) at livestock facilities
    - Expanding Environmental Quality Incentives Program (EQIP) funding
    - Improve HAB monitoring and forecasting by NOAA

        - Tributary monitoring for phosphorus

- Stakeholder consultation is an explicit requirement in the 2012 Great Lakes Water Quality Agreement. The EPA will solicit input from stakeholders on the new phosphorus loading targets for Lake Erie prior to ratification in 2016.

- EPA Region 5 has been working on the Grand Lake St. Marys Project to identify present conditions and model the Grand Lakes St. Marys watershed in order to identify problem areas and assist watershed managers with useful information to assist in decision making. The project started in July 2011 and is funded by the Regional Applied Research Effort (RARE), ORD's Regional Science Program, which responds to high-priority, near-term research needs of the EPA's regional offices. The EPA is assessing lake conditions and using USDA/Agricultural Research Services (ARS) models to identify problem areas in the watershed. USDA provided recommendations in land use management and BMP selection. Another RARE project between the EPA Region 5 and the EPA involves methods for assessing the water quality degradation through water treatment plants during algal blooms, which will evaluate cyanotoxin analytical methods, identify relationships between water quality parameters and algal toxin production/release, and evaluate treatment effectiveness of different processes on algal toxins. The project started in September 2014 and will run through 2015. The EPA has been collecting monthly samples from Lake Erie drinking water treatment plants including raw water, finished water, and effluents of all intermediate unit processes. Samples are analyzed for cyanobacterial toxins, mycotoxins, chlorophyll-*a*, phosphate, ammonia, nitrate, nitrite, dissolved organic carbon, total nitrogen, and trace metals. Bench-scale studies will evaluate the impact of oxidant dose, powdered activated carbon dose and pH on algal toxin control.

- EPA Region 6 is working closely with states and encouraging them to develop numeric nutrient criteria for causal (nitrogen and phosphorus) and response (chlorophyll-*a*; water clarity) variables for multiple water body categories (streams/rivers, lakes/reservoirs, estuaries/coastal waters). Increasing frequency of HABs and cyanotoxins in drinking water supplies further underscores the importance of regions and states stepping up their efforts to develop these criteria or translators of narrative nutrient criteria in a timely fashion and at levels protective of all uses, including the drinking water use. This also points to the need for eventual criteria development (once national criteria are available) and routine ambient monitoring for cyanotoxins in waters with drinking water uses.

- EPA Region 7 coordinates with the state drinking water programs who are working with their respective state recreational monitoring programs. In 2015, the EPA Region 7 laboratory increased its capabilities to analyze for cyanotoxins and will be collecting algal toxin samples at the end of September in the source water and the finished water of targeted treatment plants in tribal lands.

- EPA Region 8 purchased several Abraxis test strip kits to distribute to drinking water operators for raw water (intake) sampling because these strips were key to a successful HAB response in the Boysen Reservoir (in Wyoming). Abraxis test strips can be used for drinking water systems as a screening tool to determine if the ELISA method should be used. These types of field methods are useful in this part of the country, as laboratory capacity for analyzing algal toxins is limited. The Region is working with groups in each state to accelerate the development of lab capacity for cyanotoxin analysis.

- EPA Region 8 hosted a harmful algal blooms workshop September 30 – October 1, 2015, in Rapid City, South Dakota. The workshop was designed to bring together state environmental agencies, health departments, drinking water utility managers, and public water supply operators to discuss HABs issues in Region 8. Agenda items included topics such as: impacts associated with HABs; what causes HABs; HABs monitoring for drinking water and recreational impacts; new technologies for tracking HABs; and opportunities for outreach and education. The workshop also provided a forum for sharing updates on state and regional HABs-activities and building partnerships with other agencies.

- EPA Region 9 is working to assist tribes in HAB response including targeted technical assistance, analytical support, and resources for infrastructure improvements to tribes. EPA staff worked with the Hoopa Tribe in response to anatoxin and microcystin in the Trinity River (source water for Hoopa drinking water) to coordinate analyses, and later provided a source water protection grant and drinking water Tribal set-aside funds to support ozone treatment for the Tribe's drinking water system.

- EPA Region 9 and ORD-National Exposure Research Laboratory were awarded an internal, competitive 2015 ORD Safe and Healthy Communities Regional Sustainability and Environmental Sciences Research Program (RESES) program project for their proposal entitled, "Floating Vegetation Islands: Using Traditional Ecological Knowledge (TEK) for Development of Leading Indicators of Ecosystem Function for BMP Effectiveness, Water Quality Standards, Biological Criteria, and Harmful Algal Blooms (HABs)." This pilot research project will develop leading indicators of ecosystem function to determine the need for and effectiveness of best management practices. Leading indicators help decision makers be proactive in developing adaptive management plans. Leading indicators will be correlated to alterations in ecosystem functions and water quality with changes in land-use practices and climate variability. TEK from the Chemehuevi Indian Tribe and the Colorado Indian Tribes will be used to help determine ecosystem potential condition for current restoration projects.

- EPA Region 9 supports its states to address HAB concerns including: updating state guidance and thresholds for recreational exposures; providing training to agencies and waterbody managers for recognizing and responding to HABs; developing statewide field monitoring protocols; establishing lab networks (state and federal labs, identifying capabilities and sharing analytical methods/ protocols); developing a database for tracking HAB occurrence, toxin data, etc.; and coordinating with veterinary labs for tissue analysis of affected animals (e.g., dogs, cattle).

- The EPA Region 9 laboratory provides microcystin analysis by ELISA to support program requests, including: (1) analysis for numerous state and local agencies for initial assessment of HAB-impacted waters, (2) ongoing monitoring since 2006 in the Klamath River Watershed and (3) analytical support for monitoring of the 2015 bloom season at Clear Lake for 2015, (the latter two are two of the region's priority watersheds). The Region 9 Lab has analyzed 300 - 700 samples annually since approximately 2008. EPA Region 9 also has a Risk Management Program Grant through an interagency agreement with USGS and ORD/NERL to analyze and optimize cyanotoxin sample preparation methods for ELISA and LC/MS analysis.

- EPA Region 10 recently funded the Southeast Alaska Tribal Toxins (SEATT) project. The SEATT is a partnership represented by eight Alaska tribes that was funded to conduct monitoring and develop better predictive tools for HABs. With over $225K in Indian Environmental General Assistance Program (IGAP) funding from EPA, together with training support from NOAA and financial support from the Administration for Native Americans' Environmental Regulatory Enhancement Program, the partner tribes will monitor HAB events that pose a human health risk to shellfish harvesters, such as paralytic shellfish poisoning (PSP). This monitoring effort will provide weekly data on the timing and distribution of HABs, along with measurements of environmental conditions, indicators, and potential mechanisms that trigger HAB events. The data collected will be used to create a more rigorous framework for mitigating the impacts of HAB events on fisheries, rather than traditional rules of thumb which are no longer effective due to changes in the type, magnitude, frequency and duration of HABs in the region.

- In 2012-2013, EPA funding through the Puget Sound National Estuary Program supported the Washington Department of Health and Washington Department of Ecology in conducting a comprehensive sampling effort for diarrhetic HABs throughout Puget Sound and along the Washington Coast (28 sites in 2012 and 72 sites in 2013). The main HAB sampling target was Dinophysis spp. in shellfish tissue. Ancillary measurements collected during the project included temperature, salinity, and nutrients. The goal of the project is to work toward developing a HABs early warning system. One of the EPA's approaches has been to use Bayesian regression models to estimate the effect of nutrient concentrations on chlorophyll-*a* concentrations above /below a threshold given nutrient inputs. The estimated marginal densities include use of the National Lakes Assessment (NLA) sample weights, and represent the estimated Ecoregion 8 marginal densities for log10(Total Phosphorus) and log10(Total Nitrogen). The idea is this type of approach could serve as some of the basis for empirical modeling of the likelihoods of cyanobacteria blooms, whether toxic or not, including in freshwater systems that serve as drinking water sources. Additionally, the NLA (2007) data will be used for the contiguous U.S. Some modeling aspects of this work can be applied in the Northeastern U.S. where ORD is interacting with EPA Region 1 and two New England states (MA and RI).

- EPA regions and states are working together to protect the public from exposure to HABs in coastal and freshwater systems. EPA Region 1 has been working with the State of Vermont on the Lake Champlain cyanobacteria monitoring, a qualitative and quantitative monitoring program on Lake Champlain for cyanobacteria during the 2014 summer season. This project is funded through a grant to the State of Vermont Department of Environmental Conservation with the purpose of identifying areas of high concentrations of cyanobacteria, particularly toxin levels, and provide warnings to the public.

