# EPA Commentary

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## Grand Lake St. Marys, Ohio – The Case for Source Water Protection: Nutrients and Algae Blooms

### Introduction

The U.S. Environmental Protection Agency's (EPA's) Region 5 office, which includes the states of Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin, is home to more than 1,650 public water systems (PWSs) that draw drinking water from surface water sources, such as lakes and streams, including the Great Lakes (see Figure 1 for definitions). These surface water systems serve drinking water to more than 28 million people; the more than 44,000 PWSs drawing ground water in the region serve more than 19 million people. Only about 3.6 percent of the PWSs in the region draw from surface water sources, but the majority of the population served by PWSs in the region – almost 60 percent – are drinking treated surface water (EPA 2011). (See Table 1 for this information categorized by state.)

Of the community water systems (CWSs) treating surface water in the region, which comprise more than 80 percent of the PWSs using surface water, more than 350 (almost 30 percent) are drawing from only inland lakes and reservoirs (not including the Great Lakes), and more than 200 of these CWSs (less than 20 percent) are drawing only from the region's streams and rivers. More than 100 of these surface water-drawing CWSs (less than 10 percent) in the region draw from both inland lakes/reservoirs and rivers. More than 600 (about 45 percent) of the surface water CWSs in the region are treating water from the Great Lakes, which includes those systems that use both water from the Great Lakes and other surface water sources. (This information was compiled from multiple state and Region 5 drinking water data sources.)

A *public water system (PWS)* is a system for the provision to the public of water for human consumption through pipes or other constructed conveyances, if such system has at least fifteen service connections or regularly serves at least twenty-five individuals. Public water systems are regulated by the Safe Drinking Water Act, whereas private wells are not.

A *community water system (CWS)* is a PWS that supplies drinking water to the same population year-round.

*Source water protection (SWP)* refers to the protection of drinking water sources drawn from both surface and ground water. SWP areas include locations that drain to surface water used for drinking water, including lakes and rivers, as well as areas near drinking water intakes in lakes and rivers. SWP areas also include areas that recharge ground water used for drinking water, which are often referred to wellhead protection (WHP) areas.

*Source water assessments* are developed by states and are required by the Safe Drinking Water Act for each public water system. Assessments include a delineation of the area around a public water supply well or intake that could cause contamination, as well as an inventory of potential sources of contamination within that area. Assessments also discuss the susceptibility of the water supply to contamination.

A *source water protection plan* (SWPP) is based on a source water assessment and outlines activities for protecting drinking water sources from contamination.

*Figure 1. Definitions of drinking water and source water protection program terms.*

In 1996, the Safe Drinking Water Act (SDWA) was amended, and Section 1453 was added, providing states with federal funding to complete source water assessments for their PWSs. At that time, the existing wellhead protection program was extended to include surface water systems and was renamed source water assessment and protection. The 1996 Amendment created a new requirement that PWSs assess the susceptibility of the drinking water supply to the potential pollutant sources in its watershed. It is the intent of Congress that PWSs use their source water assessments to develop a source water protection plan (SWPP). Even though SDWA requires drinking water to be treated to meet health standards, the two main reasons for source water protection are: treatment sometimes fails, and treatment is expensive. The cleaner the source water, the less the water systems – and their customers – have to pay. Clean, abundant source water is important to everyone and is a major selling point for communities interested in attracting investment.

**Table 1**. Number of PWSs and Population Served by Ground and Surface Water in Region 5.

| | *Ground water* | | *Surface water* | |
|---|---|---|---|---|
| *State* | *Number of systems* | *Population served* | *Number of systems* | *Population served* |
| Illinois | 5,078 | 3,629,187 | 753 | 8,974,955 |
| Indiana | 4,267 | 2,916,810 | 119 | 2,424,533 |
| Michigan | 11,646 | 3,112,738 | 308 | 5,908,812 |
| Minnesota | 7,236 | 3,464,927 | 121 | 1,410,218 |
| Ohio | 4,792 | 3,458,712 | 322 | 7,783,314 |
| Wisconsin | 11,633 | 3,079,870 | 55 | 1,853,075 |
| **Total** | **44,652** | **19,662,244** | **1,678** | **28,354,907** |

*Source:* EPA 2011.

