EPA MOVEMENT TOWARD CYANOTOXIN REGULATION AND FRESHWATER MANAGEMENT POLICY CHANGE

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ABSTRACT

Cyanobacteria and highly potent cyanotoxins are a rapidly growing threat to human health and the sustainability of aquatic ecosystems worldwide. Cyanobacteria often form harmful algal blooms in nutrient enriched freshwaters. Freshwater management policy of the U.S. Environmental Protection Agency has focused on limiting the input of new nutrients to freshwaters for over four decades, but results have been disappointing. Although the watershed management program has successfully reduced the input of nutrients and other pollutants, the nonpoint source program has been much less successful. The Clean Water Act also calls for using waterbody treatments to help improve water quality, but that program was strongly deemphasized in the early 1990s. The increasing bloom incidence and recent major-bloom events appear to be moving the Agency toward both regulating cyanotoxins and improving freshwater management policy by reemphasizing the need for waterbody treatments, particularly to combat cyanobacteria. An adaptive, alternative approach to the traditional Total Maximum Daily Load approach appears to be best suited for improving water quality in many freshwaters. An Adaptive Systems Approach combines watershed and waterbody management tools based on cost-benefit analyses to implement feasible strategies to achieve realistic goals. The North American Lake Management Society believes that only an Adaptive Systems Approach to freshwater management can improve water quality as quickly and inexpensively as possible.

KEYWORDS

Freshwater, management, policy, harmful algal blooms, cyanobacteria, cyanotoxins, adaptive systems approach

INTRODUCTION

“Harmful algal blooms [HABs] are among America’s most serious and growing environmental challenges,” according to the Administrator of the U.S. Environmental Protection Agency (EPA, 2015). Cyanobacteria, the predominant HAB organism in freshwater, often produce highly potent cyanotoxins that are associated with multiple acute and chronic health effects. Nutrient enrichment, or eutrophication, is a primary driver of increasing freshwater HAB incidence in the U.S. and worldwide. Analyses of phytoplankton in sediment-core samples from northern hemisphere lakes indicate a rapid, disproportionate increase in cyanobacterial densities since ~1800, with a sharp upswing ~1945 (Taranu *et al.,* 2015). Results from using nonpoint source nutrient-input controls to protect and restore freshwaters are disappointing. EPA estimated that "at historical funding levels and waterbody restoration rates, it would take longer than 1,000 years to restore all the waterbodies that are now impaired by nonpoint source pollution," according to the Government Accountability Office (GAO, 2013).

The increasing HAB incidence and major events, such as the loss of drinking water use in Toledo for 3 days in 2014 and the record setting 2015 HAB along ~2/3 of the 1,000 mile-long Ohio River, appear to have prompted an EPA movement toward both the regulation of cyanotoxins and improved freshwater management policy.

EPA MOVEMENT TOWARD CYANOBACTERIA REGULATION

Regulatory Process

Regulatory determinations are made when data on toxin occurrence, health effects, and prevention, control, and mitigation methods are deemed sufficient. The EPA placed cyanobacteria and their toxins on the first Drinking Water Contaminant Candidate List (CCL) in 1998 for potential regulatory determination. The Agency prioritized cyanotoxins in 2001 based on limited occurrence and toxicity data. Microcystins, cylindrospermopsin, and anatoxin-a received high priority designations, and mid-to-high priority was assigned to anatoxins-a(s) and saxitoxin. The high priority cyanotoxins remain on the current draft CCL4 list (EPA, CCL4).

Occurrence

There is no national database on HAB occurrence in source, drinking, or recreational waters. The EPA placed the high priority cyanotoxins on the first Unregulated Contaminant Monitoring Rule (UCMR) list in 2001, as well as on the UCMR2 and 3 lists, but none were selected for monitoring. However, 10 of the 30 contaminants selected for monitoring by public water systems in the proposed UCMR4 are cyanotoxins/groups (EPA, UCMR4). Utilities will be required to monitor cyanotoxins between 2018 and 2020 if the rule is finalized. The EPA also teamed with the National Aeronautics and Space Administration, the National Oceanographic and Atmospheric Administration, and the United States Geological Survey in 2015 to develop a satellite-based system for widespread surveillance of cyanobacteria (NASA webpage).