VIII. Appendix 3. EPA's Intended Future Activities Directly Related to Freshwater HABs

Information in this Appendix is based on the EPA's proposed research project (i.e., research area), Reducing Impacts of Harmful Algal Blooms, for its 2016-2019 research cycle. Work completed under this project will provide stakeholders and decision makers with improved scientific information and tools to assess, predict and manage the risk of HABs, associated toxicity events and the ensuing ecological, economic and health impacts. The project directly addresses legislative mandates, Agency research needs, Agency Program Office initiatives, National Water Program (NWP) needs and community and other stakeholder needs as follows:

- Improve the science of HAB and toxin detection by developing HAB-specific analytical methods and sampling strategies.
- Assist the NWP in developing new HAB indicators, sampling designs and protocols for use in national-scale assessments.
- Develop improved approaches to understanding the interactive effects of increasing water temperatures and nutrient loads on HAB development and toxin production.
- Develop improved models to project risk of HABs under warming climate scenarios.
- Improve understanding of the human health and ecosystem effects resulting from toxin exposure.
- Provide drinking water treatment system operators with improved methods for detecting and treating toxins in order to limit or prevent human exposures.

This project will be focused on four intertwined research areas:

<u>Area 1: Management strategies.</u>

Research needs exist to develop new, market-ready treatment technologies, and to optimize existing technologies for the removal of toxins present in drinking water systems. Ideally, these methods would minimize capital, maintenance, and operational expenses, and be scalable to such a degree that they could be implemented in communities ranging from large and wealthy to small and economically marginalized. Active collaborations with water managers and other private and public sector stakeholders will help ensure these goals are met and streamline transfer and adoption of viable management strategies and technologies. Work in this area would be predicated on the assumption that there are no significant policy or institutional barriers to adoption.

In the area of drinking water treatment, removal effectiveness for various unit operations have been documented for a subset of the small group of toxins for which commercial standards are available. However, knowledge gaps exist for (1) the large set of toxins for which standards are currently unavailable, and (2) how to implement process and operational changes for maximum protection and cost-effectiveness under a variety of site-specific constraints.

In the area of reservoir management, existing research indicates that modifications of reservoir hydrology may help to reduce the frequency, intensity, duration and toxicity of bloom events. However, the efficacy of these efforts is site-specific, and gaps remain in the knowledge of the optimal method(s) to apply for any given set of reservoir conditions. ORD scientists and engineers will develop a scientific basis for the development and application of reservoir management strategies. In the domain of recreational area management, the primary research needs are the development of body contact exposure standards for the entire suite of known toxins as well as the development of scientifically based guidance for optimal sampling strategies.

Area 2: Health, ecosystem and economic effects.

One of the strongest drivers for changes that may be required to prevent future HABs, and/or mitigate those that occur, is the threat of serious adverse health effects in exposed populations. Research gaps to evaluate sources and routes of human exposures and their potential toxicity will need to be addressed. When HABs and toxins occur in drinking water and recreational water sources, exposed human and animal populations will need to be evaluated for health effects. The identification of exposure biomarkers that are simple to obtain are necessary for timely evaluation of exposure levels. The types of toxicity (critical organ system, chronic, developmental, and reproductive) are not known for most identified toxins and these potential endpoints will be the focus of research efforts. Mammalian effects from exposure to widespread fish toxins are also an area that needs focused research efforts, since these widespread compounds have not been evaluated in mammals. The identification of ichthyotoxins and their mechanisms of action are needed since these have had a serious effect on fish stocks, both wild and in aquaculture. The potential of freshwater algal toxins to cause adverse health effects after transport from lakes and streams into the coastal environment, and subsequent bioaccumulation in marine organisms, is known to have occurred and requires further research.

HABs have the potential to affect aquatic ecosystems. Gaps in the following research areas need to be addressed: food web disturbances resulting from toxin production and hypoxic areas, toxicity thresholds for sentinel species, and the potential for toxin bioaccumulation in fish populations, both wild and aqua-cultured.

Questions include: 1) "What are the ecological impacts of algal toxins on aquatic life through direct exposure and through food chain bioaccumulation? 2) How sensitive are real-time biomonitoring systems that use larval fish, daphnia and algae in comparison to traditional toxicity test organisms used in whole effluent toxicity testing? And 3) What are the nutrient and other environmental conditions that are conducive to establishment of toxin producing species?"

Assessment approaches will include determination of whether algal toxins inhibit zooplankton grazing behavior and population dynamics, as well as the impact on benthic filters; whether simultaneous and sequential exposure to multiple toxins, particularly the combination of multiple cyanotoxins, pose cumulative or synergistic risks to aquatic life; the potential for bioaccumulation, bioconcentration, and biomagnification of different cyanotoxins and other cyanobacterial bioactive compounds in food webs; development of algal reference toxicant tests using the top 4 toxins found during algal blooms; comparison of results of reference toxicant tests using standard species to the results obtained from real-time monitoring systems; and the culturing of toxin-producing species under laboratory conditions using various combinations of environmental conditions in order to observe the effect on toxin production.

An accurate assessment of economic effects is a critical piece of the puzzle as the Agency works to craft a response that is cost-effective and protective of public, economic, and societal health. To the best of the authors' knowledge, such an assessment does not currently exist. The assessment would be broken down into two parts:

1. A nationally representative random sample survey to estimate the direct costs generated by HABs: these may include, but are not limited to extra monitoring expenses, water treatment

plant upgrades and chemical costs and lost revenue from beach closures and drinking water advisories. The planning and implementation of such a survey, using traditional tools of economic research, represents an opportunity for cross-agency collaboration.

2. A nationally representative random sample survey to estimate the degree to which public confidence in the safety of drinking water, natural and recreational assets is affected by scientific data, general-audience news from traditional media outlets, and information across the quality spectrum circulated on social media outlets. The motivation for such a survey is the fact that information circulated through these channels has the potential to quickly shape public perceptions, and these perceptions, in turn, drive behavior at the individual and family level with potentially significant negative economic consequences. It is envisioned that such a census would employ data from a variety of information and social media platforms to track the spread of information within a strictly delineated subject area.

Area 3: Temperature impacts and bloom modeling

The scientific community generally agrees that HABs have been increasing in frequency, duration and geographical range. The factors responsible for these postulated increases are thought to include ease of global transport of species, rapid evolutionary response of algal/bacterial species to changing environments, increased nutrient loads in aquatic environments, perturbations in rainfall, and increases in the overall average temperatures of aquatic bodies. These factors all enhance the ability of algal and cyanobacterial species to move, spread and form blooms with increased temporal, locational and spatial dimensions, including different water depths. A contributing factor in bloom formation, or duration, is thought to be increased average water temperatures, which provide a suitable environment for algal growth. Both laboratory and environmental studies on harmful bloom dynamics are necessary to understand the extent of effects of increased water temperatures on bloom formation, and tendency of such blooms to generate toxins that may have adverse environmental and health effects.

Improved modeling capabilities are needed for an assessment of the risk associated with HABs under the dynamic of different climate scenarios. An understanding of the species, temporal and spatial dynamics of HABs will improve the capability to anticipate the course of HABs and their potential adverse effects. The vast majority of HABs are not comprised of one species throughout the course of the bloom, multiple species are the usual case, either at the same time or sequentially. Detailed knowledge of the roles different environmental factors play on species identity, toxic vs non-toxic bloom formation, persistence of blooms, and spatial/temporal extent of blooms is needed in order to increase the accuracy of bloom forecasts. This is also true of the types of toxins that will be formed in specific blooms. Together, an increased ability to predict the character of blooms will enable regulatory agencies at the national, state, tribal and local level to better predict the course of blooms and, therefore, respond appropriately.

Area 4: Analysis and monitoring in fresh and coastal/estuarine environments.

Effective response to HABs must be based on accurate and timely assessments of the species that comprise the bloom, the toxins, if any, that are being produced, and the ecosystem impacts resulting from the presence of HAB biomass.

Morphological, culture-based, molecular biology, and optical sensing (flow cytometry, satellite imaging) approaches have been used to identify and quantify the primary algal, and related bacterial, species in blooms. All of these strategies have strengths and weaknesses. Consequently, it is important to improve existing monitoring and analytical methods, and to develop and validate new cost- and time-effective methods that can be used by Program Offices, Regions, states and other stakeholders.

For ecosystem impacts, existing methods need to be improved, and new methods need to be developed, all with the goal of delivering the greatest possible amount of analytical power into the hands of small, local, laboratories, operating on modest budgets.

For toxins, the accuracy and precision of existing methods needs to be improved for different aqueous matrices (e.g., fresh, treated drinking water, brackish, marine, etc.) and animal tissues. Toxin analytical methods need to be standardized and, where possible, simplified in order to promote their adoption across the widest possible range of laboratories. New methods, capable of being employed from a variety of physical platforms, such as lab benches, field kits, buoys and flow-through monitors, need to be developed.