## Drinking Water Supply Concerns

Surface water sources are generally considered to be more susceptible than ground water to contamination, such as from nitrogen and phosphorus pollution. Nutrient contamination of "source waters" is of particular concern to human health because these water bodies serve as drinking water sources. For example, nitrate concentrations in drinking water above the regulated drinking water standard, known as the maximum contaminant level or MCL, is a concern because it has been linked to health effects such as methemoglobinemia – a condition involving a decrease in the ability of red blood cells to carry oxygen – which can lead to death in infants (NITG 2009). Excessive levels of nutrients have been identified as a contributor to the increase in harmful algal blooms (HABs) in freshwater; other potential causes include overfishing, hydrology changes, and non-native species introductions (Jewett et al. 2007). Gastrointestinal problems, liver damage, neurological effects, and even death have resulted from drinking water with toxins produced by HABs (State-EPA NITG 2009). Cyanotoxins, the toxins sometimes produced by cyanobacteria, which is the most common source of HABs in fresh water systems (Lopez et al. 2008), can potentially bioaccumulate in food chains (WHOI 2008). The health effects associated with chronic exposure to low doses of cyanobacteria are not known (Lopez et al. 2008).

EPA's Contaminant Candidate List (CCL), is a list of contaminants currently unregulated under the national primary drinking water regulations that are either known or expected to be present in PWSs. The CCL 3 includes three cyanotoxins, including anatoxin-a, microcystin-LR, and cylindrospermopsin, and EPA is currently evaluating the contaminants on the list to identify those that have enough information to determine whether to regulate them at PWSs.

Researchers are finding that preventing nitrogen from entering surface water may be as important as reducing phosphorus to reducing HABs. Excess nitrogen and phosphorus and the resulting algal blooms in drinking water sources can pose significant costs on PWS customers. PWSs often need to add granular or powdered activated carbon to address taste and odor issues that can be associated with HABs, such as those created by cyanobacteria (Graham et al. 2010). In addition, some surface water PWSs are purchasing equipment to monitor for and treat the toxins associated with HABs. Algal mats can pose infrastructure problems at drinking water intakes and hydroelectric facilities (Lopez et al. 2008). Excess algae also produce precursors to carcinogenic and toxic disinfection by-products (DBPs), including trihalomethanes, haloacetic acids, bromate, and chlorite. These DBPs have been associated with cancer, reproductive problems, and liver, kidney, and neurological damage (NITG 2009). DBPs are formed when disinfectants used in water treatment plants (e.g., chlorine) react with natural organic matter, such as decaying vegetation or algae, present in the source water. In addition, certain contaminants often co-occur with sources of nutrients, including pathogens, anthropogenic chemicals (e.g., pesticides), livestock medicines, and other emerging contaminants.

Potentially harmful algal blooms have been found in at all six states in Region 5, and all six states are assessing at least some of their water bodies for algae impairments (Figure 2). States list surface water impairments in their integrated reports – reports that combine several reporting requirements under the Clean Water Act – and data for the region indicate that about 170 inland lakes and reservoirs and more than 50 streams and rivers are listed as impaired for algae. These data are from the 2008 reporting cycle for Indiana, Michigan, Minnesota, and Ohio; and from the 2004 reporting cycle for Illinois and Wisconsin. Some streams and rivers have multiple "segments" listed as impaired, but the entire stream or river is not necessarily considered impaired; further, not all lakes and streams are assessed.

A national lake assessment (NLA) study conducted in 2007 by EPA and state and tribal partners analyzed water quality for the cyanotoxin microcystin, which is produced by the cyanobacteria *Microcystis*, in randomly selected lakes. Microcystin was found in one third of the sampled lakes and at "levels of concern" in one percent of lakes. The next NLA is scheduled for summer of 2012.

## Grand Lake St. Marys

The 2007 NLA study detected microcystin in more than 36 percent of the 19 Ohio lakes sampled, and the highest amount occurred at Grand Lake St. Marys (GLSM). GLSM is Ohio's largest inland lake occupying 21 square miles (nearly 13,000 surface acres) in Mercer and Auglaize counties in west-central Ohio. The Grand Lake Watershed, at 54,000 acres (84 square miles), is quite small when compared to the surface acreage of the lake itself (12,680 acres or about 20 square miles). The lake is rather shallow, averaging only five to seven feet deep, and was hand dug in 1837 as a feeder supply reservoir for the Miami & Ohio Canal. GLSM is the public drinking water supply for the city of Celina. Celina borders the lake on its northwest shoreline, and the village of St.