Health Effects

The EPA developed draft toxicological reviews for the high priority cyanotoxins in 2006. The reviews describe available dose-response data and their adequacy for developing guideline daily-intake values that are considered unlikely to cause adverse health effects. Several draft references doses for oral exposure were developed (reviewed in Hudnell, 2010 Toxicon). The Agency issued 10-day drinking water health advisory guideline levels for microcystins and cylindrospermopsin in 2015. Microcystin levels are 0.3 ug/L for pre-school age children and 0.7 ug/L for older children and adults. Comparable levels for cylindrospermopsin are 1.6 and 3.0 ug/L, respectively. The EPA published health effects support documents for all three priority cyanotoxins, but data were deemed insufficient to set a health advisory level for anatoxin-a (EPA, Health Advisories). The Agency also announced its intention to set guideline recreational-water criteria levels in 2015, and held a webinar in 2016 to discuss progress and receive public comment (EPA, Next Steps).

The EPA's activities concerning the prevention, control, and mitigation of freshwater HABs are discussed in the following section.

EPA MOVEMENT TOWARD FRESHWATER MANAGEMENT POLICY CHANGE

Background

The Clean Water Act legislation (CWA history) established three pillars of freshwater management to restore and protect freshwater designated uses, the: 1) Section 314 (1972) Clean Lakes program for restoring publicly-owned lakes and reservoirs using treatments within waterbodies; 2) Section 402 (1972) technology-based National Pollution Discharge Elimination System (NPDES) program regulating point-source pollutant discharges, and; 3) Section 319 (1987) Nonpoint-Source Management program to prevent pollutant runoff using Best Management Practices (BMPs). Together these programs form a complementary approach to the protection and restoration of Section 303(d) impaired freshwaters. The Clean Lakes program prescribes treatments within impaired waterbodies (waterbody management, WBM) that reduce stress on impaired biological, chemical, and physical processes to help enable recovery. The point- and nonpoint-source programs (watershed management, WSM) use technologies to meet NPDES limits, and BMPs to reduce pollutant runoff. Thus, the CWA's three pillars of protection and restoration provide "therapeutic treatments" with WBM technological, biological and chemical interventions, and "preventive medicine" with WSM technologies and BMPs to reduce new pollutant inputs.

However, the EPA deemphasized or virtually eliminated WBM from policy in the early 1990s to focus on WSM and the reduction of new pollutant inputs. This decision was not based on scientific or economic analyses. It was based on the mistaken belief that focusing on input reductions alone would facilitate recovery in a timely and cost-effective manner. The increasing freshwater impairment observed since that time led the former EPA Assistant Administrator for the Office of Water to regret his decision (Benjamin Grumbles, personal communication).

The WSM point-source program successfully reduced national pollutant inputs from pipes and other pathways to 5-10% of total input by 1984 (Gianessi and Peskin, 1984). Point source inputs continued to decline thereafter, as increasingly lower NPDES limits were required. Directing focus to the nonpoint-source program aimed to reduce the other

90-95% of inputs. States followed EPA policy in developing and implementing over 69,000 Total Maximum Daily Loads (TMDLs) to reduce nutrient and other pollutant inputs. However, many nonpoint-source BMPs proved to be difficult and expensive to implement over large areas, lacked cost-benefit analyses, and were only marginally effective. Furthermore, as shown in Figures 1 and 2, the program only addressed nonagricultural surface runoff, not pollutant inputs to water through atmospheric deposition, groundwater flow, or internal loading, a primary source of phosphorus in many freshwaters (Hudnell, 2015 Water Quality Technology Conference).