Finally, guidance needs to be developed that allows water managers to set up site-specific monitoring programs that take advantage of the existing suite of analytical methods, and potential *in situ* monitoring networks, in order to maximize protection while minimizing sampling and analytical effort.

In recent years, HAB-driven adverse environmental and health effects have been observed in the estuarine and marine environments of all coastal areas. Adverse health effects have been recorded in humans through direct exposures and consumption of toxin-containing seafood. Serious adverse health effects have also been recorded in marine mammals, fish and birds, some of which are endangered. These effects are largely caused by algal species with toxins that are different from those found in fresh waters. The factors that act to favor the formation of HABs are largely unknown in marine and estuarine (saline) environments. The development of estuarine- and marine-specific analytical methods and indicators is essential for the protection of the environment as well as human populations.

Analytical and monitoring efforts in fresh, estuarine, and marine environments have the potential to generate data sets across a range of temporal and spatial scales. These data sets would encompass direct readings on riparian, lake and coastal bodies of water as well as remote sensing from satellites. The monitoring of HABs is ongoing by the Agency, a number of other federal entities including the U.S. Geological Survey (USGS) and the National Oceanic and Atmospheric Administration (NOAA), and by State, Local and academic entities. Data from these monitoring efforts exist in both published and unpublished form. The utility of these large data sets depends upon their consistency and availability. Developing a data portal that integrates existing and future data into a programmatic data base would result in a more cohesive HAB program. This portal would allow data sharing, promote collaborative research and speed the development of a comprehensive view of HAB extent throughout the United States. It is recognized that the technical challenges of developing and maintaining a data portal are significant. However, the potential benefits are so significant that laying the groundwork for such a portal is an aspirational goal of this project area.

IX. *Appendix 4. Federal Agencies' Current and Proposed Activities Directly Related to HABs*

The information in this appendix is compiled from interagency efforts based on input and feedback from other federal agencies. It is intended to be representative rather than a comprehensive listing of HABHRCA-related work. This information will be further explored with the release of the HABHRCA Report to Congress, anticipated to be released by the end of 2015.

Federal Agencies' Current and Proposed Activities Directly Related to HABs

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
DHHS	CDC	HABs	HAB-related Outbreak and Illness Surveillance	CDC initiated waterborne and foodborne disease outbreak surveillance systems in the 1970s. U.S. states and territories voluntarily report to these systems via the electronic National Outbreak Reporting System (NORS), which receives aggregate data on human cases and their exposures, including exposures to harmful algal blooms (HABs) or HAB toxins. The One Health Harmful Algal Bloom System (OHHABS) is being developed for single case-level reporting of human and animal illness, and relevant environmental data. OHHABS is being programmed to inform restoration activities in the Great Lakes but will accessible to all states via NORS. The pilot version of the system is being tested in preparation for a 2016 launch.
DHHS	CDC	HABs	Great Lakes State Health Surveillance Capacity	CDC has partnered with the Council of State and Territorial Epidemiologists (CSTE) since 2013 to place and provide technical support for epidemiology fellows in Great Lakes states, including Indiana, Illinois, Michigan, Minnesota, New York, Ohio, and Wisconsin. The activity is supported by the Great Lakes Restoration Initiative. Fellows focus on waterborne disease detection, investigation, response and reporting. The fellowship has expanded state waterborne disease reporting and analytic capacity; improved state health surveillance for harmful algal blooms; and ensured dedicated staff time for waterborne disease surveillance and coordination activities.
DHHS	CDC	HABs	Health Communications	CDC's health communications activities related to HABs include the preparation of a HAB website with information for public health practitioners, clinicians, and the general public, and the expansion of the Drinking Water Advisory Communications Toolbox (DWACT) to include information about HAB-related drinking water advisories. The DWACT was created through a collaborative effort among CDC, EPA, the American Water Works Association, the Association of State and Territorial Health Officials, the Association of State Drinking Water Administrators (ASDWA), and the National Environmental Health Association (NEHA).