*Figure 2. Grand Lakes St. Marys transparency monitoring using a Secchi disk on October 6, 2010.*

Marys is located on the eastern shore of the lake. There is no SWPP for Celina's PWS. GLSM is home to a large state park and has a large seasonal and year-round population living along its shores. The Ohio Department of Natural Resources (Ohio DNR) State Park Windy Point completed a "Non-Municipal Public Water Systems Drinking Water Source Protection Checklist" in 2006.

In addition to the microcystin, the lake is highly nutrient enriched (hyper-eutrophic) as a result of agricultural nutrient-rich runoff, failing home sewage systems, internal nutrient loading, and other nonpoint sources of nutrient pollution. High nutrient inputs combined with the shallow nature of the lake contribute to a severely hyper-eutrophic condition. *Hyper-eutrophy* is characterized by a phosphorus concentration in excess of 100 micrograms per liter (µg/L). The excessive levels of phosphorus results in excess phytoplantonic production of chlorophyll-*a*. The phosphorus concentration levels within the lake regularly exceed 200 µg/L, and summer months typically are greeted with large blooms of blue-green algae and widely varying levels of dissolved oxygen, resulting in frequent fish kills.

In follow-up to the 2007 NLA study, the Ohio Environmental Protection Agency (Ohio EPA) sampled GLSM for microcystin in May 2009. The concentration was four times the World Health Organization's (WHO's) threshold for recreation. The WHO provisional guideline for low-risk recreational contact with microcystin is less than 20 parts per billion. The 2009 sampling showed levels so high that signs were posted advising people to avoid contact with the water. In 2010, a severe bloom of the blue-green alga, *Aphanizomenon gracile,* prompted recreational, human health, and fish consumption advisories to be placed on Grand Lake St. Marys (Gibson 2011). The 2010 algae were worse than 2009, forming a blue-green scum with a foul odor. Dead fish washed up on the shoreline. Twenty-three cases of human illnesses and dog deaths potentially related to the algal toxins were reported. The City of Celina PWS began testing their finished water for microcystin in May 2009 and has not had any detections of the toxin (ODH et al. 2011). As of October 2010, the estimated total costs the PWS had incurred associated with treating the nutrient pollution from Grand Lake St. Mary's, including treatment installation, toxic algae testing set-up, and estimated total O&M was $12,388,700, of which $3,381,200 was total O&M to date. This figure does not account for the alum, lime, and sludge costs associated with the high organic loads the PWS receives (Sudman 2010).

For those whose livelihoods depend on the lake and its tourism, the environmental upheaval was also an economic calamity. Declining water quality and resulting public health advisories during periods of harmful algal blooms have had drastic impacts on the area's economy. Tourism and recreation within the GLSM area accounted for as much as $150 million in annual economic activity prior to 2009. Three years of algal blooms and public health advisories, including last summer when boating and other uses were strongly discouraged to use the lake (Figure 3), have shrunk water-based recreation to a small percentage of what it once was. Several marinas and boat dealers have closed and other small businesses around the lake have either closed or witnessed substantial reduction in revenues in the area of $35 to $45 million. Park revenue is down approximately $250,000.

Grand Lake St. Marys has six primary tributaries flowing into the lake: Coldwater Creek, Beaver Creek, Prairie Creek, Big Chickasaw Creek, Little Chickasaw Creek, and Barnes Creek. Nutrient loadings from tributaries, (particularly phosphorus) are exerting the most negative impact on the lake. Phosphorus levels during runoff events were then (and still are) among the consistently highest levels in the state.

Studies between 2006 and 2008 documented high magnitude nonpoint causes of impairment including agricultural management, hydromodification (channelization), and habitat alteration (riparian tree removal), silt, sediments, nutrients. Reducing phosphorus levels – both coming into the lake from external sources and already residing and circulating within the lake – is critical to reducing harmful algal blooms, improving water quality, and restoring the local economy.