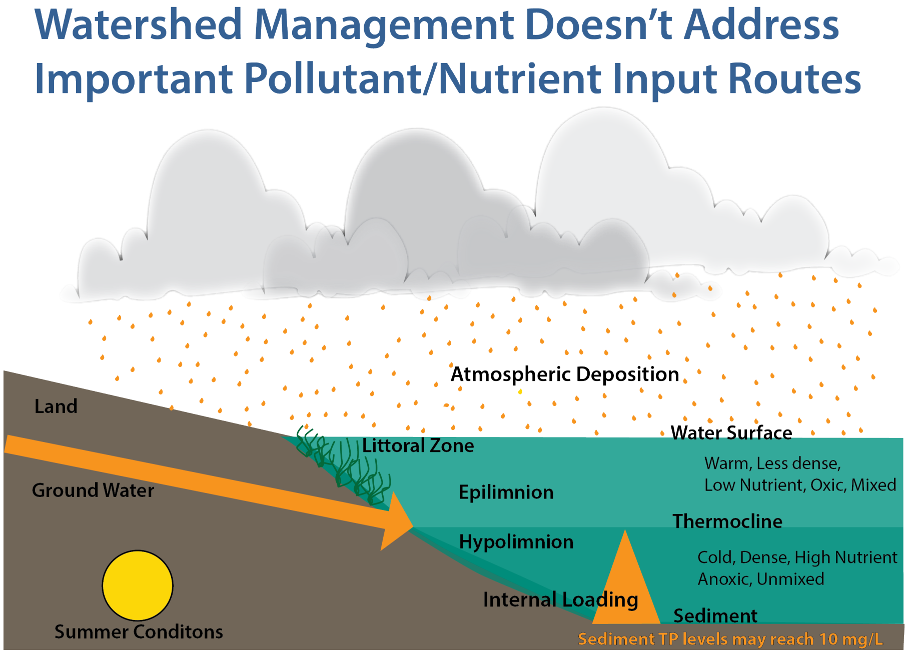


Figure 1. Current policy for restoring impaired freshwaters addresses only the reduction of new pollutant inputs from point-sources and nonpoint-source surface runoff through the watershed management program. It does not address the often-large pollutant inputs through atmospheric deposition and groundwater flow. Also unaddressed is the huge load of "legacy" pollutants such as phosphorus that accumulated over decades and cycle between sediment and the water column.

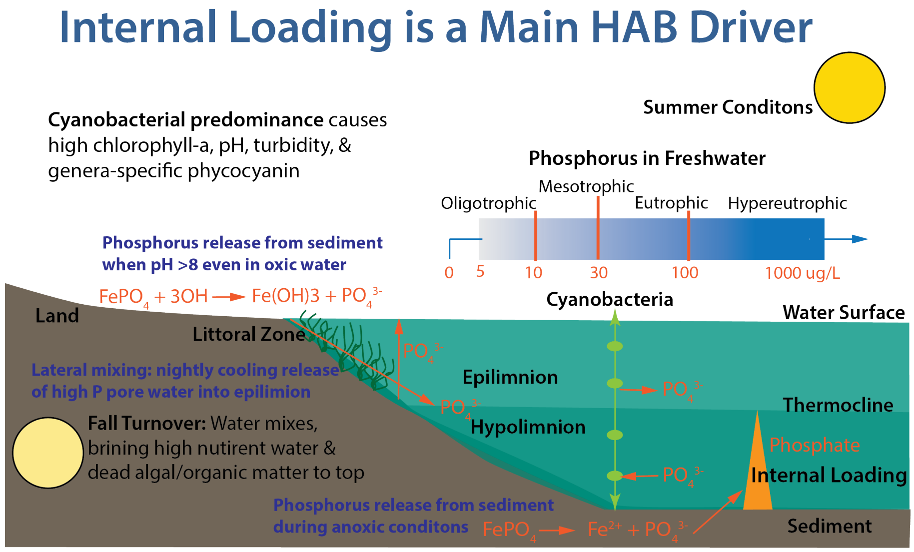


Figure 2. First, phosphorus moves from sediment into the water column during anoxic conditions. Second, phosphate releases from iron when pH > 8 even during oxic conditions. Third, when air above the water surface is cooler than the surface water, thin surface layers cool and become denser, and then fall through the water column while deeper, warmer layers rise. This process causes both lateral mixing and "fall turnover."

Current Policy

Current policy centers on TMDLs and WSM practices to reduce new pollutant input to freshwaters. As shown in Figure 3, the process begins with the development of water quality standards that consider a waterbody's designated uses in identifying water quality criteria for protecting health and the environment. Quantities and sources of impairment-causing pollutants in the watershed are assessed in developing TMDLs. TMDLs are maximum amounts of pollutant inputs to freshwaters considered to be below levels that will cause impairments. Rules that may require both point- and nonpoint-source input reductions to achieve TMDLs formalize implementation of WSM strategies. Long-term monitoring and assessments evaluate the effectiveness of the rules. When standards are not met, the typical response is to wait in anticipation that the standards will eventually be met. Rarely are strategies reassessed and altered.