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
Multiple	CDC, EPA, NOAA	HABs	Interagency Analytic Workgroup	Additional research is needed to fully characterize and understand the health risks from drinking water provided by public water systems when that water is contaminated with cyanobacterial toxins. There is a need to establish standardized biological sample collection and analysis protocols to support assessment of toxin-associated health effects. Multiple federal agencies are working together to assess sampling and analytical capabilities related to analysis of biological specimens collected from human and animals exposed to cyanobacteria toxins via contaminated water, including drinking water. The goal is to combine expertise to develop robust analytic methods to detect biological evidence of exposure to cyanobacterial toxins, to optimize laboratory and emergency response capacity in the collection, analysis, and response to harmful algal bloom-related illnesses.
DHHS	CDC	HABs		Method development, refinement, and validation for detecting human exposures to HAB toxins through the detection of toxins and specific biomarkers in clinical samples. Current methods approved for use include the detection of saxitoxin, neosaxitoxin, tetrodotoxin, and gonyautoxins (1-4), which have been applied to individual cases to confirm suspected HAB exposures.
DHHS	FDA	HABs		Method development, refinement, and validation for detecting HAB toxins; improving understanding of HAB toxin sources and vectors that impact seafood and dietary supplement safety.
DHHS	FDA	HABs		Developed, evaluated, and validated rapid screening for HAB toxins in seafood, thereby improving regulatory monitoring, surveillance programs, and outbreak response. For example, FDA developed an onboard screening dockside testing program for PSP toxins in shellfish, which led to reopening of a large portion of Georges Bank in 2013 to safe commercial harvest of clams.
DOC	NOAA	HABs	SoundToxins	The Northwest Fisheries Science Center (NWFSC) has established a new monitoring partnership called SoundToxins for the early warning of marine harmful algal blooms in Puget Sound. The NOAA National Centers for Coastal Ocean Science ECOHAB program provided 3 years of funding to develop the Puget Sound Harmful Algal Bloom (PS-AHAB) project to understand environmental controls on the benthic (cyst) and planktonic life stages of the toxic marine dinoflagellate *Alexandrium*, and evaluate the effects of climate change on the timing and location of blooms.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
DOC	NOAA	HABs	National Phytoplankton Monitoring Network	The Phytoplankton Monitoring Network (PMN) was established to monitor phytoplankton and harmful algal blooms and promote environmental stewardship though the use of citizen volunteers. PMN volunteers are trained by NOAA staff on sampling techniques and identification methods for over 50 genera, including 10 potentially toxin-producing genera, of dinoflagellates and diatoms on the volunteers watch list. Currently, 250 marine and Great Lakes sites in 22 states and U.S. territories including 52 schools, 15 universities, 298 civic groups and 40 state and federal agencies collect phytoplankton and environmental data. Since the inception of the program in 2001, more than 275 algal blooms and 15 toxic events have been reported by PMN volunteers.
DOC	NOAA	HABs	National Analytical Response Team	NOAA's Analytical Response Team (ART) provides rapid and accurate identification and quantification of marine algal toxins in suspected harmful algal blooms (HABs), and related marine animal mortality events and human poisonings. From 2009 to 2014, ART received over 4000 samples from state and federal government agencies, NGOs, and academic partners for determination of toxins associated with harmful algae. In addition to water samples, marine toxins were analyzed in samples from marine and freshwater algae, shellfish, fish, cetaceans, pinnipeds, birds and sea turtles.
DOC	NOAA	HABs	Technology Transfer Team	The Technology Transfer Team completed rigorous, international inter-laboratory trials in partnership with interagency organizations, federal agencies and private businesses to bring the receptor binding assay for paralytic shellfish poisoning (PSP) toxins to U.S. and international regulatory approval; and guided its commercialization to assure U.S. marine shellfish are safe for U.S. citizens and export throughout the world. The team also provided training on use of the method to more than 30 countries through formal agreement with the International Atomic Energy Agency to promote safe food supply and increased economic growth through the export of fisheries products and to the Southeast Alaska Tribal partnership to enable monitoring of subsistence resources.
DOC	NOAA	HABs	Ecological Forecasting	The National Centers for Coastal Ocean Science (NCCOS) develops and transitions HAB forecasts for coastal and Great Lakes waters. NOAA is also working with EPA on systematic approach to either warning state health/water quality on cyanobacteria blooms and allowing them to evaluate patterns and trends in lakes and estuaries that are at risk.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
DOC	NOAA	HABs		Continue to make satellite coverage of ocean and coastal zones more comprehensive and combine it with existing data to enable quantifiable estimates of HABs (much of this has been funded by NASA). Plan to transfer promising new monitoring and prediction technology and approaches from research to operational HAB forecasts for Gulf of Mexico, Lake Erie, Chesapeake Bay, Puget Sounds, Pacific Northwest, and California.
DOC	NOAA	HABs	Ecology and Oceanography of Harmful Algal Blooms (ECOHAB)	Developing a better understanding of marine HAB causes and impacts that form the basis for better management to reduce HABs and their impacts.
DOC	NOAA	HABs	Monitoring and Event Response for Harmful Algal Blooms (MERHAB)	National, competitive extramural research program that builds capacity for enhanced coastal and Great Lakes HAB monitoring and response in state, local, and tribal governments.
DOC	NOAA	HABs	Prevention, Control, and Mitigation of Harmful Algal Blooms (PCMHAB)	National, competitive extramural research program that develops new methods of coastal and Great Lakes HAB prevention, control, and mitigation. It also addresses the socioeconomic impact of HABs and efforts to reduce HAB impacts.
DOC	NOAA	HABs	Event Response	Provides modest support to supplement monitoring of coastal and Great Lakes HAB events, and advance the understanding of HABs when they occur.
DOC	NOAA	Hypoxia	Coastal Hypoxia Research (CHRP)	National, competitive extramural research program that develops understanding of hypoxia causes and impacts that form the basis for better management to reduce hypoxia and its ecological and socioeconomic impacts. Includes all coastal systems except the large hypoxic zone along the northern Gulf of Mexico continental shelf.
DOC	NOAA	Hypoxia	Northern Gulf of Mexico Ecosystems and Hypoxia Assessment Program (NGOMEX)	National, competitive extramural research program that develops understanding of the causes and impacts of the northern Gulf of Mexico hypoxic zone, that form the basis for better management to reduce the hypoxic zone and its ecological and socioeconomic impacts.
DOC	NOAA	Hypoxia		Continue to convene workshops to obtain stakeholder needs that drive research prioritization, and disseminate advanced knowledge and tools for hypoxia mitigation to regional managers and interagency management networks such as the Gulf Hypoxia Task Force or the Landscape Conservation Cooperative.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
DOC	NOAA	HABs		Studies molecular ecology of HABs in the Great Lakes and makes improvements to monitoring HABs and toxicity in the Great lakes. Monitors six routine stations in the western basin of Lake Erie weekly during blooms season and supplies data that supports the predictive models in Lake Erie. Developing a three dimensional lagrangian particle transport model to effectively predict HAB advection as part of the Lake Erie Operational Forecasting System, which is set to go operational through fiscal year 2015.
DOD	USACE	HABs		Responding to HABs in response to public reports/complaints in close coordination with state water quality/public health agencies. Response programs developed by individual USACE Divisions/Districts. The Engineer Research and Development Center (ERDC) is available to support Divisions/Districts in assessing HAB impacts to USACE Civil Works Projects (e.g., WQ modeling, remote sensing, and technical assistance). General WQ monitoring and HAB response to meet authorized project purposes and recreation mission requirements.
DOD	Oceanographer of the Navy	HABs		Studies the variability of in situ and remotely sensed spectral optical properties to identify dinoflagellates through field sampling and improvement of remote sensing techniques. Dinoflagellate information has been incorporated into Naval Research Laboratory's ecological-circulation models for better understanding/prediction.
DOI	BOEM	Hypoxia	Gulf Oxygen Deepwater Experiment	Study plan pending approval: To address noted data gaps that addresses deepwater oxygen dynamics such as in the Oxygen Minimum Zone in the Gulf, whereas the Louisiana-Texas (LATEX) shelf studies were on the shallower hypoxic zone.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
DOI	NPS	HABs and hypoxia	Outreach and Education	Of the 407 NPS units, there are 86 units that are considered ocean, coastal, or Great Lake parks, in addition to other park units that have extensive surface water bodies. HABs have the potential to influence all of these park units at various levels, and it is therefore important to prepare for these events in order to preserve our resources. The National Park Service is creating a website containing a public health and ecological HAB events reporting system. It also provides a point of contact for park managers to partner with local and state health and environmental agencies who will provide park personnel with technical assistance for the management of HAB events. Outreach materials (brochures, interpretive displays and materials) on HABs, their causes, the effects on the ecosystem, and the many ways to reduce or stop nonpoint source pollution, many of which are simple to implement.
DOI	USGS	HABs and hypoxia	National Water Quality Program	USGS conducts long-term monitoring of nutrients and other water-quality characteristics in surface and groundwater networks. The sources and quantities of nutrients delivered by streams and groundwater to coastal areas and the Great Lakes are monitored at 106 sites. Annual updates from the monitoring sites are made available to the public, including nutrient concentrations, loads, and yields. These data, along with data aggregated from numerous other agencies, are used to evaluate trends in critical water quality parameters including nutrients and sediment. Real-time measurements for dissolved oxygen and temperature are collected at over 500 and 2000 locations, respectively. USGS is pioneering new field sensor methods and systems for monitoring and delivering real-time nutrient data, with over 100 nitrate sensors deployed. The USGS SPARROW model quantifies nutrient sources and sediment loads to coastal areas, the Great Lakes, and inland lakes in the Eastern U.S. SPARROW has also been linked to an online Decision Support System, which allows direct exploration of the potential benefits of nutrient management for systems including the Chesapeake and the Mississippi, other coastal rivers, and the Great Lakes.
DOI	USGS	HABs and hypoxia	National Water Quality Program/National Water Quality Assessment	USGS collects fish-, aquatic macroinvertebrate-, and algae-community samples, and conducts stream physical habitat surveys to assess the effects of multiple stressors—including algal toxins—on aquatic organisms in streams in several ecoregions.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
DOI	USGS	HABs	National Water Quality Program/ Cooperative Water Program	HAB research is conducted in at least 20 USGS Water Science Centers. Studies include both short- and long-term projects focused on quantifying blooms and associated toxins and taste-and-odor compounds, and understanding causal factors. Many studies employ new and developing sensor technology to detect algal pigments. For example, a study of the primary drinking water supply for Wichita, Kansas combined long-term discrete and continuous water-quality data to develop models that estimate the probability of microcystin occurrence in near real time.
DOI, USDA	USGS, USDA-NRCS	HABs and hypoxia	GLRI	Assesses the impacts of agricultural management practices, climate change, and land use change on the timing and magnitude of delivery of nutrients and sediments to the Great Lakes at 30 sites. Works with NOAA, EPA, states, universities, and NGOs to understand how nutrient and sediment loading from the Great Lakes watershed affect hypoxia, HABs and biological communities in the near-shore environment. Edge-of-field studies in GLRI priority watershed quantify phosphorus, nitrogen, and sediment to evaluate nutrient reduction projects on agricultural land. Rapid sharing of edge-of-field monitoring results with local stakeholders allows for adaptive implementation.
DOI	USGS	HABs	Energy, Mineral, and Environmental Health/Toxic Substances Hydrology Program	Pioneer new field monitoring methods (sensors), assessment techniques, and laboratory methods needed to address harmful algal bloom issues in freshwaters. New methods include a multi-toxin method that can quantify cyanotoxin mixtures, and DNA- and RNA-based molecular methods for detecting microcystin and microcystin producers.
DOI	USGS	HABs	Ecosystems	USGS has ongoing research characterizing ecological and food web impacts of cyanotoxins. For example, a USGS study in Upper Klamath Lake demonstrated a link between microcystin and reduced young-of the year recruitment of federally endangered suckers.
HHS	NSF/NIEHS	HABs	Ocean and Human Health (OHH) Initiative and the NSF's Division of Ocean Sciences	The NIEHS supports multiple studies focused on the effects of HAB toxins on human and mammalian physiology, development of biomarkers for chronic toxin exposure, and the design and testing of novel technologies for in situ detection of algal toxins in fresh and salt water environments. For example, a number of ongoing studies are supported that analyze the effects of domoic acid on neurotoxicity as well as cognitive impacts in human cohorts, non-human primates and rodent models. Also, NIEHS is accepting unsolicited applications for support and use of time-sensitive mechanisms to allow research support for unanticipated bloom events.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
NSF	NSF	HABs and hypoxia	Ocean Observing Initiative and the National Ecological Observatory Network	Provides environmental data for studies of HABS (both marine and freshwater) and hypoxia.
NSF	NSF	HABs	Division of Ocean Sciences (OCE), NSF Ocean Observing Initiative (OOI)	Observational capabilities for research in marine systems.
NSF	NSF	HABs	Directorate of Geosciences, Prediction and Resilience Against Extreme Events (PREEVENTS)	Focused interdisciplinary research projects.
NSF	NSF	HABs	Division of Biological Infrastructure, National Ecological Observatory Network (NEON)	Observational capabilities for ecological research.
NSF	NSF	HABs	Division of Ocean Sciences	Research Support, unsolicited proposal in marine ecology.
NSF	NSF	HABs and hypoxia	Collaboration between NSF GEO, SBE, and ENG directorates, as well as USDA NIFA.	Program supporting interdisciplinary research to understand and predict the interactions between the water system and climate change, land use, the built environment, and ecosystem function and services though research and models. Several research projects are focused on nutrient movement and hypoxia mitigation strategies.
NSF	NSF	HABs	Ocean and Human Health Initiative, a collaboration between NSF's Division of Ocean Sciences (OCE), and the National Institute for Environmental Health Sciences (NIEHS)	Studies of the effects of HAB toxins on human and mammalian physiology, development of biomarkers for chronic toxin exposure, and the design and testing of novel technologies for in situ detection of algal toxins in fresh- and salt-water environments. Also accepting unsolicited applications for support and use of time sensitive mechanism to allow research support for unanticipated bloom events.
USDA	NIFA and ARS	HABs		Support of extramural and intramural research on the effects of HABs and HAB toxins on food safety, aquaculture, and livestock.
USDA	ARS	Hypoxia		Research on nutrient management, nutrient contribution to hypoxia, and aquaculture. Long-Term Agro-Ecosystem Research (LTAR) and Watershed Research Centers.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
USDA	NIFA	Hypoxia		Research support for studies of the effects of nutrient cycling, climate change, and nutrient management for agriculture.
USDA	NRCS	HABs and hypoxia	Conservation Technical Assistance (planning); Environmental Quality Incentives Program; Conservation Stewardship Program; Agricultural Conservation Easement Program Regional Conservation Partnership Program	NRCS provides conservation planning assistance to agricultural producers on cropland, grazing land, and for confined livestock operations. NRCS also has financial assistance programs to help producers implement and install practices. These programs are all voluntary and are incentive-based. For confined livestock systems, this includes, but is not limited to, practices such as waste storage structures, and associated practices like roofs and covers, roof runoff management, diversions, and a nutrient management plan for the utilization of manure. On cropland, this may include agronomic practices such as residue management, cover crops, conservation cropping systems, and nutrient management; buffer practices like filter strips and riparian forest buffers; water management practices such as grassed waterways, grade stabilization structures, drainage water management, blind inlets (to replace surface inlets), wetland restoration and creation; and prescribed grazing systems and associated practices for grazing land. The Natural Resources Conservation Service (NRCS) also assists farmers financially with edge-of-field water quality monitoring.
USDA	NRCS	Hypoxia	Great Lakes Restoration Initiative, Mississippi River Basin Healthy Watershed Initiative, National Water Quality Initiative, etc.	Under various water quality initiatives, NRCS and its partners help producers in selected watersheds to voluntarily implement conservation practices that avoid, control, and trap nutrient runoff; improve wildlife habitat; and maintain agricultural productivity. These initiatives utilize NRCS programs such as the Environmental Quality Incentives Program (EQIP) and the Conservation Stewardship Program (CSP) within targeted watersheds to provide technical and financial assistance.
USDA	NIFA and ARS	HABs and hypoxia		Supports research on best management practices for nutrient management, aquaculture, and plant breeding, among others. Specific concerns addressed by this research include manure management from animal feeding operations and water use and conservation on irrigated cropland.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
EPA	EPA	HABs and hypoxia	Water Quality Management	Diversified approach to better understand cyanobacterial HABs ecology and the development of watershed and source water management techniques, including the development of models for nutrients loadings, the optimization of watershed placement of phosphorus and sediment BMPs, and the use of water quality trading (WQT) to cost-effectively reduce nutrient loadings. It also includes an assessment of the impact of land use and infrastructure on watershed changes, and the evaluation of ecological contributors to cyanobacterial HAB development and toxin production. This research program also includes the use of molecular methods to characterize the risk in a reservoir for toxin and algal blooms, and the analysis of the impact of HABs on creating disinfection byproducts (DBPs) precursors.
EPA	EPA	HABs	Human and Ecological Health	Research support to address data gaps associated with health, ecosystem, and economic effects of HABs. Research activities include the characterization of cyanobacteria and their toxins and allergic components, the evaluation of the toxicity of multiple congeners of microcystins, and identification of biomarkers of exposure for human health risk assessments. Epidemiology studies to characterize toxin occurrence in U.S. inland lakes, and studies to determine that bioaccumulation, bioconcentration, and biomagnification of cyanotoxins in mammalian tissues and food web are also in place. EPA is also assessing occurrence and health information for the inclusion of cyanotoxins in the Contaminant Candidate List (CCL) and the Unregulated Contaminant Monitoring Rule (UCMR) program. In addition, EPA is developing Human Health Water Quality Criteria (HHWQC) for cyanotoxins in recreational waters.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
EPA	EPA	HABs	Monitoring and Analytical Methods Development	A collaborative effort of EPA, NASA, NOAA, and USGS to provide an approach for mainstreaming satellite ocean color capabilities into U.S. fresh and brackish water quality management decisions. The Cyanobacteria Assessment Network (CyAN) for freshwater systems will develop approaches to relate nutrient loads and land use to the frequency, location, and severity of cyanobacterial blooms in lakes of the United States. It will include assessing risk to human health from satellite multispectral data to assess biological conditions and risk to human health in lakes and reservoirs in the United States. EPA also provides nationally consistent and scientifically defensible assessments of aquatic resources through the National Aquatic Resource Surveys (NARS), including indicators associated with cyanotoxin exposure. EPA and its regions are also working on monitoring efforts such as the Lake Champlain Cyanobacteria Monitoring, Great Lakes Restoration Initiative projects and Phosphorus Reduction Strategy, Southeast Alaska Tribal Toxins (SEATT) project, and the Puget Sound Toxins Project. EPA is also working on monitoring projects to improve identification and removal of HAB toxins in drinking water, and evaluating the impact of temperature on bloom development. EPA is developing analytical tools including the use of real-time sensors, qPCR and fluorescence based technologies of micro spectrophotometer and flow cytometry to detect cyanobacteria organisms in source water.
EPA	EPA	HABs	Drinking Water Treatment	EPA is working collaboratively with regional offices to characterize the effectiveness of drinking water treatment techniques in reducing toxins.
EPA	EPA	HABs	Outreach	EPA conducts webinars and provides online resources to promote public awareness and information sharing.
NASA	NASA	HABs	The Ocean Biology and Biogeochemistry Program	Basic HABs research resulting in publications and new retrieval algorithms.
NASA	NASA	HABs	Health and Air Quality Applications Program	Improve the forecast resolution and frequency of risk of *Karenia brevis* toxins on every beach, every day, rather than every county, twice a week. The methods would be applicable across the Gulf of Mexico.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
NASA	NASA	HABs	Health and Air Quality Applications Program	Monitoring and surveillance of cyanobacterial harmful algal blooms (CyanoHABs) in drinking and recreational water supplies. Satellite derived products that were developed for western Lake Erie are being analyzed for their use in other regions (e.g., Chesapeake Bay and inland lakes in Ohio and Florida). This project has established methods to identify environmental thresholds that indicate the potential for cyanobacterial blooms to form or persist, and these data sets are also being made available to CDC.
	Multiple agencies and partners, including but not limited to EPA, FWS, NOAA, NPS, USACE, USDA, USGS	HABs and hypoxia	Water Quality Portal	Co-sponsors of the Water Quality Portal, a cooperative data service that makes data publically available. The data are derived from the USGS National Water Quality Information System (NWIS), the EPA Storage and Retrieval data warehouse (STORET), and the USDA ARS Sustaining the Earth's Watersheds - Agricultural Research Database System (STEWARDS). With data from over 400 federal, state, tribal, and local agencies, this efforts will improve understanding of progress in nutrient reduction efforts.
	Multiple agencies: CDC, NASA, NOAA, NSF, USDA, and USGS	HABs	ES21 Federal Working Group on Exposure Science	Exposure assessment is instrumental in helping to forecast, prevent, and mitigate exposure that leads to adverse human health or ecological outcomes. This vision expands exposures from source to dose, over time and space, to multiple stressors, and from the molecular to ecosystem level. HAB exposure assessment is addressed by ES21 Working Groups on Biomonitoring, Citizen Engagement/Citizen Science and Sensors/Dosimeters.
	Multiple Agencies, EPA and NOAA	HABs	Volunteer Freshwater Phytoplankton Monitoring Program	Volunteer monitoring program that collects baseline data on harmful algal species and builds capacity by providing data to NOAA Phytoplankton Monitoring Network and EPA. Volunteers are trained to identify algae, collect water samples, conduct basic water quality analyses, and preserve samples for further analysis by the NOAA Analytical Response Team. Network became operational in 2015 with stations in the Western Basin of Lake Erie in seven lakes in EPA Region 8, with plans to expand to Lakes Michigan, Superior, Huron and Grand Lake St. Mary in 2016.