GLSM is one of the most heavily studied watersheds in Ohio (Figure 4). As early as the mid-'70s, when the lake was examined as part of EPA's national eutrophication study (EPA 1975), researchers have been trying to identify factors contributing to ongoing water quality issues in the lake. In 1981, the U.S. Army Corps of Engineers identified livestock nutrient management concerns as a major contributor to problems associated with algae blooms in GLSM. Agriculture is the predominant land use within the watershed (more than 90 percent) with two-thirds of the farms (300 of 450) engaged in livestock production (Hoorman et al. 2008). The intensity has increased dramatically – for example, in Mercer County. The density of livestock operations has more than doubled from


*Figure 3. West Beach recreational restrictions imposed on Grand Lake St. Marys users on June 23, 2010.*

1987 to 2007 with more than 8 million poultry units, 273,000 hogs, and 80,000 cattle. Combined with a human population of 43,000, Mercer County produces phosphorus waste at a daily rate that is consistent with what would be the fourth most densely populated county in Ohio (Gibson 2011). It is important to note, every plan written in the past 40 years has identified livestock-based nutrient management as needed to help address GLSM water quality problems. The cause is clear – the solutions, extremely challenging.

The May 2009 algae bloom was a call to action. A collaboration of the Ohio Departments of EPA, Health, Agriculture, and Natural Resources, as well as Mercer and Auglaize Soil and Water Conservation Districts and the U.S. Department of Agriculture's Natural Resources Conservation Service (USDA-NRCS) developed a water quality improvement plan entitled, "Grand Lake St. Marys & Its Watershed: Water Quality Improvement Initiatives." This plan included a variety of measures above and beyond those found in previous plans. This plan included activities focused on reducing the influence of internal loadings of phosphorus within the lake sediments, as well as watershed nutrient management and source reduction activities. The approach involved assessing what watershed controls could be implemented and then estimating what the impact would be to the lake.

During the fall of 2009, EPA's Region 5 provided Ohio EPA with technical services to develop a strategy to move GLSM from a hyper-eutrophic to a eutrophic condition based on the Clean Lakes Program approach. In July 2010, Tetra Tech, Inc. completed for EPA a report titled: "Recommended Actions for Grand Lake St. Marys, Ohio," which served as the first step in the development of a comprehensive plan for GLSM. Ohio EPA supplied the leadership and the plan framework to begin implementing in-lake management measures, such as treatment with aluminum sulfate to inactivate internal nutrients; near-lake activities, such as the establishment of wetlands and treatment trains at the confluences of tributaries to GLSM; and finally, a suite of specific recommendations needed to reduce the external nutrient loadings from the watershed. Tetra Tech is completing further water quality studies to fine-tune the 2009 plan.

In response to the 2010 bloom (Figure 5), the state departments of Natural Resources, Health and Agriculture, as well as the Ohio EPA, worked closely with then-Governor Ted Strickland's staff to develop an "immediate action plan" on July 30, 2010 for the lake. This plan differentiated needed actions for dealing with internal loading of nutrients within the lake itself and external nutrient loads coming from the watershed. In addition to identifying recommendations for "immediate actions" that could be undertaken, the plan also included funding to accelerate implementation of in-lake management efforts. Actions recommended in this plan included the implementation of two demonstration projects involving treatment of the lake with aluminum sulfate to inactivate internal phosphorus loads, strategic dredging, aeration, and a variety of agricultural best management practices.

Finally, the most recent assessment of Grand Lake St. Marys was completed

1. **U.S. EPA National Eutrophication Survey, Report on Grand Lake St. Marys, Auglaize and Mercer Counties, Ohio, EPA Region 5**, Pacific Northwest Environmental Research Laboratory. June 1975
2. **Grand Lake St. Marys, Ohio Survey Report for Flood Control and Allied Purposes**, U.S. Army Corps of Engineers, Louisville District, August 1981
3. **Grand Lake St. Marys Watershed Action Plan**, City of Celina and Mercer and Auglaiz Counties, draft submitted December 16, 1998
4. **Grand Lake St. Marys – Help It Survive**: Reproduction of Information by the Lake Improvement Association, October 2005
5. **Beaver Creek/Grand Lake St. Marys Total Maximum Daily Load Study**, Ohio EPA, 2006
6. **Wabash River/Grand Lake St. Marys Watershed Action Plan**, Mercer Soil and Water Conservation District, 2008
7. **Grand Lake St. Marys & Its Watershed: Water Quality Initiatives,** principal author Ohio Department of Natural Resources, Division of Soil & Water Resources, November 2009.
8. **Recommended Actions for Grand Lake St. Marys, Ohio**, Tetra Tech, July 29, 2010
9. **The Strategic Plan for the Grand Lake St. Marys Restoration Commission**, Grand Lake Restoration Commission, December 2010
10. **Distressed Watershed Designation Analysis, Grand Lake St. Marys Watershed,** Ohio Department of Natural Resources, Division of Soil & Water Resources, January 2011