The results from applying current policy are disappointing in that freshwater quality continued to decline to the point that approximately 53% of assessed river and stream miles and 68% of assessed lake, reservoir, and pond acres are now impaired (EPA freshwater impairment). A 2010 version of the same EPA database indicated those figures were 44% and 64%, respectively (Hudnell, 2010 Peer-reviewed: Within Water-body Management). Phosphorus pollution provides a striking example. Rivers and streams with excessive phosphorus, usually the limiting nutrient for cyanobacteria, increased from 47% to 66% between 2004 and 2009 (EPA National River and Stream Assessment). Much of the increase may be due to changes in agricultural practices that increased runoff and are exempt from CWA regulations.

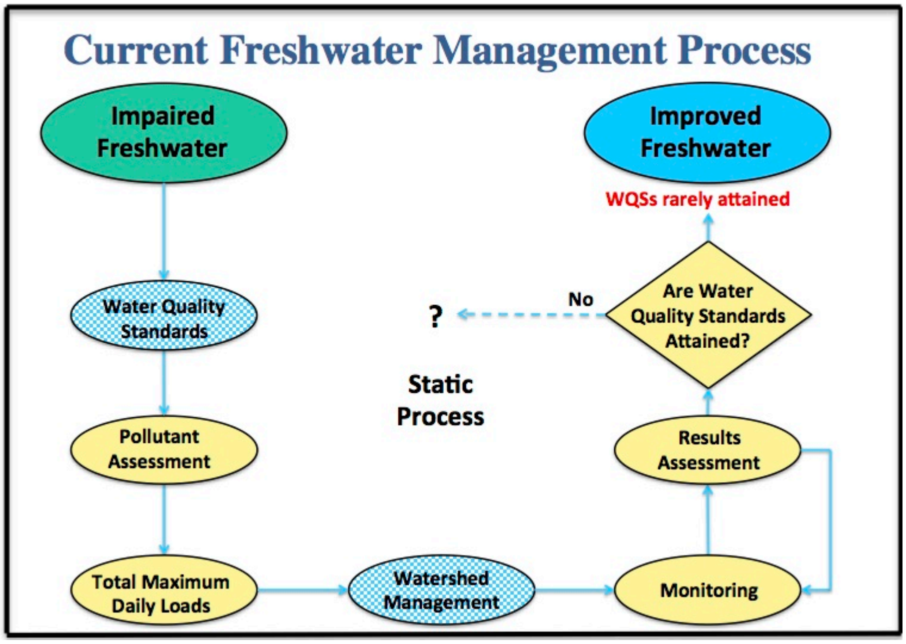


Figure 3. This diagram depicts the current EPA process for developing, implementing, and assessing WSM-based strategies to restore impaired freshwaters. Waterbody management was removed from the process in the early 1990s. Watershed management rarely achieves water quality standards, and strategy is rarely adapted.

Current Policy Results

The recovery of impaired freshwaters has been exceedingly slow. The EPA estimates that only about 8% of more than 39,000 waters listed as impaired prior to 2003 (to give time for recovery) now attain water quality standards (EPA Office of Water, personal communication). Most are small waterbodies, have small watersheds, or were previously dominated by point-source nutrient inputs (EPA, nonpoint source success stories). No impaired waterbody of at least 1,000 acres in size with at least 90% of nutrient input from nonpoint sources has ever attained water quality standards (EPA Office of Water and all 10 EPA Regional Offices, personal communications).