Office/ Dept.	Agency	HABs/ Hypoxia/ Both	Program Title (brief description)	Program Activities
	USDA/Multiple agencies, led by USDA NRCS, ARS, NIFA, FSA, and NASS. Also includes USGS, NOAA, FWS, EPA, BLM, NASA, USDA Economic Research Service and US Forest Service	Both	CEAP	The Conservation Effects Assessment Project (CEAP) is a collaborative, multi-agency effort to quantify the environmental effects of conservation practices and programs and develop the science base for managing the agricultural landscape for environmental quality. Project findings are used to guide USDA conservation policy and program development, and help conservationists, farmers, and ranchers make more informed conservation decisions. USGS will incorporate conservation data collected by CEAP into its surface water quality monitoring. CEAP-Croplands developed a National Resources Inventory (NRI) statistical approach that combines information voluntarily collected through NASS producer surveys, and conservation practice data as inputs into two process based models, the Agricultural Policy Environmental eXtender (APEX) field-scale model and the Soil and Water Assessment Tool (SWAT) watershed scale model. In addition to determining conservation practice adoption trends, the CEAP modeling team is able to estimate the environmental benefits of conservation practices and conservation treatment needs within major drainage basins of the United States. In the first CEAP-Croplands National Assessment, current conservation conditions and outstanding needs were assessed in twelve major basins, including the Mississippi River Basin, Chesapeake Bay and Great Lakes. Since the 2003-06 national survey CEAP-Croplands has revisited watersheds through special studies, including Chesapeake Bay (2011), Western Lake Erie Basin (WLEB) (2012), California Bay Delta (2013), and the St. Francis and Lower Mississippi River Basin (2014). A second CEAP-Croplands National Assessment was initiated in 2015. In addition, the Watershed Assessment Component of CEAP continues to conduct small watershed-scale studies across the United States to quantify water and soil resource outcomes of conservation practices and systems and enhance understanding of processes. Interactions among practices are investigated as well as modeling enhancements, watershed targeting approaches, and socioeconomic factors. Practice standards are developed or updated to improve effectiveness and address gaps.
USDA	Multiple agencies, led by USDA NRCS, ARS, NASS and FSA		CEAP	In 2012, NASS worked with NRCS to administer a CEAP Cropland-survey focused on the Western Lake Erie Basin (WLEB). Data from the survey and other sources is being used to assess conservation effects in the WLEB and compare trends and progress in conservation as well as evaluate additional treatment needs in that region. The assessment report is forthcoming.