*Figure 4. A selection of the numerous studies and plans that have been completed on Grand Lake St. Marys since 1975.*

by the Ohio DNR – Division of Soil and Water Resources (January 18, 2011) with the publication of the "Distressed Watershed Designation Analysis, Grand Lake St. Marys." This report was completed to support a determination of whether Grand Lake St. Marys met the criteria in Ohio Administrative Code (OAC) 1501:15:5-20(A) that defines a "distressed watershed." As part of this process, there were six identified criteria used to make this significant designation. These criteria included:

1. The watershed is listed as impaired from agricultural sources.
2. The watershed exhibits conditions that are a threat to public health.
3. The watershed exhibits evidence of algal and/or cyanobacteria blooms.
4. There is a threat to or presence of contaminants in public or private water supplies.
5. There is a threat to primary contact recreational water or bathing water.
6. Other unacceptable nuisance conditions exist including the depletion of dissolved oxygen.

Following this assessment, the Grand Lake St. Marys watershed in Mercer and Auglaize counties was designated a "distressed watershed" by the Ohio Soil and Water Conservation Commission. As a result, beginning January 19, 2013, the following rules apply to agricultural operations within the watershed:

1. Requires all livestock operations handling more than 350 tons and/or 100,000 gallons of manure to follow USDA-NRCS standards for land application.
2. Requires all livestock operations to prepare nutrient management plans and submit them to Ohio DNR's Division of Soil and Water Resources for approval.
3. Restricts winter-time application of manure between December 15th and March 1st.

While each of the numerous GLSM studies and plans mentioned above have been inspired by different parties, different events, and/or different issues, they all have a common denominator – GLSM is extremely nutrient-enriched,

*Figure 5. Grand Lake St. Marys June 2010 algal bloom.*

and any meaningful attempts to improve water quality will require a significant reduction in the loading of nutrients from the watershed. The harmful algal blooms that have plagued the lake in the past several years (Figures 6 and 7) are clearly being fueled by phosphorus – from both internal and external sources. However, just as there is no single source of these nutrients, there is no single solution. Addressing water quality issue in GLSM requires the engagement of multiple parties at the federal, state, and local levels. The complexity of the issues surrounding GLSM requires a comprehensive approach to restoration that addresses all of the various nonpoint sources of pollution within the lake and watershed. As a result, a wide array of state, local and federal implementation actions are occurring at GLSM using multiple sources of funding.

Multiple state, federal, and local agencies and organizations are focused in their areas of responsibility, authority, and expertise to bring significant financial and technical resources to bear to respond to harmful algal blooms that have severely impacted recreational use of the lake and work together to identify measures that should be implemented to reduce nutrient loads in the lake. In the past two years, almost $16,000,000 has been targeted to GLSM from various sources – a down payment for all that needs to be done. Activities have specifically focused on either internal phosphorus levels or improving agricultural management practices in the watershed to reduce nutrient-rich runoff from entering tributary streams. One action that still could be undertaken is the development and implementation of a source water protection plan (SWPP), which provides a framework for addressing sources of contamination to drinking water. From an institutional perspective, the lack of a SWPP was a contributing factor in the accelerated degradation of GLSM, because there was no framework in place to manage the dramatic changes in the agricultural industry in the watershed. To help ensure implementation of these plans, SWPPs can be integrated into existing watershed protection plan processes, which many communities – including GLSM – have already initiated. See EPA's and Ohio's source water protection program websites for more information at http://water.epa.gov/infrastructure/drinkingwater/sourcewater/protection/index.cfm and http://www.epa.state.oh.us/ddagw/swap.aspx, respectively.


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*Figure 6. Algae bloom on Grand Lake St. Marys West Beach on June 23, 2010.*

*Figure 7. Wildlife navigating algal blooms in Grand Lake St. Marys.*

figures and other materials. Jim Sullivan (Indiana Department of Environmental Management) and Anthony Dulka, Joe Konczyk, and Wade Boring (Illinois Environmental Protection Agency) provided source water information for surface PWSs in their states.

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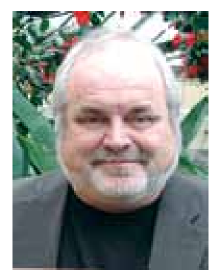

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