Cyanobacteria are commonly found in nutrient over-enriched waters. The EPA estimated in 1972 that 10-20% of lakes and reservoirs were nutrient over-enriched or eutrophic (Gakstatter and Maloney, 1975; USGS, Review of Phosphorus). The Agency's National Lakes Assessment of 2007 indicate that about 58%, 50%, 46%, and 40% are now eutrophic or hypereutrophic based on Secchi depths, and chlorophyll-a, phosphorus, and nitrogen concentrations, respectively (EPA, National Lakes Assessment). The National Lakes Assessment of cyanobacterial cell densities and chlorophyll-a concentrations indicates that health risk from exposure to cyanotoxins is moderate to high in 27-41% of lakes and reservoirs, respectively, when evaluated relative to the World Health Organization's guidelines for cyanotoxin exposure in recreational waters (WHO guidelines). The data indicated that risks are higher in reservoirs than natural lakes. The cyanotoxin class of microcystins was detected in about 30% of the sampled waterbodies, but only about 0.9% met or exceeded the WHO guideline level indicating moderate to high health risk (EPA, National Lakes Assessment). The presence of other cyanotoxins such as anatoxins, cylindrospermopsins, saxitoxins, nodularins, and β-N-methylamino-L-alanine (a.k.a. BMAA) was not assessed. However, the U.S. Geological Survey (USGS) reported that anatoxin-a, saxitoxins, and cylindorspermopsin were present in 15%, 8%, and 5% of stored samples from the 2007 National Lakes Assessment, respectively (Lofton, 2012). The USGS recently reported that microcystins were found in 39% of 75 wadeable streams sampled in the southeastern U.S. None of the microcystin levels were above the WHO guideline for moderate-to-high risk of adverse health effects in recreational waters (USGS 2016). The USGS previously reported that cyanobacteria potentially capable of producing microcystins were found in 74% of headwater streams in four southeastern states.

These trends in freshwater quality, including source waters that supply drinking water to about 80% of the U.S. population, indicate the need for improved freshwater management policy.

Improving Policy

The EPA appears to be moving toward reinstating WBM into freshwater management policy using an Adaptive Systems Approach. The Agency in December 2013 released the document, *A Long-Term Vision for Assessment, Restoration, and Protection under the Clean Water Act Section 303(d) Program* (Webpage to PDF). The long-term vision calls for the following actions by 2018.

- States to "compile an inventory of current and potential types of State approaches and rationales for pursuing near-term, **alternative approaches** [bold added] to the traditional TMDL process."
- "EPA and States collaborate to identify factors or tools to aid States in deciding to pursue a TMDL or a **non-TMDL alternative approach** [bold added]."
- "EPA and States compile a catalogue of good examples for each type of TMDL alternative approach."
- "EPA and States collaborate on a workshop and create a blueprint communicating how **adaptive management** [bold added] can be applied during the implementation of TMDL and non-TMDL approaches to achieve water quality standards."
- "EPA and States develop a reporting method for tracking non-TMDL approaches employed and their environmental results."

Subsequent actions include the following.

- May 2014 – The Agency sponsored a webinar entitled, *A Systems Approach to Freshwater Management: Waterbody Treatments* (EPA Webpage to PDF).

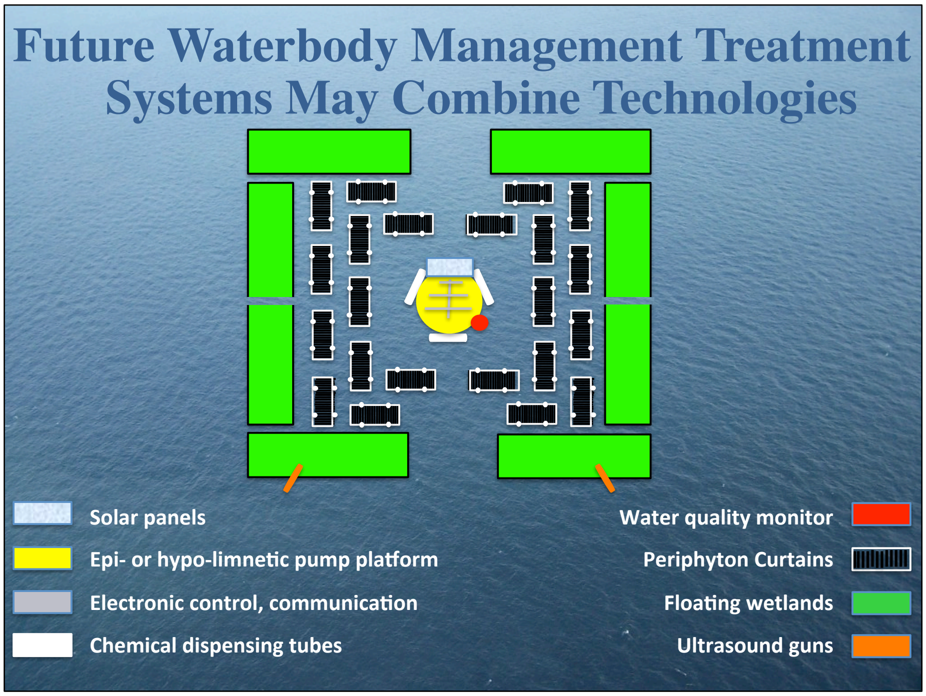
- September 2014 – The Agency posted a webpage describing waterbody treatments entitled, *Nutrient Policy and Data: Controls & Treatments* (EPA Webpage)
- June 2015 – The Agency issued the document, *Recommendations for Public Water Systems to Manage Cyanotoxins in Drinking Water*. The recommendations include monitoring for cyanotoxins, waterbody treatments, and other management strategies (EPA Webpage to PDF).
- September 2015 –The Agency held a webinar to get public input on developing a strategic plan for assessing and managing risks associated with algal toxins in drinking water in response to Congressional Act H.R. 212.
- November 2015 – The Agency submitted to Congress the document, *Algal Toxin Risk Assessment and Management Strategic Plan for Drinking Water*. The strategic plan discusses "various prevention and treatment strategies and approaches at the source, through out the treatment train, and in the finished water storage and distribution system for a PWS," as well as ongoing activities (EPA Webpage to PDF).