X. Appendix 5. Summary of Stakeholder Input

The information transcribed below is based upon oral and written comments received during the Listening Session Webinar on September 16, 2015. This summary is the EPA's best effort to accurately record input received by stakeholders. The EPA utilized the input received and incorporated elements into this strategic plan.

Public Statements

Scott Biernat, Association of Metropolitan Water Agencies (AMWA)

AMWA represents large publically owned systems. AMWA appreciates the technical and implementation challenges EPA faces in addressing the risks posed by HABs and toxin exposure via drinking water sources. Plans for addressing must be carefully crafted and implemented to achieve optimal public risk reduction and public health benefits.

HR 212 presents an important opportunity to set the path for a thoughtful collaborative approach for addressing challenges posed by algal toxins in drinking water. The process that is established for further evaluation and reevaluation of algal toxins risks is important to assure optimal risk reduction. This process must include continuous in-depth consultation with stakeholders to ensure all necessary expertise and practical experience is brought to the table. Based on the information gathered that lead to the cyanotoxin Health Advisories, EPA has a good understanding of the nature of the additional information needed to assess next steps to further reduce algal toxin risk. AMWA notes several points:

- First, the best and most cost effective long range strategy to protect the public from algal toxins is to prevent bloom-causing nutrients from entering waterway in the first place. In that regard, a meaningful reduction in algal blooms must begin with the agricultural sector. The development of a bolder, more innovative strategy for managing nonpoint source water pollution, particularly from the agricultural sector, must be a part of the strategic plan.

- Second, the strategic plan must place an emphasis on developing robust analytical methods in time for including cyanotoxins on the Unregulated Contaminant Monitoring Rule (UCMR 4). Collection of occurrence data under UCMR 4 can fill key information gaps related to algal toxin occurrence and provide a vital foundation for additional risk assessment as mandated by SDWA. These analyses will inform future stakeholder discussions and policy decisions from EPA and other local, state and federal agencies intended to ensure algal toxins do not pose human health risks if they reach drinking water supplies.

- Third, the assessment of existing guidance and support documents, including all existing health criteria documents should be identified as an iterative process within the strategic plan, drawing on lessons learned and new data as they become available to make appropriate and timely updates. With the summer bloom season under the new cyanotoxin health advisories now behind us, it is a particularly good time to reengage stakeholders to evaluate how to best address algal toxin challenges.

- Additional consideration of communication challenges regarding algal toxin health risks should be a focus of the plan. The setting of the health advisories based on a 10-day exposure and at two different age-based levels poses a unique public communication challenge. Further guidance must offer robust interpretation of how to evaluate the health advisory levels within this 10-day timeframe that corresponds to actual risk involved. Going forward it will be the strength of the collaborative process put in place to augment existing programs and processes that will determine how efficiently and effectively any data and information gaps are filled, and will help in identifying the action that will most effectively manage algal toxin risks. Combined with the already robust process for evaluating contaminant risk and evaluating the need for further regulation required under SDWA, such evaluation will ensure sound policies are developed.

In closing, AMWA thanks EPA for initial efforts in getting ahead of algal toxin issues and looks forward to collaboration on its next steps.

Steve Via, American Water Works Association (AWWA)

AWWA appreciates the opportunity for stakeholder involvement and input. AWWA understands the agency is working on a tight schedule and there is a lot of work to do to meet the deadline. Congress provided good direction, and the health advisory documents and their recommendations are important guides to taking on the task to assess and manage algal toxins. Some detailed suggestions:

- Health effects: look beyond microcystins LR, right now working on assumption that all congeners have equal health effects, and that it is true of natural congeners and degradates. That assumption might not prove valid in the long haul. Useful for agency to communicate next steps for anatoxin-*a*, the health assessment only covered microcystins and cylindrospermopsin while there were a number of identified data gaps with anatoxin-*a*.

- Important to realize goal for occurrence is both assessment and management of cyanotoxins. One of the key gaps from utilities is the need for ongoing and reliable monitoring systems, for toxins and the parameters that inform their management, both in water supplies and influent waters.

- Look to other strategies under other vehicles like the Clean Water Act, Unites States Geological Survey (USGS) and others to develop data systems to inform risk management at water supply level. Technical tools and support for action at utility level – clear awareness what information is actually useful for decision making. For example, lysing source water and using that observation as assessment of risk. To make a treatment change, that lyse data may or may not be most important especially for removal by coagulation and settling.

- Help make strong technical decisions and provide good support for a regulator rather than utility itself. There has been a lot of discussion about what methods should be used, need robust testing in relevant concentration range which is between 0.1-3 ug/L for microcystins rather than data driven by higher level concentrations.

- EPA source water collaborative with the United States Department of Agriculture (USDA) conservation division has identified a number of practices for achieving land use management, and implementation of best management practices.

- We really need to think about risk communication in context of risk management. One doesn't occur well without the other. A 10-day HA is challenging construct. Understanding impacts of management action, cost consequences for a community as they are thrown in preparation and response measures.

Beth Messer, Ohio EPA

Ohio EPA Responses to U.S. EPA HAB Webinar Questions – verbal comments

In an effort to keep the comments brief, Ohio EPA will provide verbal comments based on our experiences and what we consider the highest priority.

1) What do you consider to be the key information gaps in understanding the human health effects of specific algal toxins?

Additional research is needed for all microcystin variants, as well as saxitoxin for acute, short-term, and long-term exposures.

More information is needed on potential sensitive population exposures such as the elderly, immuno-compromised or individuals with pre-existing liver disease or on dialysis, and data is needed on whether cyanotoxins cross the placental wall and potential exposure via breastmilk

2) What do you consider to be the key information gaps in understanding the occurrence of blooms and toxin formation?

More information is needed on:

- the triggers for cyanotoxin production, release and degradation;
- triggers for cyanobacteria to release cyanotoxins to the extracellular form;
- movement of blooms within the water column, which may assist public water systems with avoidance strategies
- the role of resting cells/akinetes in the probability of future bloom formation; and
- factors that contribute to a shift in phytoplankton community dominance to HABs.

3) Please identify effective technical support or tools, including outreach and education efforts, that could benefit states' and PWSs' ability to predict, prevent and mitigate the occurrence of algal blooms and inform management decisions.

Guidance is needed on effective reservoir management strategies, in particular the impacts of algaecide application. Many public water systems rely on algaecide as a source control strategy. The effectiveness of this strategy could be improved through guidance on proper application rates and timing for different types of blooms, the effect of algaecides on akinetes, and information on the effect on community dynamics and possible long-term implications of use (specifically copper resistance).

Finally, Ohio has found remote sensing data to be useful tool, and recommends continued support for remote sensing projects including NOAA's Lake Erie HAB Bulletins and forecasts, CyAN collaborative efforts, and NASA and other research efforts on use of multi-spectral sensors (aircraft or drones).

4) **In your opinion, what are the most important steps that can be taken to improve strategies for use of HAB-related analytical methods, monitoring, and treatment of harmful algal toxins for drinking water?**

   More information is needed to optimize treatment strategies, including:

   - CT tables or cyanotoxin reaction kinetics for microcystin (including variants other than MC-LR) and saxitoxin for commonly used oxidants such as chlorine and permanganate under variable pH, temperature, and concentration ranges;
   - the effect of permanganate on cell lysis for genera other than microcystis;
   - the effectiveness and operational guidance for granular activated carbon (GAC), including different types of carbon on saxitoxin, MC-LR and other common microcystin variants;
   - saxitoxin adsorption capacity for different types of powdered activated carbon; and
   - short-term plant optimization guidance for removal/destruction of cyanotoxins via conventional surface water treatment processes.

Thank you for providing Ohio EPA the opportunity to comment.

Rob Blair, Kentucky Division of Water

The comments Kentucky put together have been addressed by other presenters.

Van McClenden and Ken Hudnell, North American Lakes Management Society

(Comments were read, and also submitted electronically. Comments appear here as they were submitted electronically)

1. I commend EPA for heightened concern about protecting the public from the health risks posed by cyanotoxins produced by cyanobacteria. The Agency has taken a number of steps in this direction, including:

   - April 2015 - Teaming with NASA, NOAA, EPA and USGS on developing a satellite surveillance system

   - June 2015 - Producing Drinking Water Health Advisories for Two Cyanobacterial Toxins

   - June 2015 - Recommending that Public Water Systems Manage Cyanotoxins in Drinking Water

   - By having two cyanotoxins on the UCMR4 candidate list and apparently moving toward implementing testing at utilities to better understand the scope of cyanotoxins in source water and finished drinking water

   - And finally, hosting this webinar to get public input on developing a strategic plan for addressing cyanotoxins in drinking water

2. I also commend EPA for realizing that the incidence of cyano HABs is increasing even as we've spent decades and many millions of dollars on the watershed management point- and nonpoint-source programs to reduce new nutrient inputs into freshwaters. I hope and think that the Agency is moving toward re-implementing the CWA's Clean Lakes program that calls for treating impaired waterbodies.

Even Ben Grumbles who made the decision to de-emphasize waterbody treatments in the early 1990s has told me he regrets that decision and no longer believes that watershed management alone can reverse the trend of increasing freshwater impairment. Movement toward fully implementing the CWA by complementing watershed management with waterbody management is indicated by:

- December 2013 – EPA produced *A Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program* (Webpage to PDF) – that allows for Alternative Approaches – "By 2018, States use alternative approaches …that incorporate adaptive management and are tailored to specific circumstances where such approaches are better suited to implement priority watershed or water actions that achieve the water quality goals…."

- May 2014 – Webinar, *A Systems Approach to Freshwater Management: Waterbody Treatments*

- September 2014 – Putting up a webpage on *Nutrient Policy, Controls & Waterbody Treatments*

3. As the Agency develops a strategic plan for addressing Algal Toxins in Drinking Water, I urge the Agency to seriously consider using an Adaptive Systems Approach to Freshwater Management as described by the North American Lake Management Society or NALMS. I'll be glad to send you a description of an ASA, but the core of an ASA is using rigorous science and cost-benefit analyses in putting together a feasible plan that uses the best of watershed and waterbody management tools. An ASA uses:

- rigorous science in consideration of the physical, chemical, and biological characteristics of freshwaters to identify the direct and contributing causes of impairments, in this case eutrophication and cyano HABs

- cost-benefit analyses of waterbodies' designated uses, in this case drinking source water, and of all watershed and waterbody management tools

- an implementation strategy for drinking water protection should reduce the risks of adverse health effects from cyanotoxins in the near term at an affordable cost. If a strategy is not being effective enough, the ASA process is reiterated, and the strategy is adapted to produce a more effective strategy

4. A drinking water protection strategy should focus on preventing cyanobacteria from proliferating in source waters by using sustainable waterbody treatments to suppress cyanobacteria and remove or deactivate nutrients in the waterbody where they are highly concentrated and easy to get to. If cyanotoxins are not in the source water, they cannot be in the finished drinking water. It is much cheaper to combine technologies to treat source waters than it is to annually spend millions of dollars on removing cyanotoxins from drinking water using activated carbon, ultraviolet irradiation, or microfiltration. And none of these ensures that all cyanotoxins will be removed from drinking water.

5. There is currently a movement towards combining waterbody treatments to suppress cyanobacteria and remove or deactivate nutrients. Projects are being planned to assess the efficacy of combining water circulation to suppress cyanobacteria and synergize nutrient removal or deactivation by other technologies. For example, circulation and ultrasound guns can likely suppress cyanobacteria in even the most difficult waterbodies where shallow, weeded areas continually seed cyanobacteria into open

waters. And circulation increases nutrient uptake by plants on floating artificial wetlands, and growth of periphyton on curtains that transfer nutrients from the water column to higher trophic levels. Circulation can keep specialized micro-pellets suspended that stimulate blooms of diatoms that also transfer nutrients from the water column to higher trophic levels. A treatment system could also meter out flocculants and keep them suspended to capture and deactivate nutrients as they enter a waterbody from a stream.

6. EPA should contribute funds to the 3 NOAA HAB research grant programs as directed by Congress in last year's reauthorized and expanded HABHRCA law. These funds could support studies such as that just mentioned, and enable utilities to make better informed decisions about approaches to source water protection.

7. To assist states and utilities, EPA should revive the Section 314 grant program that provided money for waterbody treatments. EPA can encourage states to include waterbody management treatments in their watershed management plans that EPA approves. Currently, the Agency only encourages states to use 5% of Section 319 funds for waterbody treatments.

8. Finally, EPA should request line-item funding for funds to support the 3 NOAA HAB research-grant programs and the Section 319 waterbody treatment program.

I would also like to comment and commend the EPA for moving forward on addressing such an important public health risk and to emphasize the need to move expeditiously on creating regulatory requirements for testing and treating impaired water bodies. We feel the Adaptive Systems Approach will bring a science based assessment to the problem and provide an effective cost-beneficial solution to an issue that has been under addressed in the public arena.

Thank you for allowing me to provide input on this very important project. Both I and NALMS will gladly supply any assistance that we can.

Rebecca Gorney, NY State Department of Environmental Conservation, Department of Lake Management

NY requests assistance on question #3: What are the definitions of appropriate thresholds in variety of contexts like algal biomass in terms of determining bloom concentrations and bloom existence as well as nutrient concentration and how these can be used to prevent and mitigate blooms once occurring? Also need help understanding secondary health factors related to toxin removal in drinking water. Useful to better understand secondary health factors, such as disinfection by-products and what happens after toxins are removed.

Clayton Creager, CA North Coast Regional Water Quality Control Board

Comments are not from the drinking water division, but CA is dealing with nuisance levels of blue green algae and have a total maximum daily load (TMDL) for microcystins for rivers. We have compiled endpoint numbers for public health warning across states and found quite a bit of variance. Is this an artifact of risk calculation equations, or a difference in toxicity data available to the states doing the calculations? Has anyone looked at consistency both for drinking water and health advisories and why they vary? Drinking water systems draw from rivers that are seeing more frequent occurrence of nuisance levels in flowing water. Lower flows and higher temps and more abundant growth of filamentous algae as a substrate are three things to cause issues. There is little information to evaluate the implications of this apparently increasing trend. CA has found a high correlation of 10 ug/L chlorophyll-*a* as inflection point to where species composition dramatically shifted to cyanobacteria. That became our threshold as a biomass indicator.

Lynn Thorp, Clean Water Action

Clean Water Action recognizes the ongoing work by EPA and what Congress has asked them to do, but still thinks there is value in addressing info gaps in the contribution of different kinds of pollution and source water contamination to occurrence of cyanotoxins. Also information gaps on how reductions in pollutants will help in short and long terms with the jobs that utilities and EPA now have to take on. We think this is a really important and interesting example of the integration of CWA and SDWA which has been a priority both inside and outside the agency for some time. Consider these connections as part of way to respond to Congress. Agree about risk communication as a part of the response, and need to include non-drinking water impacts of HABs, both other human health and ecological.