These actions apparently indicate that EPA freshwater management policy is moving back toward complementing WSM with WBM, particularly for the prevention, control, and mitigation of freshwater HABs. The combination of WSM and WBM in a non-TMDL alternative approach that is adaptable provides the components needed to form an Adaptive Systems Approach (ASA) to freshwater management.

AN ADAPTIVE SYSTEMS APPROACH

The North American Lake Management Society (NALMS) believes that full implementation of the CWA with an ASA to freshwater management will protect and restore freshwaters quicker and less expensively than current policy. An ASA uses both WSM and WBM tools that are selected based on cost-benefit analyses. Ecologically sustainable WBM treatments or systems (Figure 4) are needed to suppress cyanobacteria, remove or deactivate nutrients from inlets and lakes where they are concentrated and accessible, increase dissolved oxygen levels in the hypolimnion, deactivate pathogens, degrade toxic substances, and establish a balanced ecological community that can help enhance water quality.

Almost 12,000 acre Lake Houston exemplifies the use of a WBM technology in Texas. Twenty solar-powered, long-distance water circulators were deployed in 600 acres surrounding the water intake pipe of the Northeast Water Purification Plant in 2006. The project objectives were to suppress cyanobacteria with epilimnetic circulation to reduce levels of the taste and odor causing compounds 2-methylisoboneol and geosmin, and to increase dissolved oxygen levels in the hypolimnion to oxidize and precipitate iron and manganese, as well as prevent their release from sediment during hypoxic periods. Both objectives were achieved and the utility has reduced expenditures on activated carbon by about $500,000 per year since installation (other examples reviewed in Hudnell, 2010 Peer-reviewed: Harmful Algae).



Future Waterbody Management Treatment Systems May Combine Technologies

▨ Solar panels
🟨 Epi- or hypo-limnetic pump platform
▨ Electronic control, communication
☐ Chemical dispensing tubes

Water quality monitor 🟥
Periphyton Curtains ▥
Floating wetlands 🟩
Ultrasound guns 🟧

Figure 4. This diagram depicts a potential WBM treatment system designed to suppress cyanobacteria, dispense compounds to improve water quality, transfer nutrients up trophic levels, capture nutrients for removal, and collect and transfer data.

An ASA process, as depicted in Figure 5, begins with comprehensive scientific analyses of the greatest risks to health and the environment, and of the direct and contributing causes of impairments posing those risks. Determining the desired future condition entails analyses of the benefits of designated uses, the technological feasibility of reducing risks to acceptable levels, and designating water quality standards that will attain those risk levels in a specific waterbody. Cost-benefit analyses of every viable WSM and WBM tool characterize options for improving water quality across economic, degree-of-impact, and time-to-impact scales. A set of tools is selected that optimizes attainment of the water quality standards. A water quality strategy is implemented only if the standards are both technologically and economically feasible. If the strategy cannot attain the standards, or the cost is prohibitive, the above process is repeated to determine whether or not all designated uses are warranted, scientific or technological advancements can improve strategies, or acceptable risk levels can be achieved with lower standards. A feasible strategy and associated rules are implemented to achieve realistic goals. Progress is monitored to determine whether the goals are being achieved or the strategy should be adapted to improve progress.

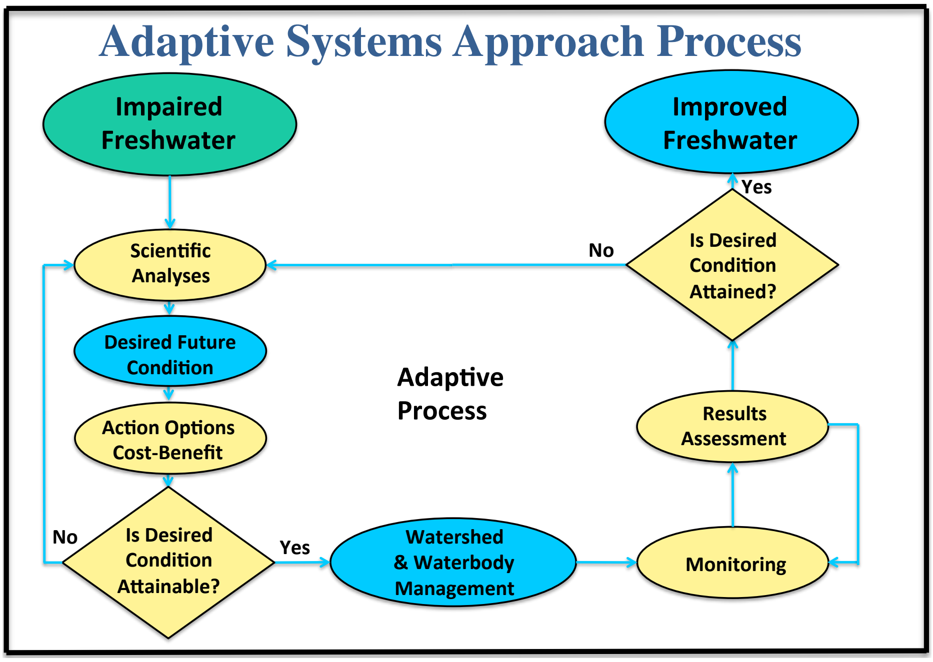


Figure 5. This diagram depicts an Adaptive Systems Approach to Freshwater Management that fully implements the Clean Water Act by complementing watershed management with waterbody management. An ASA takes a holistic view of the impaired waterbody and watershed as a single system. Rigorous scientific assessments identify the direct and contributing causes of impairment. Interventions to improve water quality can be made anywhere within the system. The desired water-quality condition and the selection of interventions to improve water quality are determined using cost-benefit analyses of designated uses and interventions. A feasible strategy is implemented to achieve realistic goals, and can be adapted over time if needed to improve progress.

NALMS position is that an Adaptive Systems Approach to Freshwater Management is needed to reverse the trend of increasing freshwater HAB incidence and freshwater impairment, and to improve water quality in the near term at an affordable cost.

CONCLUSION

The EPA is taking important steps toward obtaining information concerning cyanotoxin occurrence, health effects, and prevention, control, and mitigation methods. The Agency: 1) proposed that cyanotoxin occurrence data be obtained through the UCMR4 process; 2) issued health advisory levels for 2 of 3 high priority cyanotoxins in drinking water; and 3) issued a strategic plan for further assessing cyanotoxin risks and managing cyanotoxin levels in drinking water. This body of information will enable EPA to make regulatory determinations for cyanotoxins. The Administrator's statement that "harmful algal blooms [HABs] are among America's most serious and growing environmental challenges," indicates that EPA will likely promulgate regulations for cyanotoxin levels in drinking water, and issue guidelines for levels posing risks in recreational waters.

The EPA also is taking important steps toward improved freshwater management policy. The Agency: 1) issued a long-term vision for freshwater management that indicates the need in some cases for adaptive-management, alternative approaches to the traditional TMDL process for protecting and restoring freshwaters; 2) held a webinar, developed a webpage and issued recommendations for using WBM technologies to prevent and control cyanobacterial HABs is source waters; and 3) issued a strategic plan that includes WBM treatments. This body of information and the Agency's finding that "at historical funding levels and waterbody restoration rates, it would take longer than 1,000 years to restore all the waterbodies that are now impaired by nonpoint source pollution," indicate that EPA will improve freshwater management policy by providing states the flexibility to choose between using a traditional TMDL process or an ASA process when developing strategies to address impaired freshwaters.

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