Jessica Glowczewski, City of Akron, Ohio

(Comments appear here as they were submitted electronically)

If source water protection is going to be a focus on preventing algal blooms, someone needs to have authority to enforce and follow up on potential pollution situations which bridge gaps between townships, villages, cities, municipalities, counties and states. It doesn't have to be a utility managing the watershed they use, but there needs to be more cooperation and more enforcement and support from other jurisdictions and stakeholders, as well as enforceable penalties for pollution events.

Kim Ward, California State Water Resources Control Board

(Comments appear here as they were submitted electronically)

Helpful overview of the changes in agricultural production methods which seem to play an important role in changes observed in toxigenic blooms observed in the Great Lakes in recent decades: https://dl.sciencesocieties.org/files/publications/crops-and-soils/keeping-farm-based-p-out-of-lake-erie.pdf

"Source water protection" should include consideration of sediment/soil conditions in surface waterbodies, e.g., the possible occurrence of microcystins/other cyanotoxins in biological soil crusts (often found in arid environments) and as cyanotoxin-producing symbionts/endosymbionts in aquatic plants (e.g. cyanolichens). http://apsjournals.apsnet.org/doi/pdfplus/10.1094/MPMI-22-6-0695; http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3942747/; https://www.ncbi.nlm.nih.gov/pubmed/25752635; http://www.sciencedirect.com/science/article/pii/S0048969712001349

A key information gap concerns potential aerosol exposures in raw & finished water, e.g. research by CDC on microcystin aerosols, etc.:

Lyda Hakes, Alameda County Water District

(Submitted electronically)

1) More information is needed on the growth/death rates of harmful algal blooms and the half-life of the cyanotoxins (both extracellular and intracellular). Also, more information about what drives extracellular versus intracellular concentrations would be useful.

2) Consider regulating cyanotoxins (specifically microcystin) by grouping them as Total Trihalomethanes (TTHMs) and haloacetic acids (HAA5) are. This would better allow for the use of a quantitative instrument like Liquid Chromatography/Tandem Mass Spectrometry (LC/MS-MS) so that PWSs and regulators know exactly what is in the water and at what quantities.

3) Investigate further the nexus between climate change and the increased presence and persistence of HABs. Also, research on the relationship between drought conditions and HABs and cyanotoxins.

Amy Little, California State Water Resources Control Board

(Submitted electronically)

1) In the event of a public notification event due to a health advisory exceedance, what, if any, information should be communicated to hemodialysis centers.

2) There is literature to describe how toxins are distributed in cyanobacteria cells (intra- vs. extra-cellular) but this is likely changing throughout a bloom. If a public water system was faced with exceeding a health advisory, knowing how toxins are distributed during the exceedance would likely provide valuable information to the utility in order to target treatment optimization.

3) We have utilized fluorometers (when keeping cells intact is a treatment strategy) to evaluate cell lysis at different stages of treatment, UV254 instruments to evaluate jar tests, provided systematic technical assistance during bloom onsets on a case-by-case basis (e.g. shift intake to a lower position where the pH is lower, add acid to lower the pH, add a filter aid to improve filter performance), and we would like to explore the value of bench top charge analyzer to enhance coagulation/flocculation treatment performance.

4) We are very grateful for the steps the USEPA has taken thus far to provide comprehensive guidance and recommendations; as compiling this information was likely a tremendous task. In our opinion, expanding on satellite information to provide up-to-date information and/or predict when the blooms are toxic to govern efficient monitoring strategies would be of tremendous value.

5) Peter Moyle, a fisheries biologist in California, developed a ranking system to prioritize which dams should modify operations to significantly improve fishery habitat. This was the introduction of indexing ecological parameters as a means to rank where to target effort in order to get the most effective results. Many have expanded on this approach in nutrient loaded systems. In our opinion, developing a way to measure (and prioritize) the most effective efforts would be valuable.

Don Jensen, City of Highland Park, Illinois

(Submitted electronically)

As manager of a water utility blessed with Lake Michigan as a source, algal toxins are relatively low on my list of worries.

I am, however, concerned when the news accounts of toxic algal blooms in the Great Lakes alarm our residents.

Watershed risk assessment tools including indicators of risk (water temperature, sunlight hours, nutrient loading, dissolved organic carbon, total organic carbon etc.) and associated mapping products would be quite helpful in allaying those fears.

Of course, they would be most useful to water system managers in watersheds with higher risk of such blooms.

Darci L. Meese, WaterOne (Submitted electronically)

WaterOne

Setting the Standard for Utility Excellence

Water District No. 1 of Johnson County

October 16, 2015

Sent Via e-mail to foreman.katherine@epa.gov

Ms. Katherine Foreman
EPA

RE: Federal Cyanobacteria Management Strategy (Drinking Water Protection Act) Comments

Dear Ms. Foreman:

Background

WaterOne is an independent public water utility. We've been proudly serving the Johnson County, Kansas area since 1957. Every day, over 400,000 customers rely on WaterOne to provide fresh, clean water on demand. We can produce up to 200 million gallons per day using source water from both the Kansas River and the Missouri River.

Treat the Source - Nutrients

WaterOne agrees with the Association of Metropolitan Water Agencies (AMWA) that the long range strategy must include prevention of the nutrients from entering waterways including lakes, reservoirs, rivers, and streams. Agriculture must be engaged and non-point sources must be included in a nutrient control strategy to protect public health. WaterOne asks that EPA include nonpoint source nutrient reductions in the Federal Cyanobacteria Management Strategy (Drinking Water Protection Act).

The Whole View - Watershed Management

The Kansas River is fed from three federal reservoirs, Milford, Tuttle, and Perry, all which are controlled by the Corps of Engineers. In 2011, an algal bloom in Milford was released into the Kansas River causing taste and odor concerns along with health advisories on the river. WaterOne has the ability to switch sources and utilize the Missouri River however, others utilities using the Kansas River as a source water do not have this capability. This event caused WaterOne, the City of Olathe, the City of Topeka, the City of Lawrence, the Kansas Department of Health Environment (KDHE), the Kansas Water Office (KWO) and USGS to jointly study the both the Kansas River and removal treatment technologies through a WaterRF study. EPA has focused its efforts on lake and reservoir activity. These studies have brought to light that a flowing river can also be a source of cyanobacteria. Very little research has been conducted on rivers as a source for cyanobacteria.

WaterOne asks EPA to include the management of the watershed as a whole system and include flowing bodies of water as a potential source of cyanobacteria in its Federal Cyanobacteria Management Strategy (Drinking Water Protection Act).

10747 Renner Boulevard . Lenexa, Kansas 66219 . Tel: 913.895.5500 . www.waterone.org

Katherine Foreman
EPA
October 16, 2015

Confirming samples using LC/MS Testing

WaterOne has been using the ELISA method to conduct Mycrocystin LR testing since the summer of 2012 along with many other area laboratories. EPA focuses on this test method in its health advisory guidance. While we have proven that it is an effective method for determining the presence of the toxin, we believe there may be some conditions that affect the methods ability to accurately quantify the concentration, especially at levels near the specified detection limits of the test kits.

The manufacturer specified control for the ELISA method is acceptable within a 25% interval of the true value. Meaning a measured of value 0.200 micrograms per liter could be anywhere from 0.150 to 0.250 and still fall within the acceptable testing limits. We have noticed that extreme temperatures of samples and variations in incubation can have significant effect on the consistency of results. Additionally, we have seen a negative bias to testing when chemicals such as $FeCl2$, $AlSO4$, or $NaClo3-$ are present in the sample while the presence of CaO often results in a high positive bias.

Because all of these conditions and chemicals are common in drinking water treatment facilities and because the acceptable control limits of the testing are already pretty wide, we believe that this testing method may not be the best available technology for the accurate determination of Microcystin LR in drinking water. This is especially true when trying to determine values at or near the specified detection capability of the test which is also near the health advisory level of 0.3 micrograms per liter.

LC/MS methods are more precise, have a lower specified detection limit of 0.1ug/L, and the additional capability of determining values for 7 seven different variations of Microcystin. For determining Total Microcystin in samples there were also inconsistencies found with methods used for lysing the cells in the sample.

We are planning to begin evaluating the ELISA kits for the determination of Cylindrospermopsin in the near future but do not have any results at this time.

WaterOne asks that the LC/MS methods be used as confirming methods prior to the public notification for values at or near the health advisory limit and that EPA account for the manufacturer specified control of the ELISA LR test in its Federal Cyanobacteria Management Strategy (Drinking Water Protection Act) and health advisory guidance.

Sincerely,

Darci L. Meese
Deputy General Counsel

DLM/